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COMPARING TURKISH PRE-SERVICE STEM AND NON-STEM TEACHERS' ATTITUDES AND ANXIETY TOWARD ARTIFICIAL INTELLIGENCE

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Abstract. *Identifying student teachers' attitudes and anxiety toward artificial intelligence (AI) in regard to their field of study might be helpful in determining whether and how AI will be employed in their future classrooms. Hence, this study aims to compare pre-service STEM and non-STEM teachers' attitudes and anxiety toward AI. In this quantitative research, the causal-comparative research design was adopted. The study involved 520 pre-service teachers from a faculty of education at a public university in Türkiye. Among all, 51.5% were pre-service non-STEM teachers while 48.5% were pre-service STEM teachers. Data were collected through the Turkish versions of "the General Attitudes toward Artificial Intelligence Scale" and "the Artificial Intelligence Anxiety Scale". Diagnostic analytics were performed, and descriptive statistics and MANOVA were performed to analyse the data. As a result, pre-service teachers, in general, were mostly positive about AI, but undecided to be anxious about AI. STEM student teachers had more positive attitudes toward AI than non-STEM student teachers, and non-STEM student teachers were more anxious toward AI than STEM student teachers. The results imply that non-STEM teacher education curricula should be redesigned to be AI-integrated to better prepare teachers of the future as teachers with TPACK integrated with AI.*

Keywords: *artificial intelligence, anxiety toward artificial intelligence, attitude toward artificial intelligence, pre-service STEM teacher, pre-service non-STEM teacher, pre-service teacher*

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Introduction

The reality that society is undergoing tremendous transformation as a result of technological advancements cannot be denied. Unquestionably, one of these technologies is artificial intelligence (AI). AI-powered technology is becoming a bigger part of our everyday lives and gradually changing how we think, behave, and interact with one another (Chen et al., 2020). Specifically, the advancements in AI technology are making us re-evaluate the future of knowledge, problem-solving, and intelligence in society (Mun et al., 2022). AI is a term that has been used since 1956 (McCarthy et al., 2006). AI encompasses four processes: data perception, data analysis, data usage, and data-driven intelligence improvement. The field of machine learning studies how to use data to make machines smarter without the need for human intervention. We are already surrounded by AI applications, whether we realize it or not, since AI is utilized to enhance a great deal of our daily activities (Antonenko & Abramowitz, 2023). As AI keeps permeating consumer goods, toys, and many different smart technologies, people from every walk of life, particularly today's youth, must gain a better understanding of it (Pu et al., 2021). In this context, students should comprehend and acquire AI-related skills for future employment (Wang et al., 2022) while all teachers must be knowledgeable about AI convergence education in conjunction with their major subjects (Yi & Lee, 2022).

The significant influence of AI is likewise evident in education, where AI-driven technologies like automated grading systems and intelligent tutoring are employed (Montebello, 2018; Wang & Zhao, 2020). In K–12 education, dashboards, chatbots, automated assessment systems, and intelligent tutoring systems are the most often utilized AI-driven tools (Celik et al., 2022). For instance, ChatGPT, an AI-driven tool, has piqued the interest of many educational researchers in recent years owing to its potential to alter the way students learn and teachers teach (Ipek et al., 2023). Throughout the teaching-learning process, these AI-driven systems provide numerous opportunities for all stakeholders (Chen et al., 2020). For instance, learner-centred approaches may be promoted by AI-driven tools (Luan et al., 2020). These approaches are applied to individualized learning experiences that AI-based technologies offer (Hwang et al., 2020; Buckingham Shum & Luckin, 2019). As a matter of

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fact, enhancing learning through increased personalization, adaptability, and efficiency is the aim of integrating AI into education (Zhou, 2023). AI-based tools have also been shown in studies to aid teachers in assessing the learning-teaching process and in preparing and executing lessons (Celik et al., 2022; Zawacki-Richter et al., 2019). To fully capitalize on the opportunities presented by AI in education, teachers need to understand how AI-based tools can improve learning (Xu, 2020). When teachers possess the pedagogical knowledge required to utilize AI-based tools, teaching can be improved by the use of AI technology (Cavalcanti et al., 2021). Thus, it is imperative that teachers possess the technological and pedagogical know-how to effectively utilize AI-based systems. The knowledge needed by teachers for integration could be explained by the technological, pedagogical, and content knowledge (TPACK) framework (Mishra & Koehler, 2006).

Theoretical Framework: TPACK Theory Deeply Integrated with AI

This research is founded on Mishra and Koehler's (2006) traditional theory of TPACK deeply integrated with AI (Yao, 2021). Shulman's (1986, 1987) concept of pedagogical content knowledge (PCK) serves as the foundation for the TPACK framework. The comprehension of how a particular subject matter is organized, modified, and transformed to improve student learning is known as PCK (Shulman, 1986). To improve the understanding of teachers' knowledge for successful integration of technology, Mishra and Koehler (2006) expanded on PCK by adding technological knowledge (TK). Technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPACK) were produced as a result of this extension process (Mishra & Koehler, 2006). According to their model, teachers' knowledge is split into three categories: technology, pedagogy, and content. The relationships that these bodies of knowledge—represented as PCK, TCK, TPK, and TPACK—have with one another are crucial to the model.

Koehler et al. (2007, p. 741) defined TPACK as the *"dynamic, transactional relationship between content, pedagogy, and technology"*. When utilizing the proper pedagogical approaches and technological tools in the classroom, TPACK highlights how crucial it is for teachers to possess an institutional understanding of the intricate interactions between the three basic knowledge components (PK, TK, and CK) (Schmidt et al., 2009). To teach any subject using the best pedagogical strategy and technological resources, to remove obstacles students face throughout the learning process with the usage of technology, and to assist students in their learning through technology is known as TPACK (Mishra & Koehler, 2006). Yao (2021) proposed a novel strategy for reconstructing teachers' knowledge via the thorough AI and TPACK integration in response to the specifications for teachers in the post-pandemic age where non-engineering students need to grasp the fundamental AI ideas and its application directions in order to envision a world enhanced by AI in the future (Lin et al., 2021). The TPACK theory deeply integrated with AI necessitates that teachers simultaneously master CK, PK, and AI TK (Yao, 2021): In other words, teachers should first employ AI technology to impart concepts and knowledge that students struggle to grasp. Second, in order to broaden students' cognition, teachers should employ AI technology to obtain and incorporate deeper subject matter knowledge. Third, AI technology assists teachers in achieving smart education management and in adjusting teaching strategies. TPACK deeply integrated with AI means using AI technology intelligently as part of collaborative human-machine thinking (Yao, 2021).

It is expected that the absence of AI-integrated TPACK in teachers and teacher candidates will increase their anxiety about AI and lead to negative attitudes toward AI since they will be concerned about what they do not know. Correspondingly, research has shown that teacher candidates' TK enables them to better use AI technology (Celik, 2023) and that teachers who lack solid TK are unable to take advantage of pedagogical opportunities (Koehler & Mishra, 2009). They believe technological tools are difficult to utilize (Joo et al., 2018).

Anxiety toward AI

Today's world is being built on the interaction of humans and AI-powered digitalized systems. AI applications in health, education, law, astronomy, engineering, and other fields are becoming more prevalent in daily life. According to Çelebi and Inal (2019), questions such as "Can AI have a feeling of responsibility?" and "What are the effects of its direct intervention in human existence and the ethical issues that may develop as a result?" have emerged as issues that must be addressed. Such questions imply that people are anxious about AI, which is rapidly developing in many areas (Johnson & Verdicchio, 2017). For example, ChatGPT has alarmed education stakeholders due to ethical and legal concerns, as well as the risks of cheating, bias, and inaccuracy (Ipek et al., 2023). According to the Future of Life Institute (2016), people and society will face negative consequences if AI

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becomes out of control. This situation highlights "AI anxiety" as a problem that needs to be addressed. Johnson and Verdicchio (2017) have stated that vague attitudes toward technological progress, confusion over autonomy, and sociotechnical blindness can all contribute to anxiety toward AI technologies. To put it another way, fear and uneasiness brought on by unclear AI development paths are known as AI-Anxiety (AIA). Wang and Wang (2022, p. 621) expressed it as "a general, emotional response of anxiety or fear that prevents an individual from interacting with AI". Four categories of AI anxiety were recognized by Wang and Wang (2022): "job replacement anxiety" (fear of the detrimental effects of AI on professional life); "AI configuration anxiety" (fear of humanoid AI); "sociotechnical blindness" (fear of AI's reliance on human beings); and "AI learning anxiety" (fear of learning AI technologies).

There has been little research on AI anxiety, despite the fact that it is now evident and receiving a lot of attention (Li & Huang, 2020). Pre-service teachers were found to be unwilling to collaborate with human-like robots in classrooms of the future (Rosanda & Istenič, 2021). Banerjee and Banerjee (2023) have concluded that college teachers' levels of anxiety toward AI do not differ significantly by gender or year of teaching experience. Ayanwale and Sanusi (2023) have found that STEM and non-STEM teachers differ significantly in their levels of anxiety toward AI, intention to teach AI, and attitudes toward AI. Non-STEM teachers expressed less anxiety about AI than STEM teachers did. Despite having a tiny effect size, there was a statistically significant difference in the levels of AI anxiety. In Türkiye, Terzi (2020) has examined teachers' AI anxiety levels in relation to various demographic factors and found out that the sociotechnical blindness of teachers does not differ on gender. Contrarily, female teachers expressed greater concern about AI than did their male counterparts, particularly with regard to job replacement, learning, AI configuration, and in general. Additionally, teachers' anxiety levels were not correlated with their age or teaching experience, nor were they based on their degree levels. Ozdemir (2023) discovered a substantial relationship between teachers' AI anxiety levels, genders and branches (information technologies vs. other), while no relationship was found between their AI anxiety levels and teaching experience. According to Takıl et al.'s (2022) research, pre-service teachers exhibited a moderate degree of anxiety in relation to AI technology. Pre-service teachers of different ages, genders, and departments participated in a study by Hopcan et al. (2023) on AI anxiety and attitudes toward machine learning (ML). They looked at gender, age, and departmental differences as well as the connections between sub-dimensions of anxiety toward AI and attitudes toward ML. It has been discovered that pre-service teachers from several departments, ages, and genders are worried about the effects of AI learning on social life and employment rates, but they have no concerns about AI learning itself. The anxiety and attitude of Turkish language student teachers toward AI, as well as the correlation between the two, were studied by Eyüp and Kayhan (2023). Results have shown that Turkish language student teachers have moderate favourable and unfavourable attitudes toward AI, less than moderate anxiety about AI learning, and more than moderate anxiety about AI configuration, job replacement, and sociotechnical blindness.

Attitudes toward AI

As AI techniques advance, attitudes toward AI have begun to gain importance in a variety of professions (Zhou, 2023). It is likely that people's attitudes toward AI will have a big impact on whether AI is accepted because attitudes both influence and predict behaviour (Steinmetz et al., 2016). A study by Yadrovskaia et al. (2023) focused on a contemporary individual's reaction to the advent of AI technologies, as well as the willingness of a modern person to accept the changes that this technology entails. They have concluded that respondents perceive potential in the application of AI technologies and are favourable about their use, even though they do not capture the underlying concepts. Ghotbi et al. (2022) did research on the attitudes and moral perceptions of social science and humanities college students in Japan toward AI. They have found out that the most severe issue regarding AI technologies is work loss. The possible future impacts of AI on the labour market seem to be accurately reflected in the students' answers. An overall more favourable attitude toward AI was found through the analysis of student-written texts. Although AI experts are worried about emotional AI being used for surveillance and future citizens' privacy being compromised, the most prevalent emotion was trust, which may seem naïve. According to the experts in AI, fear was the second most prevalent emotion.

Considering the context of teacher education, Lindner and Romeike (2019) have examined teachers' views on AI and concluded that media coverage of AI and recent hype issues have a large impact on their AI knowledge. Teachers valued sociocultural and technical AI knowledge slightly more than pure application-oriented competences. Furthermore, teachers reported a scarcity of appropriate instructional materials as well as good examples and tools of practice in the AI field. Kuleto et al. (2022) conducted an exploratory study with a group of K-12 teachers in Serbia to identify genuine AI knowledge and the potential for work process automation. They have

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discovered that the more teachers are aware and knowledgeable about AI, the easier it is for them to identify and actively benefit from opportunities for AI implementation in K-12 schools. Ayanwale and Sanusi (2023) discovered notable variations in STEM and non-STEM teachers' attitudes toward AI, anxieties about AI, and intentions to teach AI. Teachers who were not in the STEM fields had somewhat worse attitudes than those who were. The difference was statistically significant in spite of the small effect size.

Despite considerable research on teachers' attitudes toward AI, how student teachers view AI-driven technologies is still unknown (Korinek & Stiglitz, 2021). A quantitative study has found that science student teachers have a low level of awareness about AI's usage in science education (AlKanaan, 2022). The results of a qualitative, phenomenological study on attitudes of pre-service teachers toward AI have revealed that they give different interpretations to AI, feel mostly negatively about it, and express a desire to live in a society where AI is not in charge. Moreover, they thought AI could have both advantages and disadvantages as well as positive and negative effects on education (Haseski, 2019). In Türkiye, Eyüp and Kayhan (2023) sought to ascertain the anxiety and attitudes of Turkish language student teachers regarding AI, as well as to explore their relationships. The results have demonstrated that Turkish language student teachers' attitudes toward AI are mixed.

Significance

Playing a critical role in adapting and timely preparing to cope with the advancement of AI education (Banerjee & Banerjee, 2023); teachers' anxiety toward AI will influence their future intentions to use AI products and applications (Wang & Wang, 2022). Therefore, it is believed that identifying student teachers' anxiety and attitudes regarding AI in relation to their field of study will be important in providing ideas for how AI will be used in K–12 education going forward. The current study is also expected to close a gap in the literature because it has been found that there are not many studies on student teachers and AI in Türkiye. Numerous of these studies have concentrated on student teachers' perceptions of AI (Çam et al., 2021; Haseski, 2019) and its applications (Bayram & Çelik, 2023; Kelleci & Aksoy, 2021; Tapan-Broutin, 2023). However, it is important to note that there has not been a comparison of pre-service STEM and non-STEM teachers' attitudes and anxiety levels regarding AI in Türkiye. The current research comparing affective characteristics of pre-service STEM and non-STEM teachers with regard to AI would aid in the re-evaluation of teacher education programs in order to integrate AI into their elements such as objectives, content, teaching-learning process, and assessment. Therefore, this research sought to identify student teachers' levels of anxiety and attitudes toward AI and compare Turkish pre-service STEM and non-STEM teachers' attitudes and anxiety about AI. The following were the questions this research attempts to answer:

- What are pre-service teachers' levels of attitudes toward AI?
- What are pre-service teachers' levels of anxiety toward AI?
- What differences in pre-service teachers' attitudes toward AI are caused by their field of study (STEM or non-STEM)?
- What differences in pre-service teachers' anxiety toward AI are caused by their field of study (STEM or non-STEM)?

Research Methodology

Research Design

This is a quantitative, causal-comparative research. A causal-comparative study tries "to determine the cause or consequences of differences that already exist between or among groups of individuals" (Fraenkel et al., 2011, p. 389). The exploration of effects (attitudes toward AI and anxiety toward AI) brought on by membership in a particular group (STEM or non-STEM) from a faculty of education at a public university is the type of this causal-comparative research conducted in the 2023 – 2024 academic year (Fraenkel et al., 2011, p. 367).

Sampling

Selected by convenience sampling, data were gathered from 520 pre-service teachers registered at a faculty of education at a public university in Türkiye. For causal-comparative research designs, a minimum sample size of 64 participants per group is needed to detect a moderate, two-tailed statistically significant difference with .80 statistical power at the 5% level of significance (Onwuegbuzie et al., 2004 cited in Onwuegbuzie & Collins, 2007).

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Hence, each group (STEM, non-STEM) can be considered large enough to generalize the findings. In addition, the sample volume was calculated based on Krejcie and Morgan's (1970) sample size determination table. As the accessible population of this research comprised 875 pre-service teachers based on the records of the Student Affairs Office of the relevant faculty of education, the sample size should be between 265 and 269 at minimum (Krejcie & Morgan, 1970). Therefore, the sample can be regarded as representative enough to achieve valid conclusions. Data were voluntarily gathered from a convenient sample of pre-service teachers. The sample was 77% female. Of the participants, 51.5% were pre-service non-STEM teachers (26.7% Turkish Language Education, 24.8% Social Studies Education) while 48.5% were pre-service STEM teachers (29% Elementary Mathematics Education, 19.4% Elementary Science Education). Among all, 24.7% were first-year students; 22.9%, second-year students; 23.5%, third-year students, and 28.9%, fourth-year students. Of all pre-service teachers, 93.1% reported that they used AI applications. On average, participants spent 29.8 minutes per day for the use of AI applications (*SD* = 33.8, range = 0–240 minutes per day).

Instrument and Procedures

Turkish Version of the General Attitudes toward Artificial Intelligence Scale

"The General Attitudes toward Artificial Intelligence Scale" (GAAIS) developed by Schepman and Rodway (2020) and adapted into Turkish by Kaya et al. (2022) was used to measure student teachers' attitudes toward AI. With 12 items in the Positive GAAIS and 8 in the Negative GAAIS, the Turkish GAAIS consists of 20 items in total. A five-point Likert-type scale (1 = strongly disagree through 5 = strongly agree) is used for scoring. In the Turkish sample, the two-dimensional factor structure was validated (χ^2 = 255.38, *df* = 169, χ^2/df = 1.51, CFI = .974, NNFI = .971, SRMR = .066, RMSEA = .038). The internal consistency reliability of the scale was good, with α = .82 for Positive GAAIS and α = .84 for Negative GAAIS (Kaya et al., 2022). The current study also confirmed the Turkish GAAIS factor structure. CFI and NNFI > .90, as well as RMSEA and SRMR < .08, were considered as criteria, as is typically the case with fit indices (Byrne, 2010; Hu & Bentler, 1999; Kline, 2016; Schumacker & Lomax, 2010; Tabachnick & Fidell, 2014). The CFA results (χ^2 = 491.38, *df* = 165, χ^2/df = 2.98, CFI = .96, NNFI = .95, SRMR = .055, RMSEA = .062) have shown that these fit indices indicate acceptable fit. Moreover, in the pre-service teacher sample, Cronbach's α was .83 for the negative GAAIS and .86 for the positive GAAIS.

Turkish Version of the Artificial Intelligence Anxiety Scale

"The Artificial Intelligence Anxiety Scale" (AIAS) (Wang & Wang, 2019), translated into Turkish by Terzi (2020), was used to measure pre-service teachers' anxiety toward AI. The Turkish AIAS has 21 items and four dimensions: eight in the "Learning" dimension, six in the "Job Replacement" dimension, four in the "Sociotechnical Blindness" dimension, and three in the "AI Configuration" dimension. A rating scale of seven points, ranging from 1 for never to 7 for completely, is used to score the items. The Turkish sample provided confirmation of the four-dimensional factor structure (χ^2 = 458.268, *df* = 178, χ^2/df = 2.57, CFI = .94, TLI = .93, SRMR = .069, RMSEA = .084). As reported by Terzi (2020), the scale's internal consistency reliability was good, with α = .96 for the total AIAS, α = .89 for the "Learning" dimension, α = .95 for the "Job Replacement" dimension, α = .89 for the "Sociotechnical Blindness" dimension, and α = .95 for the "AI Configuration" dimension. Similar findings were found in this study. As is typically the case with fit indices, the following criteria were used: RMSEA and SRMR < .08, CFI and NNFI > .90 (Byrne, 2010; Hu & Bentler, 1999; Kline, 2016; Schumacker & Lomax, 2010; Tabachnick & Fidell, 2014). The CFA results (χ^2 = 617.69, *df* = 177, χ^2/df = 3.49, CFI = .98, NNFI = .98, SRMR = .075, RMSEA = .069) have shown that the fit indices indicate acceptable fit. In addition, Cronbach's α was .94 for the total AIAS, α = .90 for the "Learning" dimension, α = .93 for the "Job Replacement" dimension, α = .87 for the "Sociotechnical Blindness" dimension, and α = .94 for the "AI Configuration" dimension in the pre-service teacher sample.

Data Collection

It took roughly 20 minutes to administer the scale after obtaining the required ethical approval (Date: October 18, 2023, Number: 2023/289) from a public university's institutional review board. The study's purpose was explained to the student teachers who completed the scales on paper. Pre-service teachers were also assured that their information would remain confidential.

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Data Analysis

Diagnostic analytics were used to determine the root causes of the events (Balali et al., 2020). To ascertain pre-service teachers' attitudes and anxiety levels regarding AI, descriptive statistics namely, means and standard deviations were computed. Through the use of a parametric test, such as multivariate analysis of variance (MANOVA), it was tested whether pre-service teachers' attitudes and anxiety levels toward AI varied significantly based on the fixed independent variable (area of study, i.e. STEM, non-STEM). The significance level was set at .05. All of these analyses were performed with statistical software.

Research Results

Pre-Service STEM and Non-STEM Teachers' Attitudes toward AI

Pre-service STEM and non-STEM teachers' attitudes toward AI appear in Table 1.

Table 1
Pre-service STEM and Non-STEM Teachers' Attitudes toward AI

Field of Study		*M*	*SD*
STEM (*n* = 252)	"Positive attitudes toward AI"	3.75	0.52
	"Negative attitudes toward AI"	2.89	0.66
Non-STEM (*n* = 268)	"Positive attitudes toward AI"	3.59	0.62
	"Negative attitudes toward AI"	2.99	0.70
Total (*n* = 520)	"Positive attitudes toward AI"	3.67	0.58
	"Negative attitudes toward AI"	2.94	0.68

As demonstrated by Table 1, pre-service teachers in general were mostly positive about AI ($M = 3.67$; $SD = 0.58$). STEM student teachers ($M = 3.75$; $SD = 0.52$) had more favourable attitudes toward AI than non-STEM student teachers ($M = 3.59$; $SD = 0.62$). On the other hand, compared to STEM student teachers ($M = 2.89$; $SD = 0.66$), non-STEM student teachers ($M = 2.99$; $SD = 0.70$) had more negative attitudes toward AI.

Pre-Service STEM and Non-STEM Teachers' Anxiety toward AI

Pre-service STEM and non-STEM teachers' anxiety toward AI is displayed in Table 2.

Table 2
Pre-service STEM and Non-STEM Teachers' Anxiety toward AI

Field of Study		*M*	*SD*
STEM (n = 252)	Anxiety toward Learning	3.16	1.10
	Anxiety toward Job Replacement	4.93	1.29
	Anxiety toward Sociotechnical Blindness	4.92	1.19
	Anxiety toward AI Configuration	4.44	1.63
	Anxiety toward AI	4.18	1.01
Non-STEM (n = 268)	Anxiety toward Learning	2.98	1.18
	Anxiety toward Job Replacement	5.10	1.39
	Anxiety toward Sociotechnical Blindness	4.93	1.36
	Anxiety toward AI Configuration	4.61	1.81
	Anxiety toward AI	4.19	1.12

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Field of Study		*M*	*SD*
Total (n = 520)	Anxiety toward Learning	3.07	1.14
	Anxiety toward Job Replacement	5.02	1.34
	Anxiety toward Sociotechnical Blindness	4.92	1.28
	Anxiety toward AI Configuration	4.53	1.73
	Anxiety toward AI	4.19	1.07

As understood from the data displayed in Table 2, student teachers, in general, were undecided to be anxious about AI (*M* = 4.19; *SD* = 1.07). Pre-service teachers partially agreed to be anxious about job replacement (*M* = 5.02; *SD* = 1.34), sociotechnical blindness (*M* = 4.92; *SD* = 1.28), and AI configuration (*M* = 4.53; *SD* = 1.73), respectively. But, they partially disagreed to be anxious about learning (*M* = 3.07; *SD* = 1.14). Pre-service non-STEM teachers (*M* = 4.19; *SD* = 1.12) seemed to be more anxious about AI than STEM student teachers (*M* = 4.18; *SD* = 1.01). In particular, STEM student teachers (*M* = 3.16; *SD* = 1.10) were more anxious only about learning than pre-service non-STEM teachers (*M* = 2.98; *SD* = 1.18), pre-service non-STEM teachers (*M* = 5.10; *SD* = 1.39) were more anxious about job replacement than STEM student teachers (*M* = 4.93; *SD* = 1.29), non-STEM student teachers (*M* = 4.93; *SD* = 1.36) were more anxious about sociotechnical blindness than STEM student teachers (*M* = 4.92; *SD* = 1.19), and non-STEM student teachers (*M* = 4.61; *SD* = 1.81) were more anxious about AI configuration than pre-service STEM teachers (*M* = 4.44; *SD* = 1.63).

Field of Study Differences in Pre-Service Teachers' Attitudes toward AI

While the two factors of the Turkish GAAIS are dependent variables, the independent variable is pre-service teachers' fields of study namely, STEM or non-STEM. MANOVA was used to test whether pre-service teachers' attitudes toward AI differ depending on their fields of study. The MANOVA postulates were double-checked prior to analysis. Due to the unmet homogeneity of covariance assumption (Box's *M* = 11.73, $p < .05$), a more reliable statistic called Pillai's Trace was used. Based on the findings of the Levene test, the homogeneity of variance assumption is satisfied for "negative attitudes toward AI" [$F_{(1, 518)} = 2.42$, $p > .05$], but not met for "positive attitudes toward AI" [$F_{(1, 518)} = 8.73$, $p < .05$]. Hence, the level of significance was decreased to .04. Table 3 displays the findings of the univariate and multivariate analyses of variance.

Table 3
Field of Study Differences in Pre-Service Teachers' Attitudes toward AI

	MANOVA		ANOVA			
			"Positive attitudes toward AI"		"Negative attitudes toward AI"	
	$F_{(2, 517)}$	Partial η^2	$F_{(1, 518)}$	Partial η^2	$F_{(1, 518)}$	Partial η^2
Field of study	7.96*	.03	9.25**	.018	3.02	.006

*$p < .04$, **$p < .02$

The MANOVA results indicated that pre-service STEM and non-STEM teachers' attitudes toward AI differed significantly (Pillai's Trace = .03, $F_{(2, 517)} = 7.96$, $p < .04$, partial $\eta^2 = .03$). The effect size was small to moderate based on widely recognized standards (Cohen, 1988). The Bonferroni correction was applied in order to calculate the univariate *F* statistics. Due to two dependent variables, the *F* statistics were rated at a .02 significance level. The positive attitudes that pre-service teachers had toward AI ($F_{(1, 518)} = 9.25$, $p < .02$, partial $\eta^2 = .018$) varied significantly based on their fields of study. However, student teachers' negative attitudes toward AI ($F_{(1, 518)} = 3.02$, $p > .02$) did not significantly differ on their fields of study. The findings suggest that among STEM and non-STEM student teachers, the only significant differences are in the levels of positive attitudes toward AI ($p < .02$). In contrast to pre-service non-STEM teachers (*M* = 3.59; *SD* = 0.62), pre-service STEM teachers (*M* = 3.75; *SD* = 0.52) demonstrated more positive attitudes toward AI.

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Field of Study Differences in Pre-Service Teachers' Anxiety toward AI

While the four factors of the Turkish AIAS are dependent variables, the independent variable is pre-service teachers' fields of study namely, STEM or non-STEM. MANOVA was used to test whether pre-service teachers' anxiety toward AI differs depending on their fields of study. The MANOVA postulates had been verified twice before the analysis was conducted. Due to the met homogeneity of covariance assumption (Box's $M = 11.15$, $p > .05$), Wilks' λ was consequently selected for reporting. The Levene test results show that the homogeneity of variances assumption is satisfied for anxiety toward learning [$F_{(1, 518)} = .87$, $p > .05$], but not met for anxiety toward job replacement [$F_{(1, 518)} = 5.6$, $p < .05$], anxiety toward sociotechnical blindness [$F_{(1, 518)} = 6.9$, $p < .05$], and anxiety toward AI configuration [$F_{(1, 518)} = 5.7$, $p < .05$]. Hence, the level of significance was decreased to .04. Table 4 presents the findings from the univariate and multivariate analyses of variance.

Table 4
Field of Study Differences in Pre-Service Teachers' Anxiety toward AI

			ANOVA							
	MANOVA		Anxiety toward learning		Anxiety toward job replacement		Anxiety toward sociotechnical blindness		Anxiety toward AI **configuration**	
	$F_{(4, 515)}$	Partial η^2	$F_{(1, 518)}$	Partial η^2	$F_{(1, 518)}$	Partial η^2	$F_{(1, 518)}$	Partial η^2	$F_{(1, 518)}$	Partial η^2
Field of study	3.36*	.025	3.09	.006	2.06	.004	.014	.000	1.34	.003

*p < .04

The MANOVA results revealed that pre-service STEM and non-STEM teachers' levels of anxiety regarding AI differed significantly (Wilks' $\lambda = .98$, $F_{(4, 515)} = 3.36$, $p < .04$, partial $\eta^2 = .025$). The effect size varied from small to moderate based on widely recognized standards (Cohen, 1988). Pre-service non-STEM teachers ($M = 4.19$; $SD = 1.12$) were found to be more anxious toward AI than pre-service STEM teachers ($M = 4.18$; $SD = 1.01$). Due to four dependent variables, the significance level of .01 was applied when assessing the F statistics using the Bonferroni correction. The ANOVA results indicated that student teachers' levels of anxiety toward learning ($F_{(1, 518)} = 3.09$, $p > .01$), anxiety toward job replacement ($F_{(1, 518)} = 2.06$, $p > .01$), anxiety toward sociotechnical blindness ($F_{(1, 518)} = .014$, $p > .01$), and anxiety toward AI configuration ($F_{(1, 518)} = 1.34$, $p > .01$) did not differ significantly on their fields of study. In other words, pre-service STEM and non-STEM teachers' levels of "anxiety toward learning", "anxiety toward job replacement", "anxiety toward sociotechnical blindness", and "anxiety toward AI configuration" do not significantly vary ($p > .01$).

Discussion

Student teachers in general were found to be mostly positive about AI, but undecided to be anxious about AI despite the fact that people worldwide are concerned about the risks associated with AI, international attitudes toward technology are ambiguous at best (Neudert et al., 2020), and that student teachers oppose the use of social robots with humanoid embodies in classrooms (Istenic et al., 2021). Furthermore, it was discovered that STEM and non-STEM student teachers' attitudes toward AI differ significantly from one another. Positive attitudes of pre-service teachers regarding AI varied significantly depending on their fields of study. However, pre-service teachers' negative attitudes toward AI did not significantly differ on their fields of study. The findings suggest that among STEM and non-STEM student teachers, the only substantial differences are in the levels of favourable attitudes toward AI. In contrast to non-STEM student teachers, STEM student teachers demonstrated more favourable attitudes toward AI. Zhang et al. (2023) have found out that the key factors influencing the intentions of student teachers to utilize AI technology are perceived utility and perceived usability, with perceived utility being more influential than perceived usability.

Given that STEM student teachers are more positive about AI than pre-service non-STEM teachers, it could be read that STEM student teachers perceive AI technology as more useful than pre-service non-STEM teachers. More positive attitudes of pre-service STEM teachers toward AI might be accounted for by their AI literacy. Lin et al. (2021) have highlighted that engineering students consider AI as a technology, whereas non-engineering students see AI as a tool and studied the impact of STEM-based course on non-engineering students' levels of AI literacy

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and awareness of AI ethics. It has been found that the STEM-based course effectively improves non-engineering students' levels of AI literacy and that students having low AI literacy show higher levels of awareness regarding AI ethics. Based on these findings, STEM student teachers in this study may be more AI-literate or have higher levels of TPACK deeply integrated with AI than pre-service non-STEM teachers due to the teacher education curricula they are exposed to. This possibility raises the question of whether AI technology courses are included in the teacher preparation curricula in Türkiye to which the student teachers participating in the research are being exposed. While there is no single course on AI in teacher preparation curricula of student teachers studying in the fields of STEM and non-STEM, there are courses on technology use and integration into the classroom. Information technologies and instructional technologies courses are offered in all teacher education curricula (Higher Education Council [HEC], 2018a, 2018b, 2018c, 2018d). Furthermore, the elementary science teacher education curriculum includes courses on applications of science in technology and science and technology-related problems (HEC, 2018a); the elementary mathematics teacher education curriculum includes courses on algorithms and programming, as well as computer-supported mathematics teaching (HEC, 2018b). There are two courses namely, "science, technology, and society" and "information technologies in social studies teaching" in the social studies teacher education curriculum (HEC, 2018c). However, there is no single technology-related course in the Turkish language teacher education curriculum (HEC, 2018d). It is clear in this context that student teachers majoring in STEM fields, in contrast to those majoring in non-STEM fields, are more likely to take courses that include technology- and AI-based applications. This could have resulted in an increase in the TPACK or AI literacy levels of pre-service STEM teachers, resulting in a more positive attitude toward AI use and a lower level of anxiety toward AI. Correspondingly, science teachers' levels of TPACK self-confidence were discovered to be high (Bağdiken & Akgündüz, 2018; Yıldırım, 2022), mathematics teachers' levels of TPACK self-efficacy (Karataş & Aslan Tutak, 2017) and TPACK (Organ Ulus & Aşiroğlu, 2022) were found to be high and adequate (Dağlı, 2018). Balcı et al. (2021) have found out that science teachers' levels of self-efficacy for Web PCK are extremely high and significantly differ on their teaching experience, and that science teachers use the Web for practice, experiments, lectures, videos, visual aids, and making up for a lack of resources and should be trained to use the Web in their classrooms. Nevertheless, social studies teachers were found to be less competent in TK (Bal & Karademir, 2013; Aksin, 2014), and social studies and Turkish language teachers' TPACK levels were found to be moderate (Saka Öztürk, 2017). Another reason for more positive attitudes of STEM student teachers toward AI could be the opportunities given to use AI applications in the faculty. In fact, student teachers must possess the required knowledge, skills, and attitudes to successfully do AI-based teaching in schools (Seufert et al., 2020). For instance, the use of AI-driven virtual classroom simulations significantly improved the TPACK application skills of pre-service teachers (Aksoy & Kelleci, 2023). The strategic integration of AI has a significant potential not only for improving STEM education (Triplett, 2023), but also for designing AI-enhanced lesson plans in collaboration with teachers from STEM and non-STEM fields such as history, language arts, and so on (Lin & Van Brummelen, 2021). The other reason behind more positive attitudes of pre-service STEM teachers toward AI might be that they observe more AI-enhanced lessons during their classroom teaching practice than pre-service non-STEM teachers.

Additionally, it is determined that pre-service STEM and non-STEM teachers' levels of anxiety regarding AI differ significantly from one another. Pre-service non-STEM teachers were detected to be more anxious toward AI than pre-service STEM teachers. Pre-service non-STEM teachers might be afraid of machines that could take over the world due to their misconceptions about AI (Dai et al., 2020). Pre-service non-STEM teachers might not be tech-savvy (Pinto Dos Santos et al., 2019) and enthusiastic about AI and might not see it as a useful technology (Dai et al., 2020). As a result, non-STEM student teachers may be viewed as unprepared for AI adoption (Suseno et al., 2022). There are no significant differences in the levels of "anxiety toward learning", "anxiety toward job replacement", "anxiety toward sociotechnical blindness", and "anxiety toward AI configuration" among pre-service STEM and non-STEM teachers. Student teachers, nonetheless, were found to be concerned about the influence of AI on social life and employment, but not about AI learning (Hopcan et al., 2023).

Conclusions and Implications

This research aimed to determine pre-service STEM and non-STEM teachers' levels of attitudes toward AI as well as anxiety about AI. In addition, whether differences in their attitudes toward AI and anxiety toward AI are caused by their field of study (STEM or non-STEM) or not were examined. As a result, student teachers in general were mostly positive about AI, but undecided to be anxious about AI. STEM student teachers had more positive attitudes toward AI than non-STEM student teachers. Non-STEM student teachers were more anxious toward AI

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than STEM student teachers. The results of this study suggest that the curriculum, instruction, and faculty-school collaboration, particularly in non-STEM teacher education, should be reconsidered again in terms of the development of TPACK deeply integrated with AI and provide the following recommendations for further research and practice: To make Turkish pre-service non-STEM teachers' attitudes toward AI more positive and reduce their anxiety toward AI, non-STEM teacher education curricula should be redesigned to be AI-integrated to better prepare them as teachers of the future as teachers with TPACK deeply integrated with AI. To develop such curricula, AI might be utilized to assess non-STEM student teachers' cognitive and affective needs (Chen et al., 2021). Such reforms might create positive pre-service teacher perceptions of the usefulness of AI. Aravantinos et al. (2024) did a systematic review on the use of AI in primary education and concluded that AI and ML concepts are primarily covered in STEM and STEAM, mathematics and geometry, English as a foreign language learning, arts, and a variety of other subjects, the activities students engage in are apply-engage-interact-use, multiple project-based learning activities, experiential and practicing activities, and tutoring, and that the AI activities or tools are taught via experiential learning, project-based learning, AI-assisted learning, and constructivism. To better equip student teachers to teach in such classrooms, courses and/or practices that will enhance pre-service non-STEM teachers' TPACK integrated with AI should be added to the current non-STEM teacher education curricula being implemented in faculties of education around Türkiye in accordance with the authorization given by the HEC (2020) to redesign their own teacher education curricula. As suggested by Aravantinos et al. (2024), foundations of AI, ML, and computational thinking, AI applications for a range of common classroom tasks and activities, AI implementations of curriculum, instructional methods, assessment, platforms, and tools, and implications and difficulties of AI such as AI ethics and inclusivity might be considered. As hands-on activities can help students understand AI better (Lin et al., 2021), pre-service non-STEM teachers should collaborate on interdisciplinary AI-based projects with pre-service STEM teachers. Regarding teaching practice, student teachers ought to be matched with teacher educators and mentor teachers who are skilled at incorporating AI technology into their classrooms. Pre-service teachers will learn AI applications in teaching non-STEM and STEM from their teacher educators and mentor teachers and will improve their TPACK integrated with AI or become AI-literate. However, such recommendation requires further research on how competent teacher educators and in-service STEM and non-STEM teachers are in the use of AI in their classrooms. On-site observations should be conducted to obtain a better understanding of how successful AI is being used in faculties of education as well as schools. Consequently, training in the application of AI in faculty and school contexts should also be provided to teacher educators and in-service teachers (Aravantinos et al., 2024). Furthermore, why STEM student teachers are more positive about AI than pre-service non-STEM teachers, and why non-STEM student teachers are more anxious toward AI than pre-service STEM teachers should be studied qualitatively by conducting semi-structured interviews with pre-service STEM and non-STEM teachers. Last but not least, this research should be replicated with a sample of STEM and non-STEM teachers and teacher educators from Türkiye.

Declaration of Interest

The authors declare no competing interest.

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