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Exploring teachers' perceptions of integrating artificial intelligence (AI) in STEM education using the TPACK framework: an exploratory case study

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Abstract

Background As artificial intelligence (AI) continues to transform various sectors, including education, the perceptions and attitudes of teachers remain underrated. AI-based tools such as Intelligent Tutoring Systems (ITS) and chatbots have recently gained traction in education, offering innovative ways to enhance teaching and learning.

Aims This case study aims to examine the perceptions and attitudes of STEM teachers in Qatar regarding the integration of AI tools into their practices. This study also aims to assess teachers' awareness of the ethical concerns associated with AI-based tools, primarily concerns related to fairness, inclusiveness, privacy, and bias.

Material and methods This case study employs an exploratory approach using online questionnaires as a data collection instrument. The TPACK framework guided the questionnaire items to further explore how teachers' technological, pedagogical, and content knowledge influences their attitudes towards using AI-powered tools in their teaching. The online questionnaires were distributed to three STEM schools in Qatar between April and May 2023. The sample size was 12 teachers.

Results This paper reveals that while STEM teachers perceive themselves as possessing moderate technological knowledge of AI tools, they recognize the potential of AI in delivering personalized and adaptive learning experiences. The findings reinforce existing literature on the pedagogical affordances of AI in enhancing teaching practices and improving student learning outcomes. Moreover, the study underscores a critical need to strengthen teacher readiness for AI integration, highlighting the role of targeted professional development in equipping educators with the skills and confidence necessary to effectively leverage AI in STEM education.

Limitations and recommendations Few limitations affect the findings of this study. Limited sample size may affect the depth and breadth of the findings; therefore, future research is needed to increase the population and expand the findings by involving different stakeholders. Also, self-reporting bias and timeframe constraints may affect

the results, thus addressing these in future research will contribute to the ongoing debate about the effectiveness of AI-based tools in education.

Keywords Artificial intelligence, AI-tools, K-12 Education, Teachers, Perceptions, STEM, TPACK, Case study

1 Introduction

Artificial Intelligence (AI) is rapidly transforming various industries including healthcare, finance, transportation, and others [20]. Education is not an exception. In recent years, there has been a growing interest towards the integration of Artificial Intelligence in classrooms with aims to enhance learning, teaching, assessment, and administration.

1.1 Background

AI-based tools are rapidly being developed to achieve certain educational outcomes and improve practices in educational settings. For example, one of the potentials of integrating AI applications into education is offering personalized learning experiences [5, 39]. In other words, AI-based tools that incorporate algorithms and machine learning can facilitate the collection and analysis of students' data to highlight students' strengths and weakness areas and then recommend learning paths that are customized based on student's needs and academic performance. Additionally, AI-based tools such as Intelligent Tutoring Systems (ITS) use natural language processing and machine learning algorithms to provide personalized feedback [5]. Such systems enable teachers to perform their administrative roles such as monitoring their students, grading assignments, checking attendance, and managing students' records [39]. ITS has helped teachers reduce work overload and free up teachers' time to allow them to focus more on their teaching strategies and how to support their students further [3]. AI-based tools enable teachers to detect areas where students encounter difficulties and deliver timely personalized interventions [5]. These systems support students in overcoming academic challenges by providing targeted feedback and tailored learning opportunities based on individual performance. For example, in ITS, interventions are operationalized through real-time data monitoring, active feedback and scaffolding [8].

Recent research has reviewed the implementation of AI in higher education [6, 37], yet the K-12 education in developing countries has yet to be explored further. Additionally, teachers' attitudes and perspectives have been explored in some developed countries such as Hong Kong [7], Estonia [8] and Taiwan [25], however, it is better to gain holistic insights about integrating AI-based tools in K-12 education in various socioeconomic and cultural settings. Despite previous studies pointing out the need to prepare teachers in developing countries to better integrate AI into their practices, only a few considered teachers' perceptions towards this integration [7, 8]. Few studies examined the perceptions of teachers from developing countries with various socioeconomic and cultural backgrounds [17]. Therefore, this study aims to fill this gap and contribute to global literature related to integrating AI-based tools for learning in various sociocultural backgrounds.

1.2 Context: STEM education in Qatar

Technology is one of the core disciplines of STEM education. In recent years, the field of STEM (Science, Technology, Engineering and Mathematics) has been emphasized as

a key approach to excellence in education [35]. In the Gulf Corporate Council (GCC), a great effort has been made by authorities to implement best practices and educational policies shared during educational reform over the past two decades. For example, Qatar and the United Arab Emirates (UAE) have attained progress in developing their education systems [17] by achieving high standards in international tests [26]. According to Struyf et al. [35], the importance of STEM education relies on its ability to potentially equip students with real-world solutions to real-world problems around the world. Additionally, with the increasing demands to connect students with everyday life experiences to better understand the world trends and problems around them, STEM education can be the enabling approach to support students to be critical thinkers. In Qatar, the Ministry of Education and Higher Education (MoEHE) realized the need to adopt this approach by integrating STEM in K-12 curriculums and establishing several STEM schools that are dedicated to supporting passionate students with an intensive accredited STEM curriculum [9, 17, 29, 32]. Some examples of STEM high schools in Qatar are the Qatar Academy of Science and Technology (QAST) which has a unique curriculum that nurtures students' passion for STEM, and the Qatar Science and Technology Secondary School for Boys (QSTSS BOYS). Both schools offer learning experiences dedicated to STEM for students aged 14–18 years old. STEM teachers utilize technology in their daily professional practices to support their students acquire content knowledge and skills. Teachers use Google Suite to support students with resources and learning materials and communicate with students through announcements and Gamils. For learning management systems, teachers also use Managebac (https://www.managebac.com), a learning platform to support teachers and students in accessing resources and materials, communicating and completing tasks and assignments. With the advancement of AI tools, it is important to understand how STEM teachers think of such technological tools. Additionally, as mentioned earlier, In the context of STEM education, where technology is a central component, it is crucial to investigate not only the integration of AI tools to better evaluate their effectiveness and facilitate their integration but also the perceptions of teachers towards their acceptance and use of these tools. Understanding the interplay between teachers' technological, pedagogical, and content knowledge (TPACK) is essential to uncover the factors that shape teachers' acceptance and use of these tools. Therefore, to ensure successful implementation, a comprehensive understanding of teachers' perceptions and readiness to adopt AI tools is needed. While previous literature explored AI in K-12 in developed countries, this study aims to address the gap and explore the perceptions of STEM teachers in different socioeconomic contexts.

In this research, we are presenting a case study of how teachers in STEM schools in Qatar integrate AI-based tools into their practice and what their perceptions are towards this integration. This paper aims to address the following research questions:

RQ1. What are the perceptions of STEM teachers in Qatar towards the integration of Artificial Intelligence (AI) in their teaching practices?

RQ2. To what extent does the relationship between Technological Knowledge (TK), Pedagogical Knowledge (PK) and Content Knowledge (CK) influence the integration of AI-based tools in STEM education?

The insights of this study contribute to the AI literature in education and the applicability of TPACK as a theoretical lens in educational research. The findings have many implications to policy and practice; to inform decision-making and policy design to better facilitate the integration of AI-based tools into educational settings and to inform professional development interventions to provide training and support to educational stakeholders.

2 Literature review

2.1 AI in education

The increasing development of AI tools within the past decades has been profound and rapid [2]. With an overarching goal of enhancing learning and teaching, education stakeholders realized the need to adopt the new trends [3, 30]. While AI-based technologies remain new to K-12 education, how to use these tools to enhance teaching and learning, build content knowledge and encourage engagement and motivation is still unknown [10, 11, 22]. Researchers argued that preparing students and teachers alike to be able to integrate these promising tools is still an existing challenge [19]. According to [13], there are two ways in which AI is positioned as an emerging educational tool, one is "learning with AI" and the other is "learning about AI". The former refers to the direct involvement of AI in learning such as adaptive learning, personalized learning and intelligent learning management systems. The latter, on the other hand, is an approach to teaching AI as a learning content that aims to equip learners with skills to design, develop and utilize AI algorithms based on their understanding of AI (Baker & Smith, 2019). This paper focuses on "learning with AI" with an emphasis on exploring teachers' perceptions towards the AI-based tools they integrate into their teaching practices. Learning with AI is often referred to as AI-based tools that are designed for the use of learners to facilitate their learning practices. These tools have been 'repurposed' for learning [13]. Investigating AI-based tools for learning can help teachers to better address students' needs and, hence, enhance learning outcomes.

2.2 AI for education

AI-based technologies have been researched recently to assess their positive impacts and limit their negative effects. For instance, Chen and Lin [4] identified three positive impacts of AI-based tools in early childhood education,these were 1) personalized learning, 2) personalized interactive support, and 3) accessibility. As for 1) personalized learning, it is evident that AI-based tools offer personalized learning opportunities using adaptive learning platforms that use AI algorithms to analyse each child's performance, abilities, pace and more (J. J. [4]). For 2) personalized interactive support, AI-based tools that provide interactive support through play and conversational agents can analyse speech and offer suitable responses. Examples of such AI-based tools can be smart toys such as AI-interfaced robotic toys [18] and PopBots which are preschool-oriented to help young children learn about programming and artificial intelligence [36]. For 3 increased accessibility, AI-based tools facilitate easier accessibility for those who have special needs and learning disabilities,such tools function as speech-to-text, text-to-speech and automatic speech recognition [4]. Speechify (https://speechfiy.com), for example, is considered an assistive AI-based technology that transfers text-to-speech to help those with learning disabilities such as dyslexia and is considered one AI-based tool

that enables users with better accessibility. Another example is the intelligent tutoring systems (ITS) that allow users to access their services anytime and anywhere. An example of an ITS is the language learning platform Duolingo (https://www.duolingo.com), which is AI-based to support users to learn languages through an adaptive learning approach and can be accessible anytime and anywhere [4]. As AI-based tools are evolving in educational settings, their effectiveness and potential benefits to support students learning while mitigating their drawbacks are often overlooked. While previous research examined AI-based tools to enhance students' learning, the perceptions of teachers are yet to be examined further to uncover the facilitating factors that enhance their usage and, hence learning outcomes.

2.3 Ethical implications

The rapid integration of AI in education persists in ethical challenges, which educators may not be able to address or mitigate. Without robust guidelines and ethical frameworks, educators and practitioners may find it difficult to assess their use of AI ethically [33]. While research ethics of AI in education has surged in recent years, there remains a need for further investigation, particularly on how educators align their use of AI tools with ethical principles. Previous research extensively discussed ethical principles of AI in education especially those related to data privacy, transparency, accountability and inclusiveness [1, 12, 28]. AI tools often collect, process, analyze and store large amounts of data which impose risks of sensitive data being mishandled, stored insecurely, or shared without consent. Adding to that, AI tools use algorithms that can reflect and reinforce existing biases in the data they are trained on which may lead to unfair treatment based on biased pre-trained datasets. Earlier studies argued that many AI systems operate as "black boxes", making decisions without clear explanations or reasoning [31], which leads to less transparency experiences with AI tools. Furthermore, integrating AI in an educational context may impose inequality since not everyone has equal access to AI tools or infrastructure to support them. All these ethical implications need to be addressed empirically to support the ethical integration of AI in education. Offering proper training and professional development interventions to teachers will develop their awareness of the ethical use of AI in their practices [30]. Preparing teachers to offer AI curriculum in a wide range of disciplinary settings is needed [23]. This study highlights the perceptions of teachers towards the key issues that might hinder the integration of AI-based tools such as lack of training and data-driven policies.

3 Theoretical framework

Before discussing the theoretical framework that underpins the basis of this research, it is essential to clarify my ontological and epistemological stands. These essential stands constitute the beliefs and viewpoints that significantly impact the selection and choice of theory and methodology of this research. From an interpretivist perspective, I acknowledge that reality is subjective and shaped by the unique and shared experiences of individuals. My perspective on knowledge aligns with social constructivism emphasizes that knowledge is a collaborative interaction within particular social contexts. This philosophical approach aligns with the exploratory use of questionnaires designed to capture educators' nuanced perspectives on technology adoption in educational settings. The TPACK framework further supports this stance by providing a structured yet flexible

lens to explore how teachers conceptualize the interplay between technology, pedagogical, and content knowledge. Together, this approach enables a rich, context-sensitive investigation into educators' beliefs and practices.

In researching technology in education, a few theoretical frameworks and models such as Cultural-Historical Activity Theory (CHAT), the Unified Theory of Acceptance and Use of Technology (UTAUT) and Technological Pedagogical Content Knowledge (TPACK) were considered. First, CHAT, rooted in Vygotsky's sociocultural theory and further developed by Engeström, is widely used in educational research to examine how human activities are mediated by tools, rules and other social structures or elements. While CHAT can offer a systematic and contextual perspective on AI integration through understanding the relationships between elements within the system, it may fail to uncover the pedagogical perspectives of individuals towards their use of AI-based tools. CHAT is widely used to examine the institutional and systemic influences rather than Individual usage and acceptance of technology. UTAUT, on the other hand, is used in research to explore the factors driving technology adoption by explaining why and how individuals adopt new technologies. While UTAUT, offers a unique lens to evaluate the motivations, barriers and external influences affecting the integration of technology, it overlooks the knowledge of teachers that may influence the use of AI-based tools. Investigating the pedagogical, content and technological knowledge of teachers is essential to understanding their perceptions towards using such tools to support their students. TPACK provides a conceptual understanding to explore teachers' perceptions of AI-based tools by analyzing their knowledge in three intersecting domains: Technological Knowledge (TK), Pedagogical Knowledge (PK) and Content Knowledge (CK). Therefore, choosing TPACK as an underpinning theoretical framework is relevant to the focus of this study.

To examine teachers' knowledge that involves effective teaching, the Pedagogical Content Knowledge (PKC) framework proposed by Shulman [34] has been widely used in previous studies [2, 10, 15, 27]. As an underpinning framework, it consists of three domains, including PK, CK and PCK. An extended model proposed by Koehler and Mishra [21] incorporated Technological Knowledge (TK) with the previous three domains, and to form TPACK, TK is added to illustrate the relationship among the core knowledge domain and to highlight the significance of understanding technology to be better integrated into education. For this purpose, TPACK is used in this study as an underpinning theoretical framework to better interpret the relationship between the core domains of TPACK and how these can influence STEM teachers to integrate AI-based tools in their teaching practices.

4 Research design

4.1 Method

This study adopts an exploratory case study design to investigate teachers' perceptions of AI-based tools in their teaching practices. While case studies are commonly associated with qualitative inquiry, the use of questionnaires and descriptive statistics aligns with the exploratory nature of this research, aiming to capture broad patterns of perceptions and usage within a defined setting. As a study design, the case study is defined by the interests of individual cases rather than the techniques and inquiries of the research [14]. The case study methodology is widely used in educational research due

to its applicability in providing in-depth investigations of a particular case such as an individual, group, organization, or even, phenomena or a process over time. It enables researchers to study a phenomenon in its natural boundaries, which enhances ecological validity [38].

4.2 Participants

This study aims to explore the perceptions of teachers towards the use of AI in their teaching practices as STEM teachers. Teachers working in three STEM schools in Qatar were invited through email to take part in this study. The sample size was 12 teachers. No demographic details such as gender, nationalities or educational qualifications were collected.

4.3 Data collection

This paper employs online questionnaires as a data collection instrument. The use of online questionnaires supports the effectiveness of the ease of data collection and data management, as well as the wide reach that online questionnaires offer to recruit potential participants. The online questionnaire consisted of 20 statements with a 5-point Likert scale (1. Strongly disagree, 2. Disagree, 3. Neutral, 4. Agree, 5. Strongly agree). The questionnaire statements were constructed using TPACK as an underpinning theoretical framework by focusing on the following six subdomains: TK, PK, CK, TPK, TPACK and Ethics.

4.4 Procedures

The online questionnaires using Microsoft Forms were distributed through email to teachers working in three STEM schools. The timeframe for data collection was two to three weeks between April and May 2023. The purpose of the study was shared and informed consent was obtained prior to the start of the data collection phase through an online consent form following the Lancaster University ethical protocol (https://portal.lancaster.ac.uk/ask/administration/policies-regulations/data-protection/data-research-ethics/). Participation is done on voluntarily basis. Questionnaires were anonymous and no demographic data were collected. Participants were totally free to withdraw from the study without providing notice. There were no risks involved. After responses from participants were collected, the data was prepared to be analyzed.

4.5 Data analysis

The online questionnaire responses were prepared for analysis. First, responses were exported to a Microsoft Excel sheet. Then duplicates and any disagreement with informed consent were removed. Finally, responses were organized, and percentages of agreeing/disagreeing were calculated. The data collected were prepared to be interpreted to address the research questions.

5 Results

In this section, findings from online questionnaires distributed to the three STEM schools in Qatar are discussed. A total of 12 responses were collected and analyzed. The results are organized according to the six domains of the TPACK framework. For each domain, both percentage distributions and **composite mean scores** are reported to

offer a more nuanced understanding of teachers' self-reported competencies. Additionally, neutral responses are discussed to reflect potential uncertainty or limited exposure to AI tools.

5.1 Technological Knowledge

Figure 1 indicates the participants' responses regarding their technological knowledge. It showed that 75% (n = 9) of participants were aware of the AI-based tools available to them and they were able to execute tasks using these tools and only 25% (n = 3) were neutral about it. However, almost all participants were less confident and negative about their familiarity with the technical capabilities of the AI tools. The mean score for TK-related items was 3.7/5, reflecting a moderate level of confidence in basic AI tool usage but highlighting a potential gap in deeper technical understanding. Neutral responses (25%) suggest uncertainty or limited hands-on experience with AI features.

5.2 Pedagogical knowledge PK

Regarding teachers' abilities to plan activities that involve independent work that is student-centered, participants who responded positively were (n = 11, 92%) and only 8% (n = 1) of participants were neutral (Fig. 2). The average PK score was 4.4/5, suggesting high self-reported competence in instructional design and delivery. The limited neutral response may indicate confidence roots in existing pedagogical training and experiences.

5.3 Content Knowledge CK

Figure 3 shows that 83% (n = 10) of participants believed that they had sufficient content knowledge. Additionally, 92% (n = 11) believed that they could provide real-world learning opportunities beyond the classroom. Similarly, 92% (n = 11) felt confident delivering personalized learning within their subject domain. The mean CK score was 4.5/5, reflecting strong perceived mastery of content and its flexible application.

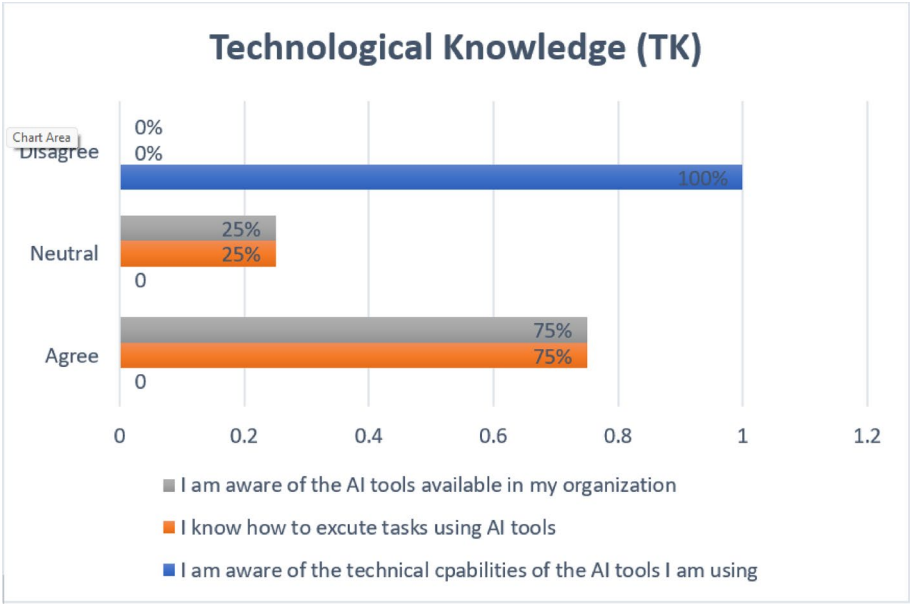

Fig. 1 Teachers' technological knowledge

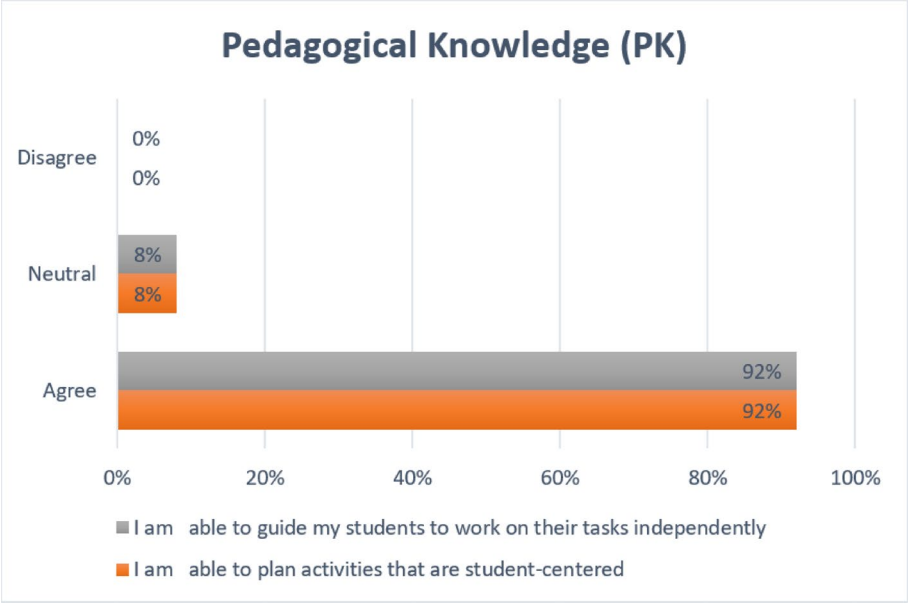

Fig. 2 Teachers' technological knowledge

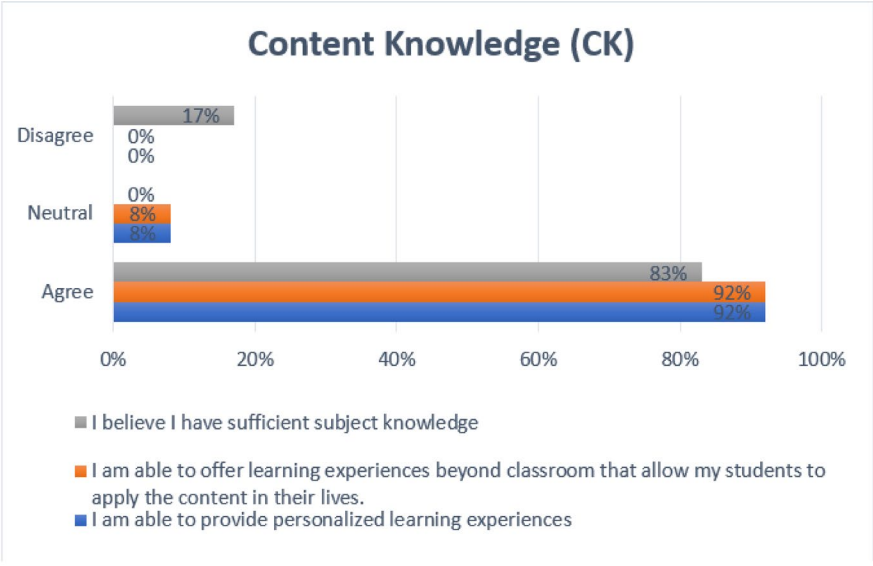

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Fig. 3 Teachers' content knowledge

5.4 Technological pedagogical knowledge TPK

Figure 4 indicates that 92% (n = 11) believed they could increase students' engagement using AI-based tools, and they could integrate such tools to achieve their lesson goals. Adding to that, 75% (n = 9) of teachers were able to support their students to use AI-based tools to complete certain tasks. Regarding providing feedback, 75% (n = 9) believed that through AI-based tools they could use students' data to provide constructive feedback. Only 58% (n = 7) believe they can select which AI-based tool to use to achieve their lesson goals. The mean TPK score was 4.1/5, indicating general competence, with room for improvement in AI tool selection and alignment with pedagogy. Neutral and lower

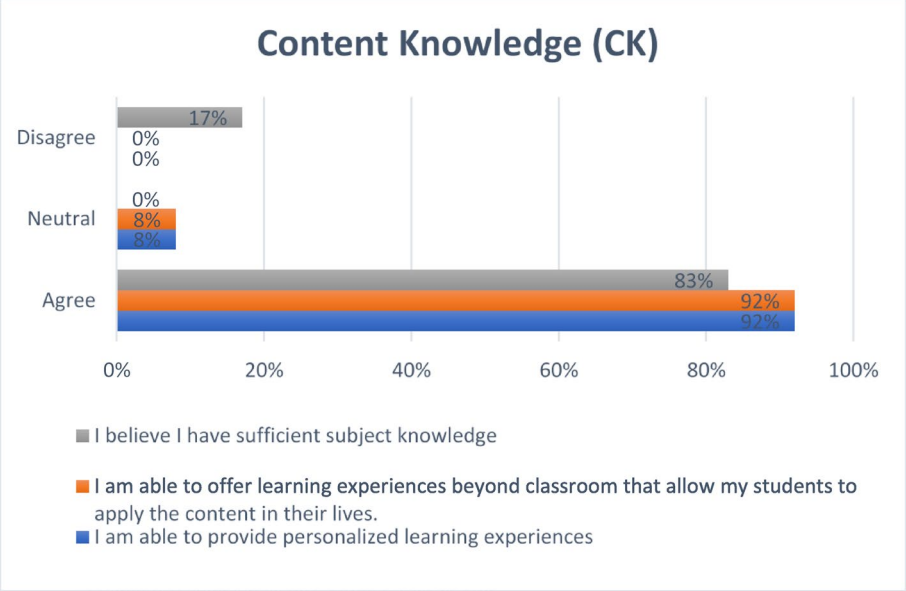

Fig. 4 Teachers' technological pedagogical knowledge

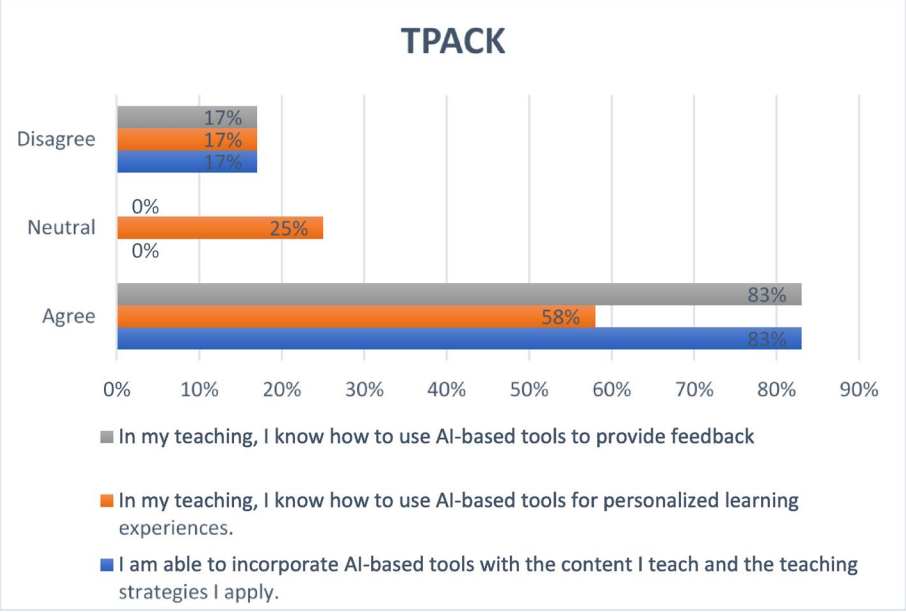

Fig. 5 Teachers' TPACK

scores in some items may reflect a lack of professional training on how to strategically choose and implement AI technologies.

5.5 TPACK

As illustrated in Fig. 5, 17% (n = 2) of teachers reported not having the knowledge to use AI-based tools to provide personalized feedback to students, while 58% (n = 7) were able to integrate AI-based tools to provide personalized learning experiences. Adding to that, 83% (n = 10) believed that they can incorporate AI-based tools with their content and the teaching strategies they apply. The TPACK domain had a mean score of 3.8/5, pointing

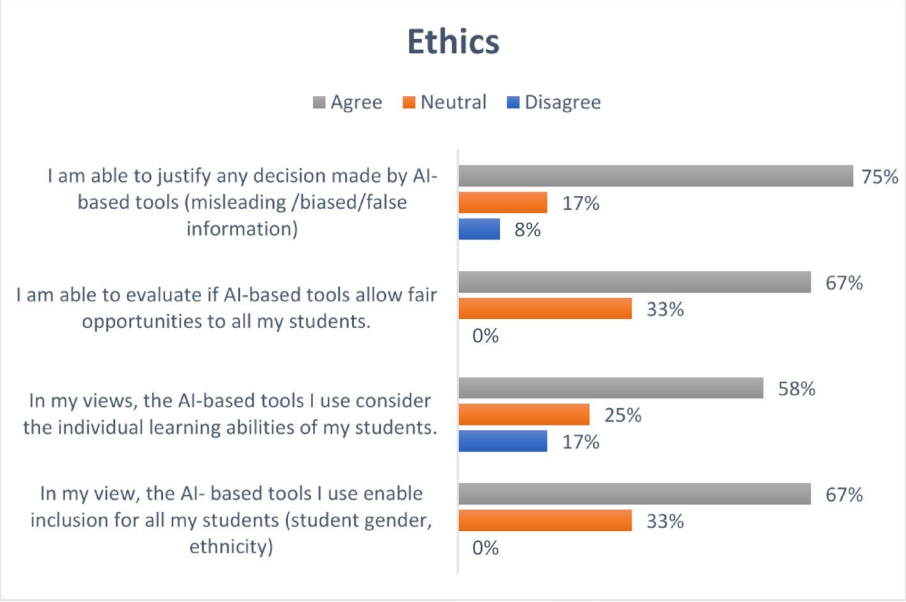

Fig. 6 Teachers' ethical awareness

to partial integration of AI with pedagogy and content. The presence of some neutral and disagreeing responses suggests a transitional stage in teachers' TPACK development when it comes to AI.

5.6 Ethics

Lastly, Fig. 6 shows that only 33% (n = 4) were neutral about whether AI-based tools enable inclusion and fairness, whereas 67% (n = 8) believed that AI-based tools are inclusive and allow fair opportunities to all their students. 75% (n = 9) believed that they were able to justify decisions made by AI-based tools and were able to identify misleading, biased and false information. The mean ethics score was 3.9/5. Neutral responses here may reflect a lack of structured training in AI ethics, which is a critical area for professional development.

6 Discussion

This paper explored the perceptions of STEM teachers in Qatar towards the integration of AI-based tools in their teaching practices. Online questionnaires were distributed to three STEM high schools, guided by the TPACK framework to capture how teachers conceptualize the integration of AI in relation to their technological, pedagogical, and content expertise. The findings offer valuable insights that contribute to the emerging literature on AI in K-12 education and inform strategic planning and policymaking in Qatar to empower STEM teachers and promote meaningful AI integration.

In response to RQ1: What are the perceptions of STEM teachers in Qatar towards the integration of Artificial Intelligence (AI) in their teaching practices?

The findings revealed generally positive perceptions among STEM teachers regarding the integration of AI in enhancing student engagement and supporting personalized learning. 83% (n = 10) of STEM teachers who responded "agree" and "strongly agree" believe that AI-based tools have the potential to increase students' engagement and hence develop their skills to accomplish tasks independently whereas only 16% (n = 2)

were not sure about that claim. The findings confirmed the previous studies that concluded the potential advantage of AI in enabling personalized learning experiences [16], scaffolding [20] and active learning [24]. Additionally, the results showed that teachers believe that they have fair technological knowledge. This finding is consistent with a previous study conducted by Chounta et al. [8] to explore the perception of Estonian K-12 teachers towards using AI as a tool to support their practices. Chounta et al. [8] claimed that teachers demonstrated fair technological knowledge, and they used AI as a tool to accomplish tasks related to their teaching practices such as organizing lessons, scheduling, and reviewing assignments. While the previous finding is evident, this perception can be challenged due to their unfamiliarity with the AI technical capabilities and suggests a degree of uncertainty, possibly due to a lack of practical exposure or confidence in deploying AI-based tools effectively. This technical unfamiliarity concurs with Hwang et al. (2020) who claimed that among the challenges that hinder the integration of AI, referring to Intelligent Tutoring Systems (ITS), is the lack of knowledge and experience of human tutors to make judgments and decisions that guide their intentions to use such technologies.

The findings further demonstrate strong Pedagogical Knowledge (PK) and Content Knowledge (CK) among the participants. Teachers reported high confidence in creating personalized learning opportunities that are student-centered. These results suggest that content and pedagogy remain foundational enablers for AI adoption, as teachers appear more willing to incorporate AI when they feel secure and confident with their subject content and pedagogical strategies.

In response to RQ2: To what extent does the relationship between Technological Knowledge (TK), Pedagogical Knowledge (PK) and Content Knowledge (CK) influence the integration of AI-based tools in STEM education?

The study examined the relationship between TK, PK, and CK in shaping the integration of AI-based tools. While results showed positive attitudes and a high correlation between PK and CK, the relative lag in TK suggests that technological literacy may be a limiting factor for integration. This highlights the interconnectedness of TPACK elements: successful AI integration depends not only on the presence of individual competencies but also on their interaction. For instance, a teacher that has a strong CK and PK, but moderate TK may struggle to effectively leverage AI in ways that align with curriculum goals. These dynamics support the TPACK model's emphasis on the necessity of integrating all three forms of knowledge to enable effective technology-mediated teaching.

Regarding ethics, STEM teachers presented themselves as being aware of the ethical implications of the AI-based tools they use. Most of them believed that they were able to justify decisions made by AI and they believed that AI-based tools enabled inclusiveness by considering the individual learning abilities of their students. However, STEM teachers were not confident regarding whether AI-based tools offer fair opportunities to their students or not, so they were skeptical towards the fairness in how AI-based tools are designed.

Based on the findings of this study, whilst STEM teachers were aware of the potential of the AI-based tools, two essential enablers should be considered; first is adequate professional training to better utilize this technology, and the second is the integration of AI in existing core curriculums. This is consistent with previous findings by Lee and Perret

[23] who suggested that AI curriculum can be integrated into existing courses to equip both students and teachers with the skills needed to use AI for learning and teaching.

7 Conclusion

As AI-powered tools continued to transform teaching and learning practices, research has surged in recent years to examine the potential and challenges of integrating these tools in educational settings. Not only exploring how to support the implementation of AI tools in classrooms but also examining the perceptions of educational stakeholders especially teachers towards this implementation. In STEM education, as technology is a core subject, teachers are expected to be proactive in integrating new technology to enhance their practices thus improving learning outcomes. In this case study, the aim is to explore the perceptions of STEM teachers in Qatar towards the use of AI-powered tools, particularly ITS in their context to enhance their teaching practices. Guided by TPACK as an underpinning framework, the research explores teachers' technological knowledge of AI tools and how their pedagogical and content knowledge may influence their attitudes towards adopting such technologies. It deploys an exploratory approach to collecting data through the online questionnaire. Findings showed that teachers believed that AI-powered tools could support students and potentially increase their engagement and motivation towards learning. Adding to that, results showed that teachers who have higher pedagogical and content knowledge are more willing to adopt AI- tools in their practices. While results were consistent with previous research, there was little evidence that teachers' technological knowledge influenced their intention to use AI tools in their context. Regarding ethical concerns, while most teachers believed that they were able to judge reliability, fairness, and inclusiveness, there were concerns related to fairness and bias that still need to be addressed. The findings of this study provide insights regarding the integration of technology in the classroom. Technology integration policies at schools can benefit from the findings of this study to redesign professional development policies and practices and encourage professional development initiatives involving technology.

8 Limitations and further research

There were a few limitations in this study. First, the limited number of participants may affect the depth and breadth of the findings, limiting their generalizability across different educational contexts. Therefore, expanding the population of similar studies in future research through employing various research designs and different data instruments is recommended. Second, there is a potential for self-report bias, as responses may reflect participants' perceptions rather than their actual practices. The use of triangulation to combine self-reported data with interviews, focus groups, or classroom observation is also recommended to mitigate self-biased results. Third, the timeframe for data collection was constrained; the period between April and May coincided with examination schedules, which may have influenced teachers' availability and willingness to participate fully in the research. One last limitation concerns the absence of demographic information. Demographic information such as age, gender and years of experience might influence the users' perceptions and attitudes towards using AI-based tools.

Given these limitations, future research is encouraged to adopt a mixed-methods approach, incorporating semi-structured interviews alongside questionnaires to allow

for deeper and more nuanced insights. Expanding the participant pool to include a larger and more diverse sample—encompassing not only STEM teachers but also STEM students—would provide a more holistic understanding of the perceptions and experiences surrounding AI tool usage. Additionally, exploring student perspectives may help identify how to guide their responsible use of AI and address associated ethical considerations. Including other key stakeholders, such as school leaders and parents, could also enrich the findings and contribute to developing more sustainable and inclusive strategies for integrating AI into education.

Despite its limitations, this study contributes to the ongoing discourse on AI integration in classrooms by offering valuable insights into how AI tools are perceived and implemented by STEM educators to enhance teaching practices.

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Author contributions
This paper is designed and conducted by the corresponding author, Moza Alkubaisi. There is a single author for this paper, and that is Moza Alkubaisi. Moza conceptualized the study and conducted a comprehensive literature review. She is responsible for collecting, analyzing, and interpreting the findings. Additionally, she drafted, revised, and finalized the manuscript. Moza Alkubaisi takes full responsibility for the accuracy and integrity of the work and approves the final version of the manuscript.

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Data availability
Data will be available upon request.

Declarations

Ethical approval and consent to participate
The research was ethically approved by the Ethics Committee of the Department of Educational Research at Lancaster University. Prior to participation, all participants were duly informed of their rights and responsibilities and provided explicit written consent. The study was conducted in agreement with the guidelines governing research involving human participants, as outlined by the Ethics Committee of the Department of Educational Research at Lancaster University.

Competing interests
The author (Moza Alkubaisi) declares that there are no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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