ARTIFICIAL INTELLIGENCE LITERACY AND ANXIETY LEVELS OF PRE-SERVICE SCIENCE TEACHERS: A MIXED METHOD STUDY

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ABSTRACT

The study aimed to assess levels of "artificial intelligence literacy" (AIL) and "artificial intelligence anxiety" (AIA) among pre-service teachers and to examine their relationship. The study used an explanatory sequential design, a mixed-methods design. Quantitative data were collected from 136 pre-service teachers using the "Artificial Intelligence Literacy Scale" and "Artificial Intelligence Anxiety Scale" through convenience sampling. Qualitative data were collected through semi-structured interviews with nine pre-service teachers using criterion sampling. Quantitative data were analyzed using ANOVA and correlation analyses, while qualitative data were subjected to content analysis. The results indicated that pre-service teachers' AIL levels did not differ significantly by GPA, AI knowledge level, or emotional state towards AI. However, they varied significantly by skill level with technological tools.

Additionally, AIA levels did not differ significantly by skill level in using technological tools or AI knowledge level. However, they varied considerably based on GPA and emotional state variables. Correlation results revealed no significant relationship between AI levels and AIA levels. The qualitative data from interviews supported the quantitative results, indicating no relationship between AIL and AIA levels. As a suggestion, training can be provided to increase pre-service teachers' awareness of AI.

KEYWORDS

Artificial intelligence anxiety, artificial intelligence literacy, pre-service teachers

HOW TO CITE

Akbay B., Karakoç Topal Ö., Bostan Sarıoğlan A. (2025) 'Artificial Intelligence Literacy and Anxiety Levels of Pre-service Science Teachers: a Mixed Method Study', *Journal on Efficiency and Responsibility in Education and Science*, vol. 18, no. 4, pp. 318–333. http://dx.doi.org/10.7160/eriesj.2025.180407

Highlights

- *It was determined that pre-service teachers' artificial intelligence literacy was close to high, and their anxiety levels towards artificial intelligence were at a medium level.*
- *It was observed that there was no significant relationship between pre-service teachers' artificial intelligence literacy and their anxiety towards artificial intelligence.*
- *Semi-structured interviews with pre-service teachers supported the quantitative result that there was no significant relationship between AI literacy and AI anxiety.*

INTRODUCTION

Artificial intelligence (AI) technology has been used in various fields, including transportation, health, agriculture, and banking. It has now also become integrated into the learning and teaching process, playing a role in education (Demir & Güraksın, 2022). Integrating AI applications in educational environments offers several advantages, including making learning more effective, personalizing teaching to accommodate individual differences, and facilitating quick feedback for evaluation purposes (Chiu et al., 2023). These AI applications in education are seen as an opportunity, and their significance grows as technology advances. Teachers and pre-service teachers need to keep up with current technological applications to adapt to the changing student profiles driven by technological development and evolution (Hussin, 2018). Digital and technology literacy concepts have gained attention, emphasizing the importance of people having the skills to reliably and effectively use digital resources to access information (Kaya Özgül et al., 2023). Technology literacy involves understanding and using technology correctly and evaluating its effects (Ejikeme & Okpala, 2017).

On the other hand, artificial intelligence literacy, first mentioned in 2015 (Konishi, 2015), refers to the ability to effectively and efficiently use and understand artificial intelligence technologies and to critically evaluate their potential effects (Long & Magerko, 2020). Artificial intelligence literacy is believed to become more important than digital and technology literacy due to its impact size and potential (Çelebi et al., 2023). Therefore, being AI-literate individuals plays a significant role in effectively using this technology, which we are increasingly in close contact with.

It is important to note that pre-service teachers need to develop artificial intelligence literacy, considering the continuous development of technology. This is crucial as they will encounter AI applications in their professional and daily lives (Laupichler et al., 2022). However, it is worth noting that there are few studies on AI literacy, and those that exist are still in their early stages (Laupichler et al., 2022). These studies include review studies (Çelebi et al., 2023; Laupichler et al., 2022), case studies (Lérias et al., 2024), test development studies (Hornberger et al., 2023), studies focusing on the development of AI literacy (Kong et al., 2022; Kong et al., 2024), and studies that have created comprehensive evaluation frameworks (Wang et al., 2023). Most of these studies use qualitative research methods or aim to develop artificial intelligence literacy, underscoring the need for further research in this area (Schiavo et al., 2024). One specific area that requires more attention is anxiety research related to artificial intelligence. The relationship between artificial intelligence (AI) literacy and AI-related anxiety among pre-service science teachers is both significant and complex. AI literacy has been found to correlate with lower anxiety levels. In other words, individuals who have a strong understanding of AI tend to feel more confident when using technology. This, in turn, reduces fears of becoming obsolete or feeling inadequate in the face of AI advancements (Ayduğ & Altınpulluk, 2025). Research by Ayduğ and Altınpulluk (2025) found that Turkish pre-service teachers with higher digital literacy reported lower levels of AI anxiety, suggesting a predictive relationship in which greater literacy can alleviate anxiety to some extent.

Furthermore, discussions about AI in educational settings have shown that when pre-service teachers learn about generative AI, their anxiety towards these technologies notably decreases. This underscores the role of familiarity in reducing apprehension (Bae et al., 2024). Therefore, educational interventions aimed at enhancing AI literacy could be a key strategy in alleviating anxiety among future educators, thereby fostering a more positive attitude towards integrating AI into the classroom (Eyüp & Kayhan, 2023).

When reviewing the literature on artificial intelligence anxiety, various groups have been included in the studies, such as health professionals (Filiz et al., 2022), candidates of different professions (Takıl et al., 2022), nurses (Seren Intepeler et al., 2022), dentists (Bulut et al., 2024), private hospital employees (Şeker et al., 2024), randomly reached individuals (Kazak, 2023), tourism workers (Çetiner & Çetinkaya, 2024), university students (Aytaç, 2022; Gültekin et al., 2022; Kaya, 2023; Aktaş Reyhan & Dağlı, 2023), teachers (Özdemir, 2023; Sevimli Deniz, 2022), public employees (Şen, 2024),

and accounting professionals (Özbek, 2024). Additionally, Schiavo et al. (2024) examined the relationship between artificial intelligence literacy, anxiety, and acceptance among participants of different ages, education levels, occupations, and nationalities. Notably, a mixed-methods study evaluating the literacy-anxiety relationship among pre-service teachers has not been found. Therefore, this study is expected to address this gap in the literature and provide guidance for future research. The study aims to assess the levels of artificial intelligence literacy and anxiety among pre-service science teachers and to explore the relationship between these two variables. To achieve this aim, the study sought answers to the following questions:

1. What is the artificial intelligence literacy level of pre-service science teachers, and does this level differ significantly according to the variables of GPA, artificial intelligence knowledge level, skill level of using technological tools, and emotional state towards artificial intelligence applications?
2. What is the level of artificial intelligence anxiety of pre-service science teachers, and does this level differ significantly according to the variables of GPA, artificial intelligence knowledge level, skill level of using technological tools, and emotional state towards artificial intelligence applications?
3. How do pre-service teachers with different AI literacy levels differ in their anxiety toward artificial intelligence?

METHODS

Research model

This study used a mixed-methods approach, combining quantitative and qualitative methods. The idea behind mixed-method research is to leverage the strengths of one method to compensate for the weaknesses of the other (Cresswell & Plano Clark, 2018). Employing multiple data collection methods, known as data triangulation, is crucial for enhancing the validity and reliability of the findings. While data triangulation demands more time and effort from the researcher, it significantly contributes to the depth, credibility, and generalizability of the research results. Given the multidimensional and complex nature of events and phenomena, employing multiple methods to understand them holistically is undeniably beneficial (Yıldırım & Şimşek, 2021).

The study employed an explanatory-sequential design, progressing from quantitative to qualitative data collection and analysis. The researcher then integrates the data from both stages to interpret how qualitative data explains quantitative data (Cresswell & Plano Clark, 2018). In the quantitative phase, the study collected data through survey research to reveal specific characteristics of the group (Büyüköztürk et al., 2013). This phase focused on examining the artificial intelligence literacy and anxiety levels of pre-service teachers across various variables. In the qualitative phase, the study utilized a case study approach to deeply examine and analyze specific situations, environments, or programs (Büyüköztürk et al., 2013). Interviews were conducted with selected pre-service teachers based on the quantitative results, using a semi-structured interview format prepared by the researchers.

Working group

The quantitative study group was formed during the 2023-2024 academic year at the Faculty of Education Science Teaching Department in a province in the Marmara region of Turkey. All pre-service teachers studying science education at the faculty who volunteered to participate in the study were included in the sample. It consisted of 136 pre-service teachers. The researchers used convenience sampling to select participants, which involves selecting individuals who are readily accessible to the researcher due to time and cost constraints. The main reason for using convenience sampling was the accessibility constraints and exploratory nature of the research. As the scales were administered face-to-face, the most accessible students at the faculty were included in the study. There were time and resource limitations in reaching the target group during the research period. The purpose of the study was explained to the participants, and additional information about the quantitative study group is provided in Table 1.

Questions	Answers	f	%
Gender	Woman	114	83.8
	Male	22	16.2
Classroom	1. classroom	34	25.0
	2. classroom	34	25.0
	3. classroom	39	28.7
	4. classroom	29	21.3
Grade point average	4.00-3.50	7	5.1
	3.49-3.00	56	41.2
	2.99-2.50	46	33.8
	2.49-2.00	21	15.4
	1.99-1.80	3	2.2
	1.79 and below	3	2.2
Skill level in using technological tools (computer, cell phone, etc.)	Medium	61	44.9
	Good	60	44.1
	Very good	15	11.0
Whether they have attended any training (course, conference, etc.) on artificial intelligence before	Yes	27	19.9
	No	109	80.1
Level of knowledge about artificial intelligence	Too much	7	5.1
	A little	101	74.3
	Too little	25	18.4
	Less	3	2.2
The feeling that artificial intelligence is becoming more and more present in our lives	Positive emotions	43	31.6
	Undecided	87	64.0
	Negative emotions	6	4.4

Table 1: Demographic information of the quantitative study group (*N* = 136 people).

Most of the quantitative study group (83.8%) consisted of women, with no significant difference in grade level, although the largest group (28.7%) was in the 3rd grade. The overall grade point averages were concentrated in the 3.49–3.00 range (41.2%), with technological tool usage skills at a moderate (44.9%) and good (44.1%), the majority (80.1%) had not received artificial intelligence training and had some knowledge (74.3%) about artificial intelligence, and finally, the majority (64.0%) felt uncertain about artificial intelligence.

The qualitative study group, comprised of pre-service teachers, was selected using criterion sampling, a purposeful sampling technique, for the semi-structured interview as part of the study's objectives. Criterion sampling involves selecting individuals with specific qualifications to participate in the research (Büyüköztürk et al., 2013). -The scores from the "Artificial Intelligence Literacy Scale" and "Artificial Intelligence Anxiety Scale" were used to categorize the pre-service teachers' total scores as "low", "medium", and "high". Subsequently, three pre-service teachers from each category were chosen, resulting in a total of nine participants. Initially, a total of nine pre-service teachers were selected, with three from each level, but throughout the process, data saturation was monitored, and additional interviews were planned if necessary. Further information about the qualitative study group is provided in Table 2.

During the semi-structured interviews with pre-service teachers, there were eight female and one male candidates. Among them, four taught 2nd grade, one taught 3rd grade, and four taught 4th grade. In terms of their proficiency levels, one candidate each had a low level of both AIL and AIA (T1, T2, and T3), two had a medium level of both AIL and AIA (T4 and T5), 1 had a medium level of AIL and a high level of AIA (T6), 1 had a high level of AIL and a low level of AIA (T7), 1 had a high level of AIL and a medium level of AIA (T8), and 1 had a high level of both AIL and AIA (T9).

Teacher candidates	Gender	Classroom	AIL level	AIA level
T1	F	3	Low (L)	Low (L)
T2	F	4	Low (L)	Middle (M)
T3	F	4	Low (L)	High (H)
T4	F	2	Middle (M)	Low (L)
T5	F	4	Middle (M)	Middle (M)
T6	F	2	Middle (M)	High (H)
T7	F	2	High (H)	Low (L)
T8	M	2	High (H)	Middle (M)
T9	F	4	High (H)	High (H)

Table 2: Demographic information of the qualitative study group (*N* = 9 people).

Data collection tools

The study data were collected in two stages: quantitative data in the first and qualitative data in the second. Quantitative data were collected using the "Artificial Intelligence Literacy Scale" (adapted into Turkish by Polatgil & Güler, 2023) and the "Artificial Intelligence Anxiety Scale" (adapted into Turkish by Akkaya et al., 2021). In the first part of the questionnaire, seven questions were prepared: 3 to collect demographic information about the participants and four to collect information about their experiences with artificial intelligence (Gündüz Hoşgör et al., 2023; Polatgil & Güler, 2023). After analyzing the quantitative data, qualitative data were collected through a semi-structured interview form prepared by the researchers. Detailed information on the data collection tools is presented below under separate subheadings: quantitative and qualitative.

Quantitative data collection tools: the AI literacy scale includes four sub-factors: awareness, use, evaluation, and ethics. It consists of two parts: the first includes the personal information of pre-service teachers, and the second comprises 12 items and four factors, including pre-service teachers' views on artificial intelligence literacy. Cronbach's alpha (α) reliability coefficient for the whole scale was found to be .939, .946 for the awareness factor, .989 for the use factor, .988 for the evaluation factor, and .862 for the ethics factor. In this study, the Cronbach's alpha (α) reliability coefficient for the entire scale was found to be .753, indicating high reliability. Pre-service teachers' views on artificial intelligence literacy were evaluated using a 5-point Likert-type rating scale (strongly disagree, disagree, undecided, agree, strongly agree), with responses coded according to the option limits. The respondent can score between 12 and 60 points. Three items need to be reversed: 2, 5, and 11.

The AI anxiety scale also consists of four sub-factors: learning, job change, sociotechnical blindness, and AI configuration. The Cronbach alpha (α) reliability coefficient for the whole scale was found to be .937, .948 for the learning factor, .895 for the job change factor, .875 for the sociotechnical blindness factor, and .950 for the artificial intelligence configuration factor. In this study, the Cronbach's alpha (α) reliability coefficient for the whole scale was calculated as .916, suggesting strong reliability.

Qualitative data collection tools: To investigate the relationship between artificial intelligence literacy and anxiety, a semi-structured interview form was developed, comprising eight open-ended questions based on the items in the sub-dimensions of the artificial intelligence anxiety scale. The questions were finalized based on feedback from experts in science and chemistry education to ensure internal validity.

Data collection

The study data were gathered in a peaceful classroom setting, outside class time, to avoid disrupting their studies.

Quantitative data were gathered over a 25-minute period, with pre-service teachers volunteering to participate.

Qualitative data were obtained through audio recordings with the consent of the pre-service teachers, who were scheduled for semi-structured interviews.

Data analysis

Qualitative data analysis: the quantitative data collected from the AIL and AIA scales were analyzed using SPSS 27.0. To determine the tests to be used for analysis, researchers first examined the normality tests (skewness and kurtosis) for each variable. It was observed that the skewness and kurtosis values for the AILS and AIAS data ranged from -3 to +3 for each variable, indicating a normal distribution (De Carlo, 1997; Groeneveld & Meeden, 1984; Hopkins & Weeks, 1990; Moors, 1986, as cited in Keleş, 2018). Additionally, the homogeneity of variances test results, a prerequisite for the tests, showed homogeneous variances ($p > .05$). Consequently, researchers employed one-way analysis of variance (ANOVA) and Pearson correlation coefficient as parametric tests.

Qualitative data analysis: Based on the quantitative data obtained, no significant relationship was found between artificial intelligence literacy and anxiety. To examine this situation in greater depth and to support/refute the quantitative results, qualitative data analysis was required. Accordingly, the data obtained through the semi-structured interview form was analyzed using content analysis. Content analysis is a systematic, repeatable method that codes words in a text according to specific rules and groups them into smaller content categories (Büyüköztürk et al., 2013). The views of teacher candidates regarding artificial intelligence were categorized into common themes and presented in separate tables.

Validity and reliability

To ensure the reliability of the data analysis, the opinions expressed by the pre-service teachers were examined by two researchers. Analysis reliability was assessed using the coder reliability formula proposed by Miles and Huberman (2015), yielding 94.1%. Because

ERIES Journal
volume 18 issue 4

Electronic ISSN
1803-1617

Printed ISSN
2336-2375

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values above 80% are considered sufficient for inter-coder reliability (Miles & Huberman, 2015), the analysis was deemed sufficiently reliable. Data analysis continued until both researchers reached a consensus on all questions. Furthermore, in the findings section, selected quotes from the pre-service teachers' perspectives were included to enhance the study's credibility and coherence.

FINDINGS

Findings from the quantitative dimension

General mean values of pre-service science teachers' AILS and AIAS scores

The average total scores of 136 pre-service teachers on the AILS were 43.14 with a standard deviation of 4.363, while their total scores on the AIAS were 48.45 with a standard deviation of 9.575. The conclusion drawn was that the pre-service teachers exhibited high levels of artificial intelligence literacy, approaching the "agree" option. However, their anxiety levels were found to be concentrated in the "undecided" option and at a moderate level.

Findings from the ANOVA test according to the independent variables of pre-service science teachers' scores from the AILS and AIAS

The results of the ANOVA test, conducted according to the independent variables, are presented in Table 3 for the scores obtained by the pre-service science teachers from the AILS and AIAS.

Scale	Variable	Variance source	Sum of squares	df	Mean square	F	p	η^2
AILS	General grade point average	Between groups Within groups Total	169.223 2401.122 2570.346	5 130 135	33.845 18.470	1.832	.111	
	Technological tools usage skill level	Between groups Within groups Total	261.842 2308.504 2570.346	2 133 135	130.921 17.357	7.543	< .001	.102
	Knowledge level	Between groups Within groups Total	147.583 2422.763 2570.346	3 132 135	49.194 18.354	2.680	.050	
	Emotion state	Between groups Within groups Total	80.223 2490.123 2570.346	2 133 135	40.111 18.723	2.142	.121	
AIAS	General grade point average	Between groups Within groups Total	1026.091 11349.549 12375.640	5 130 135	205.218 87.304	2.351	.044*	.083
	Skill level in using technological tools	Between groups Within groups Total	336.291 12039.349 12375.640	2 133 135	168.146 90.521	1.858	.160	
	Knowledge level	Between groups Within groups Total	8.692 12366.947 12375.640	2 133 135	4.346 92.985	.047	.954	
	Emotion state	Between groups Within groups Total	10193.172 11282.467 12375.640	2 133 135	546.586 84.831	6.443	.002*	.088

Table 3: ANOVA test results for independent variables.

Significant differences were found between groups in the technological tool usage skill level variable in AILS and in the overall grade point average and emotional state variables in AIAS [$F = 7.543$; $F = 2.351$; $F = 6.443$, $p < .05$]. Since the calculated effect sizes ranged from 0.06 to 0.14, they were considered of medium magnitude (Büyüköztürk, 2011). The Scheffe test revealed significant differences in favor of those with good ($\bar{X} = 44.10$) and very good ($\bar{X} = 45.33$) skill levels compared to those with medium skill levels. In the emotional state variable, significant differences were found in favor of those with positive emotions compared to those with neutral emotions ($\bar{X} = 50.38$). The Bonferroni test revealed a significant difference in favor of those with a grade point average in the 2.99-2.50 range compared to those in the 1.99-1.80 range ($\bar{X} = 50.80$) [$F = 2.351$, $p < .05$].

Findings on the relationship between the scores obtained from the AIL and AIA scales

Pearson correlation analysis was performed to examine whether there was a significant relationship between the scores of the pre-service teachers from the AIL and the AIAS.
No significant relationship was found between AILS and AIAS ($r = -.113$, $n = 136$, $p =.191$). It can be said that approximately 1% of the variability in pre-service teachers' concerns about artificial intelligence can be explained by the artificial intelligence literacy variable ($R^2 = (-.113) 2 = .01$).

Findings from the qualitative dimension

Semi-structured interviews were conducted with nine pre-service teachers selected based on the quantitative results. The responses to the interview questions are provided below:

The findings from the pre-service teachers' perspectives on the question "Does learning to use artificial intelligence applications/products make you anxious? Why?"

The subcategory with the highest frequency was "no," while the subcategory with the lowest frequency was "somewhat." These findings are presented in Table 4.

Findings obtained from pre-service teachers' thoughts on the question "How comfortable do you feel about artificial intelligence technologies?"

The subcategory with the highest frequency was "I do not feel very comfortable", while the subcategory with the lowest frequency was "I feel a little uncomfortable". The findings regarding the pre-service teachers' thoughts on the question are presented in Table 5.

Subcategory	Code	ƒ	%	Sample Student Statements
No	Helping/facilitating	4	44.44	"I would like to learn more applications. It can be more useful for me (T5)."
	Arousing curiosity	1	11.11	"It gives me hope. We are gradually being translated into such a phase. I think there is nothing to worry about. It would be professionally beneficial, it is an interesting, beautiful, curious feeling (T1)."
	Narrow field of use	1	11.11	"It is not very necessary for me because I do not do anything related to the field of use too much (T7)."
Yes	Lack of motivation	1	11.11	"I would feel very relaxed. Buying things ready-made might not satisfy me for long. It is more enjoyable to access information by researching it myself. I use it when I already have an urgent job. Otherwise, I prefer doing my own research. If I know too many applications, it would make me cumbersome and lazy (T3)."
	Superficiality	1	11.11	"It makes me lazy that way. When I do it from the book, I wonder about other things in more detail. I think you focus on something more limited there (T4)."
A little bit	Safety and ethics	1	11.11	"A little bit…You know, there's talk about whether it will take over our lives? Will it take over our professions? For example, helping with homework… In the future, I will not know whether the students do it themselves or whether they get help from artificial intelligence (T6)."

Table 4: Pre-service teachers' thoughts on learning to use artificial intelligence applications/products.

Subcategory	Code	ƒ	%	Sample Student Statements
I don't feel very comfortable	Safety and ethics	1	11.11	"The fact that computers are talking among themselves…It needs to be used carefully An article, for example. Artificial intelligence may pretend to be its own words and may actually be entering into the ethical principles in an article (T9)."
	Lazy thinking	1	11.11	"It's not so much for me, but it stresses me that we use it as the whole world. People no longer have their own opinions. No one has an opinion. With artificial intelligence, it's like everyone speaks the same language. Different thoughts will not emerge. We can stop using our brains (T5)."
	Taking away people's jobs	1	11.11	"Robots can take people's jobs. Of course, this worries me a bit. Especially jobs that require manual dexterity (T8)."
	Security	1	11.11	"It's like they're going to take us over. When I question this, yes, I feel stressed, but it's not something I normally think about. There are good uses and bad uses for weapons, and the same goes for technology. You know, because I think it will be misused. It will not always go well (T4)."
	Superiority	1	11.11	As robots increase, people get nervous. Only that part worries me too. Other than that, of course, I think that science constantly makes our lives easier (T2)."
	Similarity to human characteristics	1	11.11	"I think it has very scary dimensions. There are artificial intelligences that speak like humans. After a while, they can replace humans in a way. That's why it scares me (T3)."
Feeling uncomfortable	Lack of information	2	22.22	"I feel uncomfortable because I can't use it right now. I don't make an effort for it. I don't see such an effort from the school. So I feel uncomfortable right now, but this is completely related to the lack of training. I would be very happy if I could use it and learn its logic and functioning (T1)."
A little bit feels uncomfortable	Lack of relevance	1	11.11	"I'm not involved enough to bother too much. I am not very interested. I don't do much (T7)."

Table 5: Pre-service teachers' comfort level with artificial intelligence technologies.

Findings obtained from pre-service teachers' thoughts on the question "What do you think about the effects of artificial intelligence technologies on society?"

Among the findings from the pre-service teachers' thoughts about the question, the most frequent category was "positive-negative effect". In contrast, the least frequent categories were "helpful/facilitating" and "no idea"; the findings are presented in Table 6.

"Do you have any concerns about whether artificial intelligence technologies will take away people's jobs? Why?" question, and the findings obtained from their thoughts on the question

Among the findings from pre-service teachers' thoughts on the question, the most frequent subcategory was "can replace certain professions". In contrast, the subcategory with the lowest frequency was "cannot replace any profession," and the findings are presented in Table 7.

Category	ƒ	%	Sample Student Statements
Positive-negative impact	5	55.56	*"I think it makes society lazy. For example, making him do his work. Making a student do his homework prevents him from learning information and limits his own research. Doing our work with artificial intelligence can reduce socialization. It can reduce your circle of friends. It makes you lonely. There are also positive aspects. Saving time, easy access to information (T6)."*
Assistant/facilitator	2	22.22	*"I think it makes people's lives easier. Robots do things with less effort than humans. We can use artificial intelligence applications that they can use (T8)."*
No idea	2	22.22	*"I live in a small town, there's nothing there. Not many people know much. So I may not know much. Some of my friends use it for lessons, that I know as much as I know (T5)."*

Table 6: Pre-service teachers' opinions on the effects of artificial intelligence technologies on society.

Subcategory	Code	ƒ	%	Sample Student Statements
Specific occupation profession can take its place	Robotics	4	44.44	*"They can do people's jobs better. For example, when something is missing, they correct it with feedback. This is difficult with humans. But they can be corrected by writing code. Of course, not in every field. You can benefit in a field like medicine, but it cannot completely replace a doctor because they have no sense of compassion. It thinks like a computer (T9)."*
	Assistant/facilitator	1	11.11	*"We can integrate. We can learn, develop ourselves, and work together. I don't think it can completely take over. In health, for example, there is talk of doctors performing surgery, but can this extinguish the doctor's profession? I don't think it can; it just helps. What it does is reduce the workload of the doctor, but I don't think it completely ends the doctorate (T6)."*
All occupation profession can take its place	Continuity/efficiency Technological development	1	11.11	*"Human power is slower, more limited. It is not artificial intelligence in this sense. Let's think like this. In the past, for example, a shoe used to be processed for days. Now, the factory, o, ne, er day, millions are produced. A teacher can teach 7-8 hours a day at most, but artificial intelligence is unlimited (T2)."*
	Ease of access	1	11.11	*"Since technology is also developing, as long as every student has a computer, a phone, etc., we can learn everything from there. With artificial intelligence, they can learn, find, and do everything. So we may not be needed (T5)."*
		1	11.11	*"You know, they use such coding and artificial intelligence that after a certain point, the need for human beings may no longer exist (T3)."*
No profession has its place, can't take	Feeling numb	1	11.11	*"I don't think there will be much of a problem because they don't have human feelings. Because they are emotionless (T7)."*

Table 7: Pre-service teachers' opinions on whether artificial intelligence technologies will take away people's jobs.

"Do you have any concerns or fears about humanoid artificial intelligence techniques/products (e.g., humanoid robots)? Why?" question, "Do you have any concerns or fears about humanoid artificial intelligence techniques/products (e.g., humanoid robots)?

In the findings obtained from the pre-service teachers' thoughts about the question, the subcategory with the highest frequency was "there is", while the subcategories with the lowest frequency were evaluated as "there is some" and "there is for the future", and the findings obtained are given in Table 8.

"Do you have any concerns/fears about the artificial intelligence technique/product getting out of control/failing? Why?" question, and the findings obtained from their thoughts on the question

The findings from the pre-service teachers' thoughts about the question showed that the most frequent subcategory was "there is", while the subcategory with the lowest frequency was "there is not". The findings are presented in Table 9.

Subcategory	Code	f	%	Sample Student Statements
There is	Misuse	1	11.11	„I'm worried because of the possibility of human substitution. If used for evil purposes, it could lead to disasters if they fall into the hands of bad people. War or something (T3)."
	Capacity width	1	11.11	„I am worried. I can worry even when I see it, and he can think what we can't think. In other words, he can know everything. He has the potential to do everything (T5)."
	Capturing humanity	1	11.11	„I remember Sofia the robot. It scares me when I think about it. It is like they will take over humanity (T4)."
	Similarity to human characteristics	1	11.11	„I'm worried. He's human, and he does all the things we can do. This scares me a lot. I think it can replace humans (T9)."
	Autonomy	1	11.11	„I'm worried. They can hurt us because the people who manage them are the ones who design them in the first place. But then they manage them with their own equipment. They may be unpredictable (T2)."
No	Helper/facilitator	1	11.11	„I don't have any worries. I am emotionally neutral. It just makes people's work easier. I think positively, mostly because it makes people's lives easier (T8)."
	Not witnessing negativity	1	11.11	„I don't have any attachment. I am neutral. I did not see anything very negative (T7)."
There are some	Sameness/normality	1	11.11	„So I'm a bit worried. There could be unity among them. Creating one kind of human being. Because the personality traits of humanity are different, but the traits we attribute to them could be the same. They are all hardworking, they are all lazy... One type of person (T6)."
There is for the future	Potential to multiply in numbers	1	11.11	„I don't have any worries or concerns in the current way. They are few in number now, so I'm not afraid. We can't produce many of them because they are very expensive and don't have many functions. What are we going to do with it? There are too many people. There is no need. If their numbers increase, they will be smarter and more emotionless than we are. Therefore, they can do anything (T1)."

Table 8: Pre-service teachers' opinions on humanoid artificial intelligence techniques/products.

Subcategory	Code	f	%	Sample Student Statements
There is	Failure to intervene	2	22.22	"I would probably get stressed. I can't intervene anyway; that would stress me out. What to do when it gets out of control is also important. It depends more on the function of the product you use (T3)."
	Disruption of work	1	11.11	"So the robot can do a job wrong or make it very bad. Or a malfunction can disrupt a job. If it gets out of control, the work is disrupted. It takes time to fix it (T8)."
	Ethical breach and security	1	11.11	"The use of the photograph elsewhere scares me. Computers doing something in the background also scares me (T9)."
There are some	Security	2	22.22	"If it gets out of control, it can lead to war. Therefore, it gives me some anxiety (T5)."
	Spread of misinformation	1	11.11	"Well, for example, people may be accepting information as correct only through artificial intelligence right now. For example, when there is a malfunction, it may accept false information as true for everyone (T5)."
No	Mediocrity/simplicity	1	11.11	"I don't have too many worries since I see it as if it is a bit more like an electrical breakdown (T7)."
	Controllability	1	11.11	"What can robots do? I think I can manage it. It cannot take over and do anything because it is in my hands to manage it (T4)."

Table 9: Pre-service teachers' thoughts about the artificial intelligence technique/product getting out of control/failure.

"Do you have any concerns/concerns that the artificial intelligence technique/product may lead to robot autonomy? Why?" question, and the findings obtained from their thoughts on the question

In the findings obtained from the thoughts of pre-service teachers about the artificial intelligence technique/product leading to robot autonomy, the subcategory with the highest frequency was "there is", while the subcategory with the lowest frequency was evaluated as "there is some", and the findings obtained are given in Table 10.

Findings obtained from pre-service teachers' thoughts on the question "What do you think about the present and future of artificial intelligence technologies?"

The findings from pre-service teachers' thoughts on the question showed that the highest frequency was "positive-negative effect", followed by "wide usage area" and "gradual progress". The findings are presented in Table 11.

Subcategory	Code	f	%	Sample Student Statements
There is	Failure to control	3	33.33	"It scares the hell out of me. That's actually my concern about artificial intelligence. It's scary if they get out of control rather than if they take over. Without being able to intervene. Because we also do it ourselves. We write the code. They will be a problem for us (T9)."
	Security and numbness	2	22.22	"I mean, he can do anything. It can take over everything. When there is human intervention, at least it can stop somewhere. But when it does everything on its own, it can take over our lives. I might be worried about security. Its numbness is also very important. It has no sense of pity (T5)."
	Security and interference in human life	1	11.11	"Yes. Security, and also, for example, if there is interference in human life, I mean, a person does not want interference by another person, which is never wanted by a robot (T2)."
No	Technology is not yet developed	2	22.22	"I don't think it's developed yet. The robot is a human being. I don't think such a thing can happen yet unless that person installs that program (T6)."
There are some	Technological error/flaw	1	11.11	"I might have some concerns. Because inevitably, people may not think the same. You program the robot, and then it starts working on its own. But there may be a bug in that device, there may be something wrong. Can perceive (T8)."

Table 10: Pre-service teachers' opinions on whether the artificial intelligence technique/product will lead to robot autonomy.

Category	f	%	Sample Student Statements
Positive and negative impact	3	33.33	"They are constantly evolving. New features are always being added. So maybe they are working on things that we can't predict right now. Even though it seems under control now, I'm still worried it will get out of control in the future. It's good for today, It is fun. But it is worrying in the future (T9)."
Vitality	2	22.22	"When we look at it in general, it is quite advanced now, but I feel that in the future, all jobs will turn to artificial intelligence. I think it will be everywhere in our lives, whether it is robots, I think it will be everywhere in our lives (T5)."
Development/progress	2	22.22	"Right now, I think we are progressing very well. I don't think it's that good in our country. I can say it is as good as it can be. But for example, we see very good progress abroad. I hope it will progress more in the right way. So I think it needs to progress. I think it will progress a lot in the future. I can't think 10, 20, 30 years from now, it will progress a lot. I think it will progress more than I can imagine. I think it will be like in the movies. (T1)."
Wide area of use	1	11.11	"I think it will progress a little more. It is coming to life more in terms of robots. I don't know what makes our work easier, especially in industrial areas, such as the whole university, workpiece assembly, and painting. I think that robots like robots do the job (T8)."
Progressive progress	1	11.11	"It is developing, it will develop even more. I think we can continue our lives together by being intertwined; it can't replace us. I guess I can't think about the future yet because we are trying to keep up with what is coming out now, or we haven't fully integrated them into our lives. I think we can't integrate the new ones without integrating them. So I think it will happen slowly. It has to come into our lives. Development is instantaneous, but our use of it requires a certain process (T6)."

Table 11: Pre-service teachers' thoughts on the present and future of artificial intelligence technologies.

Integrating quantitative and qualitative data

Based on both quantitative and qualitative data, no significant correlation was found between pre-service teachers' artificial intelligence literacy and their anxiety about artificial intelligence. To gain further insights, semi-structured interviews were conducted with nine pre-service teachers. The results of these interviews are presented below:

The responses to the question "Do you have any concerns or anxieties that artificial intelligence technology/products could lead to autonomous robots?"

The findings from the responses of prospective teachers with varying artificial intelligence literacy and anxiety levels are presented in Table 12.

Quantitative result	Qualitative working group	Sample Student Statements
$r = .113$ $p = .191$ $p > .05$	LLLA	"I don't have a fear as it is now, I might have a fear if their numbers increase. If their numbers increase, they will be smarter and more emotionless than we are. So they will be able to do. They can do it. I think a little more about the security part. I don't have any concerns other than security (T1)."
	LLMA	"Yes. Security, and also, for example, if there is interference in human life, I mean, a person does not want interference by someone else, which a robot would never want (T2)."
	LLHA	"There is. There are sci-fi movies about a world ruled by robots. I think we can kind of head towards that because I don't see how we can think humanely anymore. If we can produce, if robots have an idea, they may want to get rid of us, or I don't know, different things (T3)."
	MLLA	"Yes, if I am in control, if he is in control, he cannot be stopped (T4)."
	MLMA	"I mean, he can do anything. It can take over everything. With human intervention, at least, I mean, you can stop somewhere, but when you do everything on your own, our lives could be in danger. I might be nervous about security. The numbness is also very important. There is no sense of pity (T5)." Our lives could be in danger. I might be nervous about security. The numbness is also very important. There is no sense of pity (S5)."
	MLHA	"I don't think it's developed yet. The robot is also a human being. Unless that human installs that program, I don't think it can happen yet. So right now I do not have a concern (T6)."
	HLLA	"Maybe, but here's the thing. Because it's a human being who made it, you know, how much can he get out of the way? I am not sure about that (T7)."
	HLMA	"I might have some concerns. Because inevitably, one may not think the same. You program the robot, and then it starts to work on its own, but there may be a fault in that device; it may detect something wrong (T8)."
	HLHA	"It scares the hell out of me. That's actually my concern about artificial intelligence. From their takeover without being able to… It would be much more frightening if they got out of control than if they took control. Without being able to intervene… Because we also do it ourselves. We write the code. They will be a problem for us (T9)."

Table 12: Pre-service teachers' opinions on whether an AI technique/product will lead to robot autonomy, by AI literacy and anxiety level.

The pre-service teachers' responses to the question showed similarities, with both anxious and non-anxious individuals across various literacy levels. These findings are consistent with the quantitative results ($r = .113$, $p = .191$, $p > .05$). Upon analyzing the sample statements, it was evident that pre-service teachers with low AI literacy levels expressed low levels of anxiety (T1), while those with high AI literacy levels exhibited higher levels of anxiety (T9). The scale results indicated that anxious pre-service teachers (T6, T4) expressed differing opinions.

Findings from the thoughts of prospective teachers with varying levels of artificial intelligence literacy and anxiety regarding the question "What do you think about the present and future of artificial intelligence technologies?"

The findings from responses of prospective teachers with varying levels of artificial intelligence literacy and anxiety are presented in Table 13.

Pre-service teachers' views on the present and future of artificial intelligence are similar. Only T2, T3, and T9 pre-service teachers reported anxious thoughts about the future of artificial intelligence, compared with other pre-service teachers. While the future concerns of pre-service teachers with low literacy focused on the increase in the number of humanoid robots and potential security problems, those of pre-service teachers with high literacy were similarly based on the potential for this technology to be used as a security threat. Most pre-service teachers stated that artificial intelligence is developing and will make a name for itself in the future, with many more use cases.

Quantitative result	Qualitative working group	Sample Student Statements
r = .113 *p* = .191 *p* > .05	LLLA	"Right now, I think we are progressing very well. I don't think it's that good in our country. I can say it is as good as it can be. But for example, we see very good progress abroad. I hope it will progress more in the right way. So I think it needs to progress. I think it will progress a lot in the future. I can't think 10-20-30 years from now, it will progress a lot. It will be like in the movies. I think (T1)."
	LLMA	"Today it's fine, but in the future it could get out of hand. There are many, many. If there are too many robots, we may feel strange (T2)."
	LLHA	"I think it will continue without stopping, but I think, as with everything else, too much technology is harmful. I think it should be stopped at a point where its advanced dimensions can pose a danger to people. Of course, who will decide that is another issue. But I think it is good as it is now. I don't know how far it will go in the future, but I think replacing people and so on is bad, so I have negative feelings about it. But the possibilities now for facilitating access to information and so on are enough. Overdoing it would be bad (T3)."
	MLLA	"In terms of practicalization for our own needs today, we are currently building robots that are being built. Artificial intelligence for easy access to information…But in the future, I think even flying cars, you know. I don't even need a flying car, maybe even higher. Will happen. I think the practices will progress further (T4)."
	MLMA	"When we look at it in general, it's quite advanced now, but I feel like in the future all jobs will turn to artificial intelligence. I think it will be everywhere in our lives, whether it's robots. (T5)."
	MLHA	"It is developing, it will develop even more. I think we can continue our lives together by being intertwined; it can't replace us. I guess I can't think about the future yet because we are trying to keep up with what is coming out now, or we haven't fully integrated them into our lives. We can't integrate the new ones without integrating them. I think. Therefore, I think it will happen gradually. Its entry into our lives or its development is instantaneous, but our use requires a certain process (T6)."
	HLLA	"I don't think we've heard a lot of artificial intelligence names before. In the last few years, even artificial intelligence departments have started to open. Has begun. They are trying to develop it. I think it will develop further. We will be very close in the future (T7)."
	HLMA	"I think it will progress a little more. With technology and everything, it has 20- 30 years. It comes alive more in terms of robots. I don't know what makes our work easier, especially in industrial areas, all universities, and business. I think robots do work, such as assembling parts and painting (T8)."
	HLHA	"They are constantly evolving. New features are always being added. So maybe they're working on things we cannot predict right now. Although it seems under control now, I am worried it will get out of control in the future. It is nice and fun today, but it is worrying in the future (T9)."

Table 13: the opinions of pre-service teachers with different levels of AI literacy and anxiety about the present and future of AI technologies.

The findings from the thoughts of pre-service teachers with different levels of artificial intelligence literacy and anxiety regarding the question "Do you have any anxiety or fear towards humanoid artificial intelligence techniques/products (e.g., humanoid robots)? Why?"

The findings from the responses to the question by pre-service teachers with different levels of artificial intelligence literacy and anxiety are presented in Table 14.

When analyzing pre-service teachers' opinions, the results align with the quantitative findings (r = .113, p = .191, p > .05), indicating no significant correlation between artificial intelligence literacy levels and anxiety. Some individuals with low AI literacy levels reported low anxiety (T1), while others with high AI literacy levels expressed anxiety (T9). Conversely, some with low AI literacy levels reported high anxiety (T3), while those with high AI literacy levels reported low anxiety (T7). Among the three pre-service teachers with high AI literacy levels, T7 appeared indifferent, possibly due to a lack of experience and knowledge; T8 had positive experiences and an optimistic outlook on artificial intelligence, and T9 expressed concerns about the potential job displacement resulting from the widespread use of artificial intelligence. These observations from pre-service teachers correspond to the quantitative results.

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Printed ISSN
2336-2375

Electronic ISSN
1803-1617

ERIES Journal
volume 18 issue 4

Quantitative result	Qualitative working group	Sample Student Statements
r =.113 p =.191 p >.05	LLLA	"I don't have any worries or concerns in the current way. They are few in number now, so I'm not afraid. We can't produce many of them because they are very expensive and don't offer much functionality. What are we going to do with it? There are too many people. There is no need. Their numbers will be smarter and more emotionless than ours. So they'll be able to do it (T1)."
	LLMA	"I'm worried. They can harm us. Because the people who manage them, first of all, are the people who design them, but then they manage them with their own hardware, or they may be unpredictable (T2)."
	LLHA	"I'm worried because of the possibility of human substitution. If used for evil purposes, it could lead to disasters. In the hands of bad people. War (T3)."
	MLLA	"Robot Sofia, I remember. When I think about it, it is frightening. Humanity hand in hand (T4)."
	MLMA	"I'm worried. I might even be worried when I see it. In terms of knowledge, he can think what we cannot think at that moment. So he can know everything. About everything. Has the potential to do anything (T5)."
	MLHA	"So I am a bit worried. It could be them forming a union among themselves. It could be creating one kind of human being. Because the personality traits of human beings may be different, but the traits we attribute to them may be the same. All of them are hardworking, they are all lazy… One type of person (T6)."
	HLLA	"I don't have any concerns. I am neutral. I have not seen anything very negative (T7)."
	HLMA	"I don't have any worries. I am emotionally neutral. I just want to do. It just makes it easier. I think positively, mostly because it makes people's lives easier (T8)."
	HLHA	"I'm worried. He's human, and he does all the things we can do. It scares me. I think it can replace humans (T9)."

Table 14: Pre-service teachers' opinions on humanoid AI techniques/products by AI literacy and anxiety level.

DISCUSSION

The study examined AI literacy and anxiety levels among pre-service science teachers and explored their relationship using both quantitative and qualitative data collection methods. The findings revealed that pre-service teachers exhibited high levels of AI literacy and medium levels of anxiety; however, no significant relationship was found between AI literacy and anxiety at the expected level. The preliminary findings indicate that AI literacy may operate independently of emotional reactions such as anxiety, highlighting a dynamic that merits further investigation in the context of teacher education. AI literacy among pre-service teachers was not significantly influenced by variables such as GPA, participation in AI education, AI knowledge, or emotional state toward AI. However, those with higher proficiency in technological tools exhibited greater AI literacy. Filiz et al. (2022) found that healthcare workers' levels of AI anxiety were moderate. Additionally, Şen (2024) stated in their study that public sector employees' levels of AI anxiety were above moderate. Similarly, Ayduğ and Altınpulluk (2025) found that teacher candidates exhibit a moderate level of anxiety. In contrast, Takıl et al. (2022) reported that students in the education faculty had high anxiety about artificial intelligence. The researchers suggested that pre-service teachers with advanced technological skills may have more experience and interest in technology, leading to increased familiarity and curiosity about AI. They also noted that individuals who closely interact with technology and have digital competence tend to internalize AI technologies more easily and exhibit a more supportive attitude towards its advancement. Research suggests that individuals who maintain close connections with others and actively engage with technology, as well as those who stay informed about advancements in the field, are more likely to internalize artificial intelligence technologies. Furthermore, possessing a robust level of digital literacy appears to correlate with a more favorable disposition towards the progression and integration of such technologies (Vu & Lim, 2022; Zhang & Dafoe, 2019).

Additionally, the study by Çoklar and Çalışkan (2019) found a moderate, positive relationship between pre-service teachers' perceptions of ICT competence and self-confidence. Similarly, Dringó-Horváth et al. (2025) found a positive relationship between artificial intelligence literacy and digital competence. Overall, pre-service teachers with advanced technological skills may feel more competent, knowledgeable, and literate about AI, thereby influencing their perceptions and attitudes towards AI.

The study revealed no significant difference in pre-service teachers' anxiety levels regarding artificial intelligence, regardless of their skill level with technological tools or their participation in artificial intelligence training. However, there was a notable difference in anxiety levels based on GPA and emotional state towards artificial intelligence. Pre-service teachers with a GPA between 2.99 and 2.50 exhibited significantly higher anxiety levels compared to those with a GPA between 1.99 and 1.80. Higher-GPA students may possess greater knowledge of artificial intelligence and its potential risks, which may lead to heightened anxiety. Conversely, students with lower academic knowledge may feel less concern or anxiety towards artificial intelligence due to a limited understanding of the technology. However, Batool et al. (2025) found a negative relationship between AI anxiety and academic performance and self-efficacy. In this study, students' experiences and perspectives regarding

AI may vary. Students with high academic achievement may have more confidence in AI technologies. They may also have higher self-efficacy. In this study, most teacher candidates reported having little knowledge of artificial intelligence. All these reasons may explain why the studies produced different results.

Another finding of the study is that those with ambivalent feelings toward artificial intelligence have significantly higher anxiety levels compared to those with positive feelings. Similarly, de Holanda Coelho et al. (2025) found that individuals with a positive attitude toward artificial intelligence experience less fear. It can be said that teacher candidates with ambivalent feelings toward artificial intelligence experience uncertainty about its effects on the present and the future. At this point, teacher candidates who lack sufficient information and awareness may experience dilemmas/uncertainties in assessing the potential benefits/harms of artificial intelligence technologies. This may cause them to harbor more anxiety and worry about artificial intelligence. This emotional dilemma/uncertainty that teacher candidates experience may lead them to feel more anxious about artificial intelligence. Gönüldaş & Gümüşkaya (2022) stated that situations such as uncertainty, fear, and future uncertainty cause anxiety in individuals. Furthermore, the study revealed that there was no significant correlation between the AI literacy levels of pre-service teachers and their anxiety levels ($r = .113$, $p = .191$, $p > .05$). This finding was supported by semi-structured interviews with pre-service teachers of varying literacy levels, indicating that the knowledge they possess about artificial intelligence may not directly influence the anxiety they experience. Semi-structured interviews with nine teacher candidates revealed that their responses to the posed questions aligned with the quantitative results, indicating a lack of a linear relationship between their artificial intelligence literacy and their concerns. While pre-service teachers may possess varying levels of knowledge about artificial intelligence, this knowledge does not necessarily influence their concerns and anxieties surrounding the topic. Additionally, individual differences and experiences with artificial intelligence significantly contribute to these feelings. Anxiety levels tend to fluctuate based on the personal perceptions and attitudes of the pre-service teachers. Consequently, these factors can explain the absence of a meaningful relationship between artificial intelligence literacy and anxiety levels. Moreover, the scale results indicated that teacher candidates displaying both high and low anxiety levels provided responses that contradicted the quantitative findings during the semi-structured interviews. Pre-service teachers might have been in a more positive frame of mind or felt more at ease during the interviews, which could have influenced their answers. Furthermore, some candidates may have internalized their anxiety, hindering their ability to articulate their thoughts clearly and comfortably during the interviews. Interestingly, a study by Schiavo et al. (2024) yielded contrasting results, revealing a statistically significant relationship between all sub-dimensions of AI literacy and anxiety. The authors noted that as participants' AI literacy levels increased, their anxiety towards AI decreased. It is important to consider the demographic characteristics of the sample used in this study, as participants may have had closer contact with AI technologies and greater experience, particularly given their country's technological conditions. This heightened awareness and exposure may have contributed to their more positive attitudes towards AI technologies. Several factors may contribute to the discrepancies between this study and the existing literature. The relatively small sample size and the inability to gather data from science teacher candidates across different universities may have limited the variance needed to identify potential relationships, thus reducing the statistical power of the findings. Additionally, there may be a theoretical explanation for these differences. Cengiz et al. (2025) indicated that this relationship may occur through mediating variables rather than directly, which could explain the absence of a direct correlation in this study. Overall, the lack of a significant relationship observed in this study does not contradict the existing literature; rather, it underscores the complexity of the topic. Future research should explore mediating and moderating variables such as attitudes, self-efficacy, and professional identity, while also examining the subdimensions of literacy and anxiety individually. This approach may facilitate a deeper understanding of how knowledge and perceptions of artificial intelligence interact in teacher education. Most of the pre-service teachers who participated in this study stated that they had not attended any training on artificial intelligence, had some knowledge of it, and had ambivalent feelings towards it. Based on all this data, it can be said that pre-service teachers still need to be closely involved with artificial intelligence technologies. Cengiz and Peker (2025) stated that artificial intelligence technology is still in its infancy and argued that it should be used more frequently to allow its positive effects to be seen and its recognition to increase. Similarly, Hopcan et al. (2024) stated that increased education about artificial intelligence could reduce anxiety and fear about it.

CONCLUSION

The study aimed to assess levels of "artificial intelligence literacy" and "artificial intelligence anxiety" among pre-service science teachers and to examine their correlation. The findings indicated that pre-service teachers' AIL levels were relatively high, while their AIA levels were moderate. Furthermore, no significant relationship was observed between artificial intelligence literacy and artificial intelligence anxiety. These results suggest that pre-service teachers currently lack a close familiarity with artificial intelligence technologies and may not possess sufficient knowledge and experience in this area. Given that technologies and applications related to artificial intelligence have only recently gained prominence, it is natural that pre-service teachers may not yet have extensive experience or awareness of this technology. Therefore, it may be premature to expect pre-service teachers to approach this emerging technology in a conscious, informed, and critical manner, particularly considering their limited exposure to it.

Some limitations of this study are as follows. The first limitation of the study is that the study group was determined using an easily accessible sampling method. However, as mentioned above, the main reason for using easily accessible sampling was

accessibility constraints and the exploratory nature of the research. Due to time and resource constraints in reaching the target group during the research period, science teacher candidates studying at the faculty were used in the study. While this situation raises questions about the generalizability of the study's results, we are cautious about generalizing the inferential results to a wider population. Another limitation of the study is that it involved only 3 participants per competency level, raising questions about whether data saturation was achieved. In this study, the interview data reached saturation, and no further interviews were deemed necessary. The inflexibility of the number of interviews may limit the diversity and transferability of the findings.

Furthermore, the failure to specify whether data-crystallization methods were used may undermine the reliability of the findings. It is recommended that researchers monitor data saturation throughout the process, adding interviews as needed and using diverse data sources to refine the findings. In line with the results obtained from the research, the following recommendations can be made:

- The study found that pre-service teachers lacked sufficient knowledge of artificial intelligence during semi-structured interviews. To address this, it is recommended to organize a series of training programs to enhance their understanding of artificial intelligence.
- Furthermore, the research was specifically conducted with pre-service science teachers. To provide a more comprehensive understanding, it is suggested that similar studies be conducted with different sample groups to delve deeper into the issue from a broader perspective.
- In addition to quantitative data, semi-structured interviews were conducted to gather qualitative insights from pre-service teachers. It is proposed that using diverse data collection tools can further enrich the process.
- In future studies, we recommend using probability-based sampling methods to examine similar research questions with stronger inferential power.

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