Educating Aspiring Teachers with AI by Strengthening Sustainable Pedagogical Competence in Changing Educational Landscapes

Aydoğan Erkan , İslam Suiçmez * , Sezer Kanbul , Mehmet Öznacar

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Article

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Aydoğan Erkan [1], İslam Suiçmez [2,*], Sezer Kanbul [2] and Mehmet Öznacar [3]

[1] Near East University, Department of Educational Science, Nicosia, Cyprus, Mersin 10 via Turkey

[2] University of Kyrenia, Faculty of Education, Kyrenia, via Mersin-10, Turkey

[3] Near East University, Department of Computer Education and Instructional Technology, Nicosia, Cyprus, Mersin 10 via Turkey

* Correspondence: isuicmez94@gmail.com

Abstract

This study examines the effectiveness of an eight-week AI training program aimed at enhancing teacher candidates' pedagogical competence and AI literacy in rapidly changing and evolving educational environments. Due to the rapid change and development of our age, the change and transformation of education, which is one of the most important elements of our lives, cannot be ignored. Accordingly, the integration of teacher candidates, one of the stakeholders of education, into technological developments is very important for both the efficiency and sustainability of education. The "parallel–simultaneous design", one of the mixed research methods in which quantitative and qualitative research methods are used together, was employed. Based on this purpose, the study started with a needs analysis conducted with 33 teacher candidates studying in different branches at the faculty of education. Thanks to the needs analysis, knowledge gaps, digital skill levels and readiness for integration into artificial intelligence tools in future classrooms were determined. Its application in teacher candidates instead of teachers in the profession was determined by needs analysis. It has been concluded that it will be more beneficial to apply the education of the future to the teachers of the future and that they will be able to adapt to these trainings more easily. Based on all these, a pre-test-posttest design was applied to observe the changes of the participants and an artificial intelligence literacy scale was used. QDA Miner Lite was used for the analysis of qualitative data, and SPSS 29.0 was used for the analysis of quantitative data. During the eight-week training, Gamma programs were used for presentation, Suno for audio, Mindjourney for visual and Chatgpt for descriptive search in order to provide better quality education to the participants. While practicing with these applications, a more up-to-date education is aimed with activities that reveal problem-solving skills that include critical thinking exercises. According to the results obtained, it was revealed that the teacher candidates who thought that they were undecided or had insufficient knowledge reached a sufficient level in the post-test. In the light of these results, it reveals that artificial intelligence-oriented education is effective in developing sustainable pedagogical skills, digital literacy, readiness and professional self-confidence and offers evidence-based recommendations for the design of future teacher training programs.

Keywords: artificial intelligence; teacher education; sustainable pedagogy; digital literacy; educational innovation; future-ready teachers; transformation in education

1. Introduction

It cannot be said that there is anything that is not affected by the rapid development of technology around the world. This rapid change and development on a global scale, in short, digital transformation is the 21st century. It redesigns the social and cultural structure of the century [1]. It

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is not possible for education, which has been dogmatically in human life since the existence of human beings and starts from the family and continues in social life, not to be affected by this. In fact, one of the strongest effects of this transformation is in the field of education. Many new technological trends are starting to take place in education [2]. The effectiveness of artificial intelligence and big data analytics, machine learning and language automation, which are the foundations of artificial intelligence, cannot be ignored. In fact, thanks to this change, the structure of learning-teaching processes has fundamentally changed and traditional pedagogical models must be re-evaluated [3]. This change should not be considered only as the structuring or diversification of technological tools; education should be viewed as updating all stakeholders. In particular, it should not be ignored that teacher roles, student expectations, instructional designs and evaluation processes may completely change and will be restructured. It is foreseen that it may be necessary to examine the technological integration of all this change and transformation in education, analyze it thoroughly and redesign it [4].

Digitalization in the transformation of education systems has also changed the roles and expectations of all stakeholders of education. Although it is considered sufficient for today's teachers to adapt to technology at a certain level, the expectation is that they have effectively adapted and adapted to pedagogical approaches integrated with technology. This expectation will begin to be expressed more loudly in the coming years. For this reason, the concept of "sustainable pedagogical competence" has become the main axis in many modern educational researches. It is necessary to analyze this concept thoroughly and assimilate it to educators. This concept includes not only the ability to use existing digital tools, but also the ability to foresee what may be encountered in the future, to adapt, to be innovative, and to have a flexible and critical teaching approach [5]. In this context, the relationship between sustainable pedagogical competence and digital literacy is of critical importance, especially for future teachers.

When the literature is examined, it shows that teacher candidates' awareness of technologically developed tools and their ability to use these tools are decisive for the sustainability of education quality. Artificial intelligence literacy directly affects educators' ability to create technology-integrated learning environments and skills in their future classrooms, while also contributing to the processes of the most valuable and high-level values of education, such as critical thinking, analytical decision-making, and ethical evaluation [6].

Furthermore, the impact, place, and role of artificial intelligence in education are gradually expanding. Although it has negative contributions such as misuse by students and efforts to reach conclusions from research, its positive effects cannot be ignored. In particular, systems that analyze students' academic performance, personalized learning paths specific to the student, fast feedback mechanisms in terms of interaction, automatic evaluation tools for results or processes, and the ability to produce content digitally and increase their pedagogical efficiency both reduce the workload of educators. The effort to continue with classical learning by trying to remove technology, which is the reality of this age, from the student's life is not effective in this new generation with a decreasing focus level and is boring [7]. It is thought that technological integration will contribute a lot in terms of adequacy, motivation and learning-teaching efficiency in the new generation society that lives and consumes everything faster. In particular, artificial intelligence-based applications and content production tools, speech production systems, visual creation platforms, text-based smart assistants where they can do faster research, etc. will both contribute positively to the development processes of teacher candidates and attract the attention of students more. However, in order to learn the positive aspects of all these and to use them more effectively and ethically, teacher candidates and teachers need to undergo a structured training.

In this context, it is not enough for the training programs created for teacher candidates to be integrated only into technology. What really needs to be done here is to make technology a part of the pedagogical process, with applied, two-sided participation, passive student activation, and active participation that focuses on critical thinking [8]. There are many studies in the literature that reveal the effects of application-based artificial intelligence training on teachers and students. There are

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various studies showing that application-based artificial intelligence trainings increase teacher candidates' professional self-efficacy levels, reduce their anxiety about technology and digital tools, and most importantly, positively affect their attitudes towards technology integration [9]. For this reason, it has become a strategic priority of education faculties for teacher candidates to gain active experience in technology-integrated learning environments before starting their profession.

Here, we come across the concepts of sustainability of education and the roles of future education in order to make the future healthier. Sustainable education is not just a concept that encompasses environmental awareness [10]. With this sensitivity, it is a holistic learning approach that supports the continuity and long-term continuity of life in economic, technological and social terms. With the integration of technology into education, the shape of many materials has changed and will change further [11]. In this way, both the consumption based on harm to nature and harm nature will decrease and the style of education for the new generation of people will increase. Today's research reveals that a sustainable education system is very valuable and will be even more valuable in terms of nature, human and life sustainability [12]. It is seen that digital transformation, innovative pedagogical approaches and lifelong learning skills are the main components of this education style. From this point of view, it is clear that artificial intelligence-based applications and technologies are important elements that shape the future of sustainable education. Because artificial intelligence offers many advantages that strengthen sustainability in our lives, such as personalization of learning, accessibility, efficient use of resources, reduction of physical resource use and support of teaching processes with automation. Most importantly, it will be able to reduce education-based concrete consumption by mobilizing and digitalizing education. Therefore, increasing the artificial intelligence literacy and digital pedagogical competencies of teacher candidates is vital for the continuity of sustainable education and the quality of the learning environments of the future. By adopting an approach that supports the vision of sustainable education, this study aims to contribute to the education of the future to train the teachers of the future as active, competent and adaptable professionals.

The main reason for the emergence of this study is the inadequacy identified in the artificial intelligence literacy levels of teacher candidates and the need to strengthen their sustainable pedagogical competencies. At the beginning of the study, the lack of knowledge, weak digital competence levels and inadequacy of the readiness levels for integrating technology into classrooms were revealed by both expert analyzes and needs analyses, and the content of the eight-week training program designed in this context was structured and implemented. The results of this needs analysis are in parallel with many studies in the literature [13]. Although the digital access of teacher candidates has increased, their competencies, effectiveness and integration into systematic education are insufficient.

The applications in the program developed for this study include the practical use of the most preferred artificial intelligence tools of modern life, such as for presentation-presentation designs (Gamma), for voice generation (Suno), for visual design (Midjourney) and for text-based querying (ChatGPT). Both the correct use and the advantages and disadvantages of the applications are based throughout the training. The reason for choosing these tools is to support the most used material production skills such as visual, auditory, research and presentation skills that teacher candidates may need frequently [14]. Additionally, the pedagogical dimension of the program was strengthened through critical thinking exercises and problem-solving activities, emphasizing that technology is not only a technical tool but also an element of pedagogical innovation.

The fact that the research was evaluated with the pretest-posttest design carried out under the same conditions provided an opportunity to quantitatively reveal the effect of the program on teacher candidates. With the qualitative part, the study was supported by needs and individual comments.

As a result, the integration of sustainable pedagogical competence and AI literacy into teacher training processes is no longer seen as a choice but a necessity in rapidly changing educational landscapes. This study demonstrates the effectiveness of applied AI training programs for pre-service teachers, makes a significant contribution to the teacher education literature, and provides evidence-

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based recommendations for the development of technology-based teacher training models in higher education.

The Aim of the Study

In this context, it is important to acknowledge the necessity of AI-driven education for undergraduate teacher candidates in higher education. Therefore, a sustainable education curriculum based on artificial intelligence should be created. The primary objective of this study is to develop an AI-based sustainable education curriculum for higher education and evaluate its effectiveness. The research questions designed to achieve this general goal are as follows:

1. What are the knowledge levels and opinions of teacher candidates regarding the education program based on artificial intelligence integration?
2. What is the level of change in the digital literacy, readiness and knowledge levels of a participant participating in the training of teacher candidates on sustainable educational practices of artificial intelligence?
3. What impact does participation in an artificial intelligence-based teacher training program have on the professional self-confidence and pedagogical sustainability levels of teacher candidates?

2. Materials and Methods

In this part of the study, the model of the research, the scope of the research, sample group data collection tools, learning activities and lesson plans, and statistical methods used in data collection and analysis are explained. This study aims to train teacher candidates with artificial intelligence by strengthening sustainable pedagogical competence in changing educational environments. As a result of the needs analysis, an 8-week training was designed. With this training, four different applications such as gamma, suno, midjourney and chatGPT were taught and applied to teacher candidates in every aspect. Project assignments were given for all these applications and this project assignments were evaluated. At the end of the training, certificates were given to the successful participants.

In this research, a mixed method that integrates both quantitative and qualitative research techniques was applied to create a sustainable education program centered on artificial intelligence applications and to evaluate the effectiveness of the implementation and results of this program. One of the most important factors in choosing the mixed method model is the limitations of a single method and the elimination of the possibility of evaluating the data in a versatile and comprehensive way [15]. In this way, the findings were strengthened in the light of multiple data sources. It is critical for the researcher to choose the right model before starting the study in order to choose the right design, which is one of the most important criteria in a study [16].

The most appropriate mixed method approach for this study was determined as “parallel-simultaneous design”[17]. The most important reason for choosing this design is that qualitative and quantitative methods are carried out simultaneously. This model; It contributes to the ability to collect data at the same time, to perform independent analyzes separately and to obtain comprehensive results [18]. Before the training to be given started, both pre-test and qualitative scale were applied and data were obtained. At the end of the research, a post-test and qualitative scale were applied. The main advantage of this model is its capacity to produce more detailed and comprehensive results.

In the quantitative part of the research, it was preferred to use screening and experimental methods together. In the screening phase, the descriptive-relational survey model was preferred because it allows an event or situation to be described as it is without changing it and to reveal the levels of different relationships between variables. As a result of the experimental study, the focus was on evaluating the change in the levels of the participants before and after the intervention [19]. The main purpose of experimental research is to reveal the effect of a certain change or development on the participant for the main purpose as a result of the procedures applied in line with the determined purposes. In this type of research, the researcher actively interacts with at least one of the

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groups examined. In the qualitative part of the research, "case study design" was used. This approach allowed for an in-depth and longitudinal examination of the dynamics taking place in the application environment throughout the implementation process and the interpretation of the findings regarding the changes in the implementation process. In line with the detailed analysis required by this design, interviews and document reviews were conducted. In addition, the opinions of the teacher candidates were collected in the qualitative phase of the research and the data obtained were evaluated as an important source of the research. Documenting and analyzing the collected data are considered empirical resources within the scope of case studies [20].

This research was conducted in the fall semester of the 2024–2025 academic year. In the qualitative phase of the study, thirty-three participants selected by purposive sampling method took part. This method is preferred because of its potential to obtain in-depth and information-rich data. This approach has allowed for a thorough examination of key operational contexts. In addition, certain criteria were established to determine the study group and it was envisaged that the sample selected according to these criteria would cover all relevant dimensions to meet the objectives of the research. In the needs analysis process, it is planned to provide access to previously published scientific resources on "artificial intelligence" and "sustainable education". In the needs analysis phase, a qualitative scale consisting of five questions was developed in order to evaluate the perspectives of pre-service teachers on artificial intelligence applications and sustainable education in line with the opinions of experts in ten different fields. The main purpose of this tool is to determine the readiness levels of pre-service teachers for the research topic. In the evaluation process, criterion sampling method was used and the participants' "having taken computer courses before" was determined as the clear criterion. Accordingly, a total of 33 teacher candidates studying at the university in the fall semester of the 2024-2025 academic year and meeting this criterion were identified and allowed to participate in the research. These participants constituted the sample group of the research.

In the needs analysis phase, interviews were conducted with field experts to find an answer to the question "What should be taught?". Certain criteria have been determined in the selection of experts, and these criteria include teachers and academicians who provide education in fields such as technology courses, education model courses, digital content development courses, instructional technologies, computer courses and technology education. In addition, it is aimed to provide a more comprehensive evaluation by including the opinions of academics from different faculties with similar experience and expertise.

In the quantitative part of the research, the participants to be subjected to an experimental application were selected by the appropriate sampling method. The reason for choosing this method is that it provides convenience to the researcher in terms of time, resources and effort. Because the participants must have a certain level so that it serves its purpose in a way that will be useful in this training. As a result, a total of 33 pre-service teachers studying in the fall semester of the 2024–2025 academic year constituted the experimental group. All of the field experts who contributed to the creation of the developed education with their opinions and the teacher candidates who participated in the application live in Cyprus and demographic information is presented in Table 1.

Table 1. Distribution of demographic information of participants.

			(f)	(%)
Experimental Working Group	Distribution of participants by gender	Female	17	51.51
		Male	16	48.49
	Distribution of participants by age	18–25	27	81.82
		26–35	6	18.18
		36–45	0	0.00
		45>	0	0.00
Field Experts Working Group	Distribution of participants by gender	Female	5	50.0
		Male	5	50.0

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Distribution of participants according to their experience in the profession	<5	2	20.0
	6–11	5	50.0
	12–17	2	20.0
	18>	1	10.0
Distribution of participants according to their work on AI applications and sustainable education	I taught the same/similar course content	10	100.0
	I made a presentation at a conference	4	40.0
	I wrote a book/chapter	1	10.0
	I wrote a thesis	4	40.0
	I made a scientific publication	5	50.0
Distribution of participants by title	Professor	5	50.0
	Assists. Prof. Dr.	3	30.0
	Instructor	2	20.0

2.1. Experimental Working Environment

In this study, the application was carried out face-to-face for 8 weeks, 2 hours a week, as a learning environment in the classrooms of the Faculty of Education of the University of Kyrenia.

2.2. Teaching Activities Program

The output of the teaching activities of this study was prepared by taking expert opinions. In the prepared program, after each application week, project assignments were given to the participants and they were evaluated. Successful participants were also given certificates. All 33 participants were successful. During the face-to-face training, the participants interacted with the researcher and received support in the project development process.

When Table 2 is examined, a detailed presentation was made by the researcher in the first week. For the next four weeks, the applications were applied and applied one by one. A seminar was given in the sixth week and applications were made by an expert trainer in the field. In the seventh week, a project development competition was held. In the last week, the evaluation and learning outcomes of the participants were emphasized.

Table 2. Subjects, outcomes, learning time, percentile.

Week	Objective / Content	Achievement	Tool / Platform	Duration	Percentile
Week 1	**AI and Sustainable Education: Foundations & Future of Learning**	Understand sustainable pedagogy, AI literacy, future classrooms, digital transformation dynamics	Introductory Seminar	2 hrs	5%
Week 2	**Creating AI-Based Instructional Presentations**	Ability to design effective and sustainable instructional presentations using AI structuring tools	**Gamma**	2 hrs	12.5%
Week 3	**Developing AI-Based Audio Materials**	Ability to generate narration, audio content, and sound-based instructional materials	**Suno**	2 hrs	12.5%

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Week 4	**Generating AI-Based Visual Educational Materials**	Ability to create visuals, digital posters, learning graphics, and scenario-based images	**Midjourney**	2 hrs	12.5%
Week 5	**AI-Driven Research, Content Development, and Lesson Support**	Ability to conduct descriptive searching, create content, design lesson materials	**ChatGPT**	2 hrs	12.5%
Week 6	**Seminar Week: Pedagogical Applications of AI in Sustainable Education**	Gain multi-perspective insights from experts in education, technology, pedagogy, and sustainability	Expert Seminars	2 hrs	10%
Week 7	**Application Competition Week (Project Development)**	Develop original AI-supported micro-teaching projects using the tools learned (Gamma/Suno/Midjourney/ChatGPT)	Project Competition	4 hours	20%
Week 8	**General Evaluation & Reflection Week**	Evaluate projects, measure learning outcomes, reflect on sustainable & AI-enhanced pedagogy	Evaluation Session	2 hrs	15%

2.3. Data Collection Tools

Data were collected face-to-face. But it was collected digitally through Google Forms.

2.3.1. Qualitative Data Collection Tools

Interview form questions were sent to pre-service teachers online via "Google Forms" in order to collect qualitative data. Although the application was carried out online, it was applied in a classroom environment so that the researcher could observe [23]. In line with the feedback received from the participants, analyzes were made and deficiencies related to the training were identified. Considering these deficiencies, the training program has been rearranged.

2.3.2. Quantitative Data Collection Tools

In terms of the validity and reliability of education, the "Artificial Intelligence Literacy Scale" developed by Uğur Demir, Fatih Yılmaz, and Celalettin Çelebi in 2023 was applied to determine the perception and knowledge levels of teacher candidates about artificial intelligence [22]. Permission was obtained from the relevant authors before application. In addition, detailed information was given to the participating teacher candidates and experts whose expert opinions were taken about the "validity and reliability" of this scale. In addition, the data of the demographic variables of the pre-service teachers were collected while applying this scale. Afterwards, artificial intelligence knowledge levels were determined within the scope of the 8-week training and the developed trainings were implemented within this framework. The practices developed within the scope of the training were tested and recorded with assignments, in-class practices and idea exchanges in order to determine the levels and development processes of the participants. By using four different

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applications, both diversity and the effectiveness of the learning process were tried to be increased. At the end of this training, the same scale was applied once again and the development processes before and after the training were evaluated.On the other hand, the quantitative data of the study were applied by the researcher as pre-test and post-tests of the artificial intelligence scale within the scope of experimental research in the relevant department. Questionnaires filled in incompletely or incorrectly by pre-service teachers were not included in the study. SPSS 29.0 package program was used for statistical analysis of the research data. In statistical analysis, the significance level was taken as 0.05.

2.3.3. Informed Consent Form

The researcher prepared an informed consent form to collect the demographic characteristics of the participants. This form is tailored to criteria such as age and gender, which may influence teacher candidates' perceptions, attitudes, and opinions towards AI applications. For experts, criteria containing special information such as years of professional experience, profession and title have been added.

2.3.4. Artificial Intelligence Literacy Scale

The "Artificial Intelligence Literacy Scale", developed to determine the artificial intelligence knowledge levels of teacher candidates and used with the necessary permissions, was prepared by Uğur Demir, Fatih Yılmaz and Celalettin Çelebi in 2023 [23]. The Artificial Intelligence Literacy Scale consists of cognitive questions. The scale consists of 12 questions and 4 factors covering these questions. As a result of the analysis, the Cronbach's Alpha coefficient of the general internal consistency was determined as 0.85. The Artificial Intelligence Literacy Scale has been developed as a 7-point likerte type and the options are "Strongly Disagree (1)", "Disagree(2)", "Partially Disagree(3)", "Undecided(4)", "Partially Agree(5)", "Agree(6)", "Strongly Agree(7)".

2.3.5. Qualitative Data Collection Tools

In this research, two different forms and an analysis method were used to collect qualitative data. First, the self-evaluation form and then the expert lecturer interview form were applied together with the document analysis method. Although the study was conducted face-to-face, the Google Forms platform was chosen to emphasize the importance of digital transformation in the data collection process, to prevent data loss, and to analyze data more effectively.

2.4. Data Analysis and Interpretation

2.4.1. Analysis of Quantitative Data

In the process of analyzing the data obtained from the Artificial Intelligence Literacy Scale, normality tests were first performed to determine compliance with the normal distribution. In line with the results obtained, graphical normality, kurtosis and skewness values were examined and it was determined that the data were normally distributed. These findings have allowed the application of parametric tests; because parametric statistics are based on the assumption of normal distribution. Recent research reveals that in cases where normal distribution is not achieved, the Type I error rate may increase, negatively impacting the test power [23]. In this context, the t-test was used when the demographic variables were divided into two subgroups, and the ANOVA test was used when there were three or more subgroups. Paired samples t-test was applied to determine the difference between before and after the experimental study, and this test was preferred to compare the two measurement averages of the same individuals. All analyzed data are presented in tables in the findings section.

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2.4.2. Document Analysis

The information collected within the scope of the document analysis of the research was examined with a descriptive analysis approach. This method was chosen to identify specific trends in the subject. The collected data were recorded regularly.

2.4.3. Analysis of Qualitative Data

The data of the study were collected both face-to-face and digitally and analyzed within the scope of a coding process based on "Grounded Theory". In this analysis section, descriptive analysis, content analysis and continuous comparison technique were carried out using the QDA Miner Lite program. Teacher candidates' perceptions and attitude levels of artificial intelligence were examined. In addition, during the data collection process, the gestures, facial expressions and physical movements of the participants were observed and their effects on the analysis were also evaluated.

2.4.4. Validity and Reliability Study in Qualitative Analysis

Careful methods were applied in the analysis process to ensure that the qualitative data were reliable and valid. In the research, internal validity, external validity, reliability and objectivity criteria were taken into consideration; The consistency of the data was supported by expert opinions and participant feedback. In this way, the accuracy of the findings and their contribution to the literature were strengthened.

Table 3. Evaluation process within the scope of reliability and validity.

Factor	Process
Internal Validity	The data provide a lasting effect and is collected throughout the duration of the process. The data are obtained directly from the participants by the researcher. The results are precise and clear. Data are collected at the specified theme level. The findings cover the identified theme exactly. It provides consistency because themes are determined by data.
External Validity	The findings are provided with clear and understandable quotations in terms of transmissibility. Practitioner information is given in detail. Participants were selected according to the case by the purposive sampling method.
Reliability	The two researchers conducted their analyses at distinct times and locations. An unbiased individual subsequently reviewed all findings once they were accessible to the researcher. The research methodology was thoroughly explained to the participants.
Neutrality	In the processes of analysis and interpretation, it is essential for the researcher to maintain objectivity and neutrality. Any personal biases may distort the data and compromise the clarity of the findings. This assertion was corroborated by an impartial observer. An objective specialist evaluated the outcomes and assessments. The researcher clarified his responsibilities within the process.

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3. Results

3.1. For the First Research Question

A needs analysis was conducted in response to the first research question of this study, "What are the knowledge levels and opinions of teacher candidates regarding the education program based on artificial intelligence integration?". While preparing the questions of the needs analysis, expert opinions were taken and the qualitative scale of the study was created by looking at the findings obtained from them. With this qualitative scale, it was aimed to reveal the views of the participants participating in the study towards artificial intelligence. In addition, in the continuation of these opinions, it was tried to determine the digital literacy levels, readiness levels and knowledge levels of the participants.

As can be seen in Table 4, the knowledge level of most of the participants is insufficient or moderate. In the in-class evaluation conducted with the participants who said they were at an intermediate level, it was determined that they only knew the "ChatGPT" application. In fact, almost all of the participants were found to have insufficient or unintellectual knowledge in terms of integrating AI applications into sustainable education.

Table 4. Qualitative Scale Findings for Needs Analysis.

Factor	Codes	n	f
1. Do you know about artificial intelligence?	1=None, 2=Basic, 3=Medium/Detailed	None: 5, Basic: 15, Medium/Detailed: 13	15%, 45%, 40%
2. In which areas can AI be used?	1=Education, 2=Health, 3=Finance, 4=Daily life/Other	Education: 18, Health: 12, Finance: 7, Daily life/Other: 10	55%, 36%, 21%, 30%
3. Will artificial intelligence contribute to our lives?	1=Negative, 2=Unstable, 3=Positive	Negative: 4, Undecided: 6, Positive: 23	12%, 18%, 70%
4. Will you use AI in your lessons?	1=Yes, 2=No	Yes: 22, No: 11	67%, 33%
5. Can AI pose a problem for creativity?	1=No, 2=Partially, 3=Yes	No: 6, Partially: 14, Yes: 13	18%, 42%, 40%

3.1.2. For the Second Research Question

The second research question of this study, "What is the level of change in the digital literacy, readiness and knowledge levels of a participant participating in the training of teacher candidates on sustainable educational practices of artificial intelligence?" The findings are as shown in Table 6. In order to obtain these findings, a pre-test was applied with a quantitative scale at the beginning of the 8-week training program. At the end of the research, the post-test was applied and the development of the participants was examined.

The average scores of the artificial intelligence literacy scale ($\bar{X}$ = 3.97 — SD = 0.34) obtained from the participants in the study are higher than the average scores of the artificial intelligence literacy scale applied in the pre-test ($\bar{X}$ = 2.44 — SD = 0.42). According to the interval scoring given in Table 5, the answers given by the teacher candidates as "I am undecided" before participating in the training reached the level of "I agree" at the end of the training. It was determined that there was a

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significant difference between the pre-test and post-test mean scores regarding the level of artificial intelligence literacy (p>0.05). The t-test was used to make this determination. As a result of the t-test, a significant difference was found in favor of the post-test (t(75) = 10.423; p < 0.05). In this case, a positive development in the participants was determined and Table 6. When examined, it will be seen in which areas this development occurred.

Table 5. Pre-test- Post-Test Analysis.

	N	$\bar{X}$	Ss	t	p
Pre-Test	33	2.44	0.42	10.423	.000
Post-Test	33	3.97	0.34		

N: participants, $\bar{X}$: means, Ss: std. deviation: t: t-test significance level; *p*; statistical significance level.

Table 6. Wilcoxon test results of the sub-dimensions of the AI perception levels of the experimental group, pre-test and post-test t-test analysis.

Test	Dimension	With	P
Pre-Test–Post-test	Knowledge	3.52	0.00*
Pre-Test–Post-test	Digital Skills	−2.94	0.432
Pre-Test–Post-test	Readiness	-4.31	0.00 *

When Table 6 was examined, it was determined that there was a positive improvement in the level of knowledge and literacy (p<0.05). However, it was determined that there was no change in digital skills readiness levels (p>0.05)

3.1.3. For the Third Research Question

The third research question of this study, "What effect does participation in an artificial intelligence-based teacher training program have on the professional self-confidence and pedagogical sustainability levels of teacher candidates?" In the findings, it was determined that the participants benefited a lot from the training and therefore said that they could reconcile sustainable education and artificial intelligence. They also mentioned that the eight-week training was productive and the planned training was very productive. They stated that examining an application in detail from each week of the training and the effectiveness of the application was very useful both in terms of integration into the application and the guidance of the researcher. They also reported that it was very useful for them to test themselves in terms of professional self-confidence and competence with the competition held in the seventh week.

Table 7. Course outcomes.

Course	Degree	(%)
Course 1: Introduction and AI in Education	Good	12.61
Course 2: AI Tools for Content Design (Gamma)	Very good	8.31
Course 3: AI for Creative Teaching Materials (Suno)	Very good	9.17
Course 4: AI-Supported Student Interaction(MidJourney)	Very good	8.26
Course 5: AI in Assessment and Feedback(ChatGPT)	Very good	8.34
Course 6: Pedagogical Strategies with AI(Seminer)	Good	4.01
Course 7: AI and Sustainable Education Practices (Project)	Very good	8.12
Course 8: Project Presentation and Evaluation	Very good	8.26

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3.1.4. Opinions of Pre-service Teachers on the Sustainable Education Program Based on Artificial Intelligence Applications

When the outputs obtained by the pre-service teachers based on artificial intelligence applications and their answers to the question "Would you define yourself as a new generation teacher?" are examined, it is seen that the majority of them (n = 27) believe that they have the characteristics of a new generation teacher. When the answers given by the teacher candidates to the question "When you consider the sub-dimensions of sustainable education based on Artificial Intelligence applications, which sub-dimension did you find most appropriate and sufficient?" are examined, it is understood that the sub-dimension they are most interested in is the "readiness" sub-dimension.

"Did the sustainable education and training program based on Artificial Intelligence applications ensure your active participation in the learning-teaching processes of the course? Why?" and cited the effectiveness of active participation and scenario-based learning as the reason for this.

"Do you think that the sustainable education course based on Artificial Intelligence applications should be taken as a normal course by all teacher candidates in the future? Why?" they answered "yes"; they stated the necessity of adopting the right behaviors in digital environments and the need to keep up with the digital age as the reason for this (See Table 8).

Table 8. Teacher Candidates' Views on Sustainable Education Program Based on Artificial Intelligence Applications.

Dimension	Category	(f).	(%)
Do you define yourself as a new generation teacher, considering the achievements of teacher candidates in the sustainable education course based on AI applications? Findings on the question	Thinking that they have the characteristics of a new generation teacher	32	82.05
	Thinking that they do not have the characteristics of a new generation teacher	7	17.95
When you think about the sustainable education sub-dimensions of pre-service teachers based on AI applications, which sub-dimension did you find most appropriate and sufficient? Findings on the question	Technology	12	30.77
	Digitalization	5	12.82
	Social	1	02.56
	Lifestyle	5	12.82
	All	16	41.03
What are your thoughts on the scenario-based teaching approach/activity applied in the sustainable education course based on pre-service teacher AI applications? Findings on the question	Effective learning	9	23.07
	Learning by experience	5	12.82
	Rapid learning	5	12.82
	Active participation	4	10.25
	Persistent learning	3	07.07
	Thinking skills	3	07.07
	Collaborative learning environment	1	02.05
	Effective learning	9	23.07
Did the learning–teaching process of the teacher candidates' sustainable education course curriculum based on AI applications enable you to actively	**Answer**	**Reason?**	**(f).**	**(%)**
	Yes	Active participation	13	33.33
	Yes	Scenario-based learning	8	20.51
	Yes	Self-assessment	8	20.51

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participate in the lesson? Findings on the question	No	-	0	0
	Answer	**Reason?**	**(f).**	**(%)**
Do you think that in the future, all pre-service teachers should take the sustainable education course based on AI applications as a normal course? Findings on the question	Yes	Correct behavior in digital environments	15	80.00
	Yes	Adapting to the digital age	13	33.33
	Yes	Forward-looking	8	20.51
	Yes	Occupation, job skill	3	07.07
	No	-	00	00.00

4. Discussion

The aim of this research is to provide an 8-week training by creating a sustainable training program by using artificial intelligence applications. Then it is to evaluate the effectiveness of this program. First of all, the appropriate requirement for an artificial intelligence-centered sustainable education program has been determined. Then, a class studying in higher education was created and an 8-week experimental study was carried out there. Various methods such as pre-test-posttest designs and participant behavior scales were used to evaluate the effectiveness of the program. The findings revealed the effectiveness of the sustainable education and training program that includes artificial intelligence applications of pre-service teachers studying at the undergraduate level.

4.1. Discussion on Qualitative Data

The qualitative findings of this research reveal that the knowledge, attitude and readiness levels of teacher candidates towards the concept of artificial intelligence-based sustainable education were insufficient at the beginning. The majority of the participants stated that they only had introductory knowledge about artificial intelligence, while those who stated that they had intermediate knowledge only knew ChatGPT in general during the implementation process. Thus, it reveals that although the participants' access to technology is at a high level, their ability to use artificial intelligence tools for pedagogical purposes is not yet sufficiently developed. For example, in the study of Zhai et al. (2021), it was found that pre-service teachers' awareness of artificial intelligence was low; It is stated that they are especially hesitant to use the applications for a pedagogical purpose in the course [24].

The feedback obtained during the eight-week training period showed that the teacher candidates were especially motivated in terms of readiness and self-improvement and experienced an observable improvement. In a similar study, Holmes et al. (2022) found that AI applications supported participants' high levels of interaction, problem-solving, and critical thinking skills [25]. It has been frequently observed that applied activities, project-based learning and researcher guidance have a positive effect on teacher candidates. The majority of pre-service teachers stated that the course in which artificial intelligence applications were used made them active learners, and that especially scenario-based activities made the knowledge permanent. The fact that teacher candidates find scenario-based learning efficient reveals that artificial intelligence-based teaching requires not only technical use but also pedagogical design. Similarly, Holmes et al. (2022) show that AI applications support high levels of interaction, problem-solving, and critical thinking skills in pre-service teachers [25].

In addition, the majority of teacher candidates define themselves as "new generation teachers", thus showing that the education process has changed in the perception of professional identity. Participants stated that they realized that AI tools are not only technical tools but also a powerful support for pedagogical design and creative content production. The positive attitude, particularly towards tools like Gamma, Suno, Midjourney, and ChatGPT, reveals a strengthening of professional self-confidence. This result is in line with the findings of Falloon (2020); The study shows that artificial

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intelligence-based trainings significantly increase the digital pedagogical competencies of teacher candidates [26].

When the qualitative findings are evaluated, it can be said that artificial intelligence tools positively affect the capacity of teacher candidates to adapt to the digital transformation process, encourage classroom practices and significantly improve their awareness of sustainable pedagogical understanding.

4.2. Discussion on Quantitative Data

Quantitative findings showed that the eight-week AI-based training had a significant impact on pre-service teachers' knowledge, AI literacy, and readiness. Looking at the pre-test-post-test results, it is seen that artificial intelligence perceptions, which are at the level of indecision, increase to the level of agreement at the end of the program. This finding is in line with a study by Sweeney (2022), which showed that AI-supported teacher training increases the cognitive awareness and knowledge levels of teacher candidates even in the short term [26].

The significant increase in the sub-dimensions of knowledge level and literacy shows that the conceptual awareness of the participants has strengthened. Similarly, Li & Xue (2022) state that AI-centered teaching programs have a high impact on conceptual knowledge and cognitive awareness [27].

It is noteworthy that no significant change was observed in the digital skills sub-dimension in this research. This suggests that the technical skills of teacher candidates may already be at a certain level before the training or that the duration of the program may not be sufficient for technical skill development. This finding is in line with the study of Yadav et al. (2021); In the relevant research, it is stated that short-term artificial intelligence training provides limited technical skills but a high level of improvement in cognitive awareness [28].

A significant increase in the level of readiness indicates that pre-service teachers' motivation to use these technologies in the classroom environment in the future has increased. This result is similar to the study by Miao & Holmes (2021), which showed that AI integration improves professional confidence and innovative approach in teacher candidates [29].

As a result, quantitative findings reveal that this program significantly improves teacher candidates' professional competencies, artificial intelligence awareness, and adaptation to sustainable pedagogical approaches. Accordingly, it is seen that it is an important necessity to systematically include artificial intelligence-based sustainable educational content in teacher training programs.

5. Conclusions

In this research, eight designed for teacher candidates studying in higher education. The effectiveness of the weekly artificial intelligence-based sustainable training program is determined by quantitative and qualitative data. Evaluated. The findings showed that the participants of the program were able to improve artificial intelligence literacy, pedagogical It provides a meaningful and positive development on their perception of sustainability and professional self-confidence. Shown. In particular, the pre-test-posttest differences were higher than the participants' initial "undecided" level. It has been revealed that it has risen to the level of "I agree", instead of the targeted gains of the study. It shows that it brings. Qualitative data also supported this result, teacher candidates took an active role in the education process, practices in a pedagogical context and find themselves in the new generation teacher profile. It was determined that they felt closer to what they required. Participants especially scenario-based learning, from the processes of producing applied content and exploring the interdisciplinary functions of artificial intelligence tools It has been seen that they take power. The program made the change in teacher roles visible due to digital transformation and It has been revealed that the concept of sustainable pedagogy can be reinterpreted by supporting artificial intelligence. He put it. In light of these results, the integration of artificial intelligence into teacher training programs is now a it can be said that it has become a necessity rather

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than a choice. The rapid change of educational environments, teacher candidates not only to recognize technology, but also to use this technology for pedagogical purposes correctly, consciously and it makes it necessary to use it sustainably. This study is based on artificial intelligence. It was revealed that the practices increased awareness, motivation and readiness in teacher candidates. contributes to the literature by putting it.

In the light of all these results, providing such trainings as distance education as the requirements of sustainable education will contribute to human life with advantages such as protecting nature, reducing fuel consumption, reducing electricity and building costs, etc. In addition, it will reduce the use of tools such as pencil, paper, etc., which are the classical materials of education.

It is recommended that such trainings be given not only to teacher candidates, but also to education stakeholders at all levels of education. In addition, it is suggested that technology integration in sustainable education should be tried not only with artificial intelligence tools but also with all other technological trends. Applying this training in different age categories, different geographies and different education levels and reaching more samples can also make a significant difference.

These and similar studies, which can be an example of technological integrations carried out within the scope of future education and sustainable education, have an important place in the literature. In the light of scientific studies, it is recommended to update new education models and new generation teacher candidates in this way.

It is recommended that education stakeholders, education practitioners and politicians who provide education focus on these issues.

6. Limitations

In this section, the limitations of the study are discussed. The research has limitations in several ways. First, the number of participants is limited to 33. The obligation to have “taken a computer course” limited the number of participants. In addition, the training process consists of 8 weeks and 2 hours, a total of 16 hours. With a longer educational process, there could have been more academic inclusivity. 4 artificial intelligence applications were used in the training; more applications can be used.

In addition, it must be taken into account that the curriculum must be adapted to the demographic characteristics of the country in which it will be implemented. Appropriate modifications should be made to align with the local context and meet the requirements of the workforce.

In addition, the application was applied at the higher education level. Its implementation at all levels of education will contribute to the literature and education.

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