



The implications of generative artificial intelligence on the 21st - century skills of pre-service and in-service teachers: A mixed methods study

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Abstract

This study aims to investigate the impact of using generative artificial intelligence tools, such as ChatGPT, on the development of 21st-century skills among pre-service and in-service teachers in the United Arab Emirates. The study adopted a mixed quantitative and qualitative research methodology. The quantitative sample consisted of 240 pre-service and in-service teachers. The qualitative phase included semi-structured interviews with 35 pre-service and in-service teachers. The results of the statistical analysis showed that the averages of in-service teachers were statistically significantly higher than those of pre-service teachers in critical thinking, creative thinking, and collaboration skills, while no statistically significant differences were found in communication skills. The results also showed a moderate to high level of AI impact in supporting 21st-century skills among pre-service and in-service teachers. The interviews revealed that generative AI contributes to stimulating critical thinking through interactive dialogue and exploring creative alternatives that can be adapted to classroom needs. Interviews also showed that these tools support professional communication and collaboration, but also revealed concerns about overreliance on AI. The integrated results indicate that in-service teachers are more capable of employing AI practically in real classroom situations.

Keywords: 21st-century skills, 4Cs, Generative artificial intelligence ChatGPT, In-service teachers, Pre-service teachers, United Arab Emirates.

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Contribution of this paper to the literature

This study contributes to the existing literature by comparing the perceptions of pre-service and in-service teachers regarding generative artificial intelligence in light of the four core 21st-century skills, explaining these differences through integrated quantitative and qualitative evidence specific to the United Arab Emirates.

1. Introduction

Over the past two decades, educational practice has been significantly transformed by rapid developments in artificial intelligence technologies, especially generative AI, which is now capable of producing text, images, and multimodal educational materials that resemble human-generated content (Kasneci, Sessler, & Bannert, 2023; Zhai, 2023). The emergence of tools such as ChatGPT, Gemini, and Copilot has reshaped the educational roles of both teachers and learners. Contemporary teaching increasingly depends on teachers' ability to interact effectively with learners and to make productive use of data-driven and AI-supported tools inside and outside the classroom (Holmes, Bialik, & Fadel, 2022; Schepman & Rodway, 2023).

Within this context, 21st-century skills have become a central framework for defining the competencies teachers need in digitally mediated learning environments, particularly critical thinking, creative thinking, collaboration, and communication. Recent educational reports indicate that these skills are no longer optional; rather, they have become essential professional requirements in rapidly evolving learning environments (OECD, 2021; UNESCO, 2023). Teachers who possess these competencies are better able to plan active learning experiences, make effective instructional decisions, and respond flexibly to classroom challenges (Jubaidah, Nuruddin, Ilham, & Annisa, 2024; Kasap, Acar, & Kasap, 2024).

Recent studies also suggest that generative artificial intelligence has considerable potential to support the 4Cs by helping teachers interpret information and make decisions, generate creative instructional ideas, facilitate collaborative activities, and improve the clarity and organization of professional communication (Kasneci et al., 2023; Kong, 2022). However, the educational impact of these technologies may vary according to teachers' professional experience and the contexts in which they are used. Research studies have also shown that in-service teachers are often better prepared than pre-service teachers to integrate technology into instruction, partly because they have more opportunities to apply and evaluate digital tools in authentic classroom settings (Chen, Zhang, & Lin, 2021; Dai & Lin, 2024).

Based on the available literature, the researchers identified a relative lack of Arabic studies examining the implications of generative AI for teachers' 21st-century skills, particularly in relation to differences between pre-service and in-service teachers. This raises an important question about whether the use of generative AI contributes to the development of these skills and whether its perceived impact varies across stages of teachers' professional development. Accordingly, the present study addresses this gap by adopting a mixed-methods design that integrates quantitative and qualitative data to provide a more comprehensive understanding of the role of generative AI in supporting teachers' 21st-century skills. The study is guided by the following questions.

1. To what extent are pre-service and in-service teachers aware of the effects of using generative AI in the acquisition of 21st-century skills (Critical thinking and creative thinking, collaboration, communication), and what qualitative explanation goes with this awareness?
2. Do pre-service and in-service teachers show statistically significant differences in their awareness of the effects of using generative artificial intelligence in the development of 21st-century skills, and what are the qualitative descriptions of these differences?

2. Purpose of the Study

This study aims to determine the level of awareness among pre-service and in-service teachers regarding the effects of using generative artificial intelligence on the development of 21st-century skills and to examine the qualitative explanations accompanying this awareness. Additionally, it seeks to highlight variations in perceptions between pre-service and in-service teachers concerning AI's influence on these skills and to incorporate qualitative explanations to clarify the reasons for these differences. Finally, the study intends to provide a comprehensive explanation that combines both quantitative results and qualitative data, offering a deeper understanding of the role of generative AI applications within educational settings.

3. Significance of the Study

3.1. Theoretical Significance

The present study contributes to the growing body of research on 21st-century skills by linking these skills to the increasing use of generative AI in education. It also provides a conceptual framework that connects teachers' digital practices, including the use of ChatGPT and similar tools, with their professional development in critical thinking, creative thinking, collaboration, and communication.

3.2. Practical Significance

The findings may support decision-makers in teacher education institutions and ministries of education in designing training programs that foster teachers' 21st-century skills through the critical and responsible use of AI tools. The study may also help pre-service and in-service teachers identify strengths and limitations in their AI-related practices and recognize areas for further professional growth.

3.3. Methodological Significance

Methodologically, the study is significant because it adopts an explanatory sequential mixed-methods design that combines quantitative and qualitative data. This design enables a more comprehensive understanding of the implications of generative AI for teachers' competencies and enhances the credibility of the findings through methodological triangulation.

4. Variables of the Study and Procedural Definitions

4.1. Independent Variables

1. Teacher stage.
 - Pre-service: Students who have already completed their bachelor's degree and are enrolled in a higher diploma program, but have not been hired yet as teachers.
 - In-service: Teachers who are already working in schools and pursuing higher diploma programs.
2. Academic specialization: It refers to the area of study of the teacher and was split into three specializations based on the distribution of the samples (Arabic language, Islamic education, and social studies).
3. Degree of generative AI use: It refers to how often teachers indicate they apply tools like ChatGPT during lesson planning, activity development, evaluations, and professional communication. It is determined on an 8-point subscale and rated as low, moderate, or high.

4.2. Dependent Variables

21st-Century Skills (4Cs):

- Critical thinking: A skill of analyzing the information in education, evaluating options, and making evidence-based teaching decisions based on a score in the dimension of critical thinking (7 items in the questionnaire).
- Creative thinking: The capacity to work out new and unconventional education concepts and solutions as indicated by the creative thinking dimension (6 items in the questionnaire).
- Collaboration: Teamwork of the teachers in teamwork and joint projects, both with peers and with students, assessed through the dimension of collaboration (7 items in the questionnaire).
- Communication: The capacity to communicate educational information and messages effectively and clearly, whether verbally or in a written form, as assessed by the communication dimension (7 items in the questionnaire).

5. Theoretical Framework and Literature Review

The study concentrates on two key intersecting themes: Generative artificial intelligence in education and 21st-century skills (4Cs), and how the two are related based on the prior body of work and research studies.

5.1. Generative Artificial Intelligence in Education

Generative artificial intelligence refers to a collection of computer models that can generate new content (textual, visual, or audio) based on the data or input provided by the user. These models are based on the methods of deep learning and have developed advanced neural networks since 2020, which have received a significant boost in development due to their high level of generative and analytic capabilities, thus making them an inevitable part of the modern learning environment (Dwivedi et al., 2023; OpenAI, 2023).

The common use of generative AI tools like ChatGPT, Gemini, Copilot, and others has become a part of the digital space of both teachers and students in recent years (Elmahdi & Aljohani, 2023; Susnjak, 2022). It is proven in the literature that these models do not simply reproduce the content, but they provide a reorganization of ideas and knowledge in the form of texts, activities, or learning situations that can be used by the teacher in various situations within the classroom and outside it (Kasneci et al., 2023; Zhai, 2023).

Generative AI is regarded as a valuable asset in the educational sector that can be utilized to aid the professional activities of teachers, as it may be applied when creating lessons and activities, proposing learning outcomes, and creating questions and lesson plans that consider the various levels of students (Kong, Yang, & Chen, 2023). It is also applicable in the analysis of educational performance, providing first-time feedback on students' answers or offering alternative explanations for difficult concepts. Research indicates that teachers with critical awareness of AI applications can turn these outputs into opportunities for active learning, either by redefining suggested tasks or discussing with students why AI-generated solutions are relevant in real educational contexts (Holmes et al., 2022; Yang, Chen, & Jia, 2024).

While generative AI has a lot of opportunities, literature also suggests that it has several challenges and risks. On the one hand, generative models can be associated with issues of information accuracy, bias of the data on which the model is trained, or lack of explicit references to the sources, resulting in teachers having to exercise a consistent supervisory and evaluative role to ensure learners adopt it in educational environments (Gilson, Saunders, & Hughes, 2023; Hussein & Alhallak, 2023). Conversely, it has been feared that the ignorant app usage might bring about trends of excessive dependence or superficial dependence, like they may become an alternative instead of an impetus to critical thinking, or are misused to do immoral acts like cheating academically or plagiarizing (Cotton, Cotton, & Shipway, 2023; Mhlanga, 2023). Thus, many papers indicate that the application of generative artificial intelligence in educational practice should be a component of a comprehensive educational vision that aims at equipping teachers both technologically and ethically (Kasneci et al., 2023; UNESCO, 2023; Zawacki-Richter, Marín, Bond, & Gouverneur, 2019).

5.2. 21st-Century Skills (4Cs)

The 21st-century skills are a reference framework that is used to describe the skills required by teachers and learners in the digital era. Critical thinking is one of the four Cs that make up the model of critical thinking, creative thinking, collaboration, and communication (Voogt & Roblin, 2022). Recent literature stresses that fast technological changes, an increasing amount of information, and the complication of an educational setting make these skills a condition of successful professional practice in teaching (Kereluik, Mishra, & Koehler, 2022; OECD, 2021).

Critical thinking is viewed as a teacher's ability to dissect information and educational conditions, evaluate evidence, compare alternatives, and make decisions based on rational and cognitive bases. A skillful teacher should have an evaluative eye, learn not to believe what one sees but to measure it against the truth, relevance, and

context standards (Hodges, Moore, Lockee, Trust, & Bond, 2020). In addition, creative thinking can be associated with the capacity of the teacher to come up with new ideas, invent non-standard solutions and activities, and use the available resources in different ways to meet the needs of the students. Artificial intelligence tools are used to increase this skill, providing several options for solutions (Kewalramani, Horan, & Nuttall, 2022). Moreover, collaboration is a key dimension, as contemporary schools require teachers to work collaboratively in professional teams that share planning, exchange experiences, and analyze student learning outcomes. Finally, communication is the backbone of these dimensions and includes oral, written, and digital expression skills, the preparation of presentations, and learning platforms (UNICEF, 2021).

According to the reports of the international organizations, the development of these skills in teachers helps to enhance the quality of learning and the engagement and participation of students (UNESCO, 2023). Also, research studies confirm that teacher preparation programs that implement the activities aimed at forming 4Cs skills enable teachers to better adjust to technological and educational changes (Chan, Fong, & King, 2022).

5.3. The Relationship between Generative AI, 4Cs Skills, and Previous Studies

There is a close connection between the practice of using generative AI and the creation of 21st-century skills in teachers. It has been suggested that when talking to AI systems and asking about their solutions and recommendations, teachers can get a chance to get better at critical thinking by forcing them to contrast what they were taught in educational theories and practices with what these systems are offering (Dwivedi et al., 2023; Holmes et al., 2022). It is also demonstrated that the capability of artificial intelligence to produce a variety of ideas to apply to educational tasks and tools helps expand the creative boundaries of teachers, although they must have them altered instead of mindlessly copying them as they are (Kasneji et al., 2023; Yang et al., 2024).

Within the framework of collaboration and communication, recent studies reveal that the efficiency with which teachers cooperate and the time wasted on the less significant work are positively affected by their use of generative tools in making joint plans and writing professional letters or reports (Mhlanga, 2023). The introduction of those tools to make language structure and structure ideas also positively affects the quality of professional communication in the school (Cotton et al., 2023).

Several studies on the connection between artificial intelligence or advanced digital technologies and teachers' skill development indicate that teachers with experience working with technology are more likely to use open-ended teaching methods, cooperative work, and project-based learning (Dai & Lin, 2024). It is also stated that in-service teachers tend to be more competent in using technology in education compared to pre-service teachers, as, at times, they have more opportunities to apply in practice and evaluate the success of digital activities at work (Chen et al., 2021).

Nonetheless, the analysis of the literature demonstrates a relative scarcity of studies on generative AI as a specific independent variable linked with the acquisition of 4Cs skills in teachers, particularly in the Arab environment. This renders the present work to fill a gap in the research due to its adoption of a mixed-method research design, which combines both quantitative and qualitative data to elaborate on the effect of generative AI on those competencies.

6. Materials and Methods

6.1. Design and Research Perspective

The present study used the explanatory sequential design, beginning with the initial measurement of quantitative data through a questionnaire. This data then informed the structure of the qualitative stage, involving interviews, and helped explain the findings. The rationale for this design is its pragmatic approach, allowing the integration of both quantitative and qualitative methods. This approach suits the research problem by emphasizing the development of knowledge relevant to teacher preparation and professional development contexts.

6.2. Study Population and Sample

The study population consisted of pre-service and in-service teachers enrolled in educational diploma programs in Arabic language, Islamic education, and social studies at two higher education institutions in Abu Dhabi and Sharjah, United Arab Emirates, during the second semester of the 2024-2025 academic year. Both institutions offer teacher preparation and professional qualification programs within comparable academic and professional contexts, which provide an appropriate basis for comparing the two groups.

In the quantitative stage, the study sample was selected through systematic random sampling, where participants were chosen from lists of students enrolled in teacher preparation programs based on the stage variable (pre-service and in-service) and the specialization variable. The sample included 160 pre-service teachers and 80 in-service teachers, as shown in Table 1.

Table 1. Distribution of the teacher sample according to the variables of stage and specialization.

Specialization	Pre-service (N)	Percentage (%)	In-service (N)	Percentage (%)
Arabic Language	70	29.2	35	14.6
Islamic Education	50	20.8	25	10.4
Social Studies	40	16.7	20	8.3
Total	160	66.7	80	33.3

In the qualitative phase, targeted sampling was used to select 35 participants for interviews (20 pre-service and 15 in-service) based on diversity in participants' specializations and willingness to participate in the interview.

6.3. Questionnaire

The researchers developed the questionnaire based on previous literature related to 21st-century skills and their relationship to the use of educational technology. The questionnaire consisted of two main sections.

1. Demographic data.

This section included a set of basic variables, namely.

- Teacher stage (Pre-service/in-service).
 - Specialization.
 - Level of digital technology use in general (Low/moderate/high).
2. 21st-century skills (4Cs) questionnaire in light of artificial intelligence.

This section was used to measure participants' awareness of the impact of generative artificial intelligence on enhancing the following four skills.

- Critical thinking (7 items).
- Creative thinking (6 items).
- Collaboration (7 items).
- Communication (7 items).

A five-point Likert scale was used according to the following classification.

1. Strongly disagree.
2. Disagree.
3. Unsure.
4. Agree.
5. Strongly agree.

For the purpose of interpreting the statistical results, the following thresholds were adopted for the mean responses.

- 1.00–2.33 = Low.
- 2.34–3.66 = Moderate.
- 3.67–5.00 = High.

6.3.1. Validity and Reliability

The questionnaire items were reviewed by five experts specializing in educational technology and teacher training to verify their clarity, cultural appropriateness, and scientific accuracy. Based on their comments, some linguistic adjustments were made to remove ambiguity and avoid repetition. The questionnaire was also administered on a trial basis to a sample of 25 participants, and the reliability coefficients were recalculated. The results showed that Cronbach's alpha coefficients for the four skill dimensions ranged between 0.84 and 0.90, while the overall reliability coefficient for the instrument was 0.89, which is evidence of a good level of internal consistency for the instrument in educational contexts.

6.4. Interview Protocol

After the first quantitative analysis, a semi-structured interview guide was designed, which included the most important points:

- The experience of the teachers concerning the use of ChatGPT and similar resources in the lesson planning, assessment, or classroom activities.
- Their understanding of the impact of such use on their individual capabilities, such as critical thinking, creativity, collaboration, and communication.
- The particular instances when they believed artificial intelligence either strengthened or weakened their abilities.
- The professional and ethical issues experienced in such situations.
- Recommendations on the implementation of artificial intelligence in teacher training.

Each interview lasted between 30 and 45 minutes and was conducted either face-to-face or via video conferencing platforms, depending on the participant's preference. The interviews were audio-recorded with informed consent and then transcribed for analysis.

6.5. Data Analysis

6.5.1. Quantitative Analysis

- SPSS software was used to analyze the data.
- Descriptive statistics (Mean, standard deviation) were calculated for the 4Cs skill levels.
- A t-test was performed on two independent samples to compare pre-service and in-service teachers across the four dimensions.

6.5.2. Qualitative Analysis

Qualitative data were analyzed using thematic analysis following the six phases proposed by Braun and Clarke (2006): familiarization with the data, generation of initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the report. Additionally, inductive coding was adopted, guided by the study questions. Trustworthiness was enhanced through member checking by sharing theme summaries with selected participants to ensure accurate representation, as well as peer discussion among researchers.

7. Results

7.1. The Impact of Using Artificial Intelligence on 4Cs Skills

7.1.1. Quantitative Results

To answer the first question, the arithmetic means and standard deviations of the pre-service and in-service teachers' perceptions of the impact of using generative artificial intelligence on the development of 21st-century skills were calculated. Table 2 shows the results.

Table 2. Descriptive statistics for the 4Cs skills of the two groups.

Field	Pre-service (M, SD)	In-service (M, SD)	Cronbach's alpha
Critical thinking	3.44 (0.96)	4.14 (0.89)	0.85
Creative thinking	3.60 (0.97)	4.20 (0.91)	0.84
Collaboration	3.70 (0.99)	4.35 (0.90)	0.89
Communication	3.85 (1.02)	4.40 (0.96)	0.86

The table shows that the averages for in-service teachers are higher than those for pre-service teachers in all four areas, while skill levels ranged from moderate to high according to the adopted interpretation standard, with high stability across the dimensions of the scale.

7.1.2. Qualitative Findings

The thematic analysis of the interviews yielded three main themes reflecting pre-service and in-service teachers' perceptions of the impact of using generative AI on developing 21st-century skills.

First: Deepening critical thinking through dialogue with AI.

Several participants mentioned that they began using ChatGPT as a "discussion partner" to help them examine their ideas and compare them with other suggestions. One pre-service teacher said:

"When I ask ChatGPT for a lesson plan, I don't use it as is, but compare it to what we've learned in the curriculum, deleting and adding. This makes me think more: Why do I prefer this activity? And why do I reject that one?"

Second: Expanding creative horizons in designing educational activities.

Participants noted that AI helps them generate initial ideas for various activities (Educational games, collaborative tasks, simulation scenarios), which they then adapt to their context. One teacher in service said:

"Sometimes I get stuck with the same type of activities, so I ask ChatGPT for suggestions for collaborative activities in a particular lesson, then I choose and modify them. This opens doors for me that I hadn't thought of."

Third: Supporting professional communication and collaboration with concerns about over-reliance.

Some teachers explained that using AI to prepare presentations, emails, or instructions for students helped improve communication quality and reduce time pressure, but it also raised questions about the limits of reliance on the tool. One participant said:

"Artificial intelligence has helped me write more professional letters to parents, but sometimes I worry that I will lose my personal touch if I rely on it too much."

These qualitative findings indicate a growing awareness among teachers of the importance of using artificial intelligence as a tool to support thinking, rather than as a substitute for it.

7.2. Differences Between Pre-Service and in-Service Teachers

7.2.1. Quantitative Results

To answer the second question, a t-test was conducted on two independent samples to compare the two groups in each of the 4Cs domains. Table 3 shows the results.

Table 3. Results of the independent-samples t-test for 4Cs skills by teacher stage.

Field	Group	N	M	SD	t	df	Sig. (p)
Critical thinking	Pre-service	160	3.45	0.94	4.10	238	0.000*
	In-service	80	4.12	0.88			
Creative thinking	Pre-service	160	3.60	0.97	3.85	238	0.000*
	In-service	80	4.20	0.91			
Collaboration	Pre-service	160	3.70	0.99	3.95	238	0.000*
	In-service	80	4.35	0.90			
Communication	Pre-service	160	3.85	1.02	1.95	238	0.052
	In-service	80	4.40	0.96			

Note: * Statistically significant at the 0.05 level.

The results indicate statistically significant differences in favor of in-service teachers in critical thinking, creative thinking, and collaboration. However, no statistically significant difference was found in communication skills ($p = 0.052$), indicating that the two groups showed relatively similar perceptions in this dimension.

7.2.2. Qualitative Findings

The interviews revealed differences in the nature of AI use between the two groups.

- Pre-service teachers tend to use ChatGPT as a source of ideas, a quick reference for theoretical explanations, and a tool for drafting lesson plan components.
- In-service teachers use it more for: analyzing real classroom situations, formulating question scenarios for students, and developing communication materials for parents and colleagues.

One in-service teacher said:

"I sometimes ask ChatGPT to suggest a dialogue between a misbehaving student and a teacher, and then I discuss with my colleagues which responses are most appropriate for our culture and school. This gives us a starting point for professional dialogue."

Meanwhile, a pre-service teacher said:

"I often use it to help me design activities or questions, but I feel I need more field experience to know how to apply all this in the classroom."

This suggests that field experience makes the use of AI more meaningful and relevant to real educational situations, which explains why in-service teachers excel in some of the 4Cs skills.

7.3. Challenges Associated with the Use of AI

The qualitative analysis revealed three main areas of challenge.

1. Time constraints and lack of structured training.

Many participants mentioned that learning to use AI effectively requires time that is not always available alongside the burden of teaching or studying.

2. Ethical awareness and over-reliance.

Some teachers expressed concern about falling into the trap of relying on ready-made texts or unintentionally contributing to academic cheating among students.

3. Cultural and educational appropriateness of content.

Several participants pointed out that some of the suggestions provided by ChatGPT need to be culturally and methodologically adapted to suit the local context, which requires additional critical effort.

8. Discussion

The results of this study show that the use of generative artificial intelligence is associated with relatively high levels of teachers' awareness of its impact on the development of 21st-century skills, especially among in-service teachers. This is consistent with recent perceptions that technology is not merely a tool, but a new context in which the roles of teachers and learners are redefined, and teachers' professional competencies are reformulated (Ata & Alpaslan, 2024; Chen & Huang, 2024; Xie, 2023).

The results also showed that generative AI can be a catalyst for critical thinking skills when used for discussion, analysis, and comparison of alternatives, rather than for uncritical reliance on its outputs. This is consistent with trends that emphasize the need to teach students and teachers to think with AI, not instead of it (Hading, Rustan, & Ruing, 2024; Walter, 2024).

The significant differences in favor of in-service teachers in critical and creative thinking and collaboration indicate that field experience provides them with concrete contexts in which to use AI. They do not merely generate activities or questions, but test their usefulness in the classroom and modify them, using the results to build deeper professional collaboration with colleagues (Chen et al., 2021). In contrast, pre-service teachers appear to need a "bridge" between the experimental use of the tool and real classroom situations, which can be achieved by integrating projects based on solving real problems in schools using artificial intelligence as a support tool (Albayrak & Ozden, 2021; Demirtaş & Karakış, 2025).

The challenges identified by participants, such as time constraints, lack of systematic training, and concerns about overreliance on the tool, highlight the importance of accompanying policies for integrating AI into education with clear ethical and pedagogical awareness, rather than leaving it to individual discretion (García-Ruiz, Lupión-Cobos, & Blanco-López, 2021; Tunjera & Chigona, 2020; Zakaria & Hashim, 2024).

9. Implications and Recommendations

Based on the study results, the researchers recommend integrating training modules on artificial intelligence into teacher preparation programs. These modules should include practical activities that utilize ChatGPT and similar tools in lesson design, classroom situation analysis, and assessment tool development, with an emphasis on critical thinking about the outputs of these tools. In addition, it is recommended to design ongoing professional development programs for in-service teachers by focusing on using AI to enhance their 4Cs skills and those of their students through collaborative projects among teachers within the school or among schools. Moreover, it is commendable to build clear institutional policies for the use of artificial intelligence in education. This includes controls related to privacy, security, and academic integrity, defining what is permissible and what is unacceptable in the use of these tools by teachers and students. Finally, it is advisable to promote a culture of professional reflection that encourages teachers to use AI as a mirror for their practices, not as a substitute for their thinking, by documenting successful experiences and discussing examples in professional learning communities.

10. Limitations of the Study

The results of this study should be interpreted in light of several limitations, notably the geographical and institutional context. The study was limited to two educational institutions in the United Arab Emirates, which restricts the generalizability of the results to other contexts that differ in policies, culture, or technical infrastructure. Additionally, reliance on questionnaires for quantitative data is another limitation, as measurements are based on participants' self-perceptions, which may be influenced by social or personal biases. Finally, while the interview sample provided rich data, expanding it in the future to include a larger number of teachers in different disciplines and regions may deepen understanding and increase the transferability of the results.

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