A SYSTEMATIC REVIEW OF ARTIFICIAL INTELLIGENCE IN TEACHER EDUCATION: APPLICATIONS, TOOLS, TECHNIQUES, AND TOPICS STUDIED FROM 2012-2022

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ABSTRACT

The growing interest in Artificial Intelligence (AI) in other fields gave an impetus to conduct this systematic literature review to analyze whether and how AI is used in teacher education. Mainly, AI applications, tools, techniques, and topics covered about AI in teacher education were systematically analyzed. This study would call to reform teacher education programs and incorporate AI in teacher education to inculcate higher-order thinking and innovative pedagogical skills. An electronic search using ("Artificial Intelligence") AND ("Teacher Education") was performed in three databases, namely: Science Direct (Total=11/74), ERIC (Total=7/34), and EBSCO (Total=4/21). Out of 129, 22 studies that met the eligibility criteria were included for further analysis. The findings revealed that virtual reality and simulation, computerized expert models and learning packages, machine learning and artificial neural network, facial expression recognition, flipped learning network and blended learning, collaborative concept mapping, video annotation tools, google teachable machine, TPACK, and social robots were applications of AI in teacher education. Tools that are being used to integrate AI in teacher education are: web-based computers, mobiles, and robots, and the techniques include simulations, virtual role plays, artificial neural networks, facial recognition, blended classrooms, and machine learning. All these applications, tools, and techniques are being used to study affective skills, prepare teachers, manage a classroom, teach language, predict achievement, assess teaching skills, analyze cognitive levels of questions in classrooms, teach mathematics, and encourage collaboration. These findings suggest that AI can be a valuable approach in teacher education because it reduces their workload, helps them develop professionally, and remains updated about current developments in their field. At last, the implications of the study and recommendations for policymakers, teacher education departments, curriculum developers, trainers, software developers, and teachers are discussed.

Keywords: Artificial intelligence, teacher education, AI in teacher education, and systematic review.

Introduction

Artificial intelligence (AI) is the simulation of human intelligence processes by machines, especially computer systems these processes include learning, reasoning, and self-correction. It is predicted that AI will be incorporated into our educational system at all levels (Schiff, 2021). According to Horizon Report 2018, AI in education is likely to increase by 43% in the period 2018-2022 and a more significant increase will be observed in teaching and learning. Educators need to understand that nowadays, teaching and learning are heading towards creative styles that embrace the use of innovative technologies such as AI (Gupta & Bhaskar, 2020). AI applications in education have received growing attention in recent years (Zawacki-Richter, Marín, Bond, & Gouverneur, 2019). The intervention of AI in teacher education programs can result in the development of innovative pedagogical skills and higher-order thinking. Technological advancement in education enabled teachers to perform their jobs more efficiently and effectively, for instance, Tarnation for plagiarism detection in assignments and theses can

be traced easily with AI-efficient sources (Tian, Wang, Gao, Chen, & Wu, 2020) well designed Intelligent Tutoring System (ITS) can complete the tutoring task at all educational and cognitive levels (Sahu, 2016). Artificial intelligence in education opens new opportunities, potentials, and challenges in educational practices. Integration of AI in education is not only limited to technological advancements, it is a diversified term starting from the teacher's end and finishing at the student's end (Hwang, Xie, Wah, & Gašević, 2020; Ilkka, 2018).

The field of AI originated from computer science and engineering but it is strongly influenced by other disciplines such as cognitive science, economics, neuroscience, and philosophy gives the trans-disciplinary definition however, technology has advanced in recent years but concerning the introduction of AI-based tools (robotics, e-services, digital tools, steam approaches, and TPACK frameworks) in teacher education programs has limited work (Salas-Pilco, Xiao, & Hu, 2022). The use of AI applications in teacher education is crucial for developing pedagogical skills and high-order thinking. The study ascertained that AI has broadly been adopted and used in education, particularly in teacher education programs. Many studies are focusing on education; however, little work has been conducted on artificial intelligence in teacher education. In light of this gap in the literature, the current is an attempt to provide an overview of the applications, tools, techniques, and topics being explored and studied with the use of AI in teacher education. This study will help teacher education departments and policymakers to integrate AI to support teacher education and prepare teachers according to global standards. As Garbett and Ovens (2012) discussed in teacher education programs teachers must be equipped with both pedagogical and technological skills to survive in the digital world.

Research Questions

The following research questions were answered through a systematic review:

1. What are the most common instances of Artificial Intelligence in teacher preparation programs?
2. Which tools and techniques of Artificial Intelligence are being used in teacher preparation programs?
3. Which topics of teacher education are being focused on in artificial intelligence applications?

Methodology

The main purpose of the current systematic review was to provide the latest information about how AI is being implemented in teacher education around the world, the types of tools and techniques being used in teacher education, and the topics of teacher education that are being studied with the help of AI. A systematic review is an obvious and precise process for identifying, extricating, and combining information acquired from an assortment of empirical studies to respond to and explore questions (Zawacki-Richter, Kerres, Bedenlier, Bond, & Buntins, 2020). Also, Sleeter (2014) featured the need to do systematic reviews on educator training to give a more exhaustive comprehension of inquiries that stay under-explored.

The present systematic review was conducted by following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The search was conducted in Science Direct, EBSCO, and ERIC, and ("Artificial Intelligence") AND ("Teacher Education") keywords were used in all three databases. Furthermore, filters were applied such as journal articles in English language published from 2012-2021. The following criteria were used according to PRISMA guidelines: a) journal articles published from 2012-2021; b) published in the English language, c) both qualitative, quantitative, and review studies as long as they include the application, tools, techniques and example of AI in teacher education, d) research papers around the teacher education topic including either pre and in-service teacher preparation and e) articles only related to AI in teacher education. However, papers that were not available in full form, published before 2012 or after 2021, non-English language publications, related to AI but not in teacher education, and related to teacher education but did not include AI were excluded.

As far as data extraction was concerned, research papers' APA reference, year, country, methodology, AI example in teacher education, tools and techniques used, and topics of teacher education covered were done. All co-authors analyzed all the databases separately and after that, they sat together and finalized which papers to be included or excluded. Similarly, analysis was also done by concerning with all co-authors, and themes were developed after consulting all co-authors. The emerged themes are displayed in tables by mentioning themes, references of articles, and frequency of articles. The search generated a total of 129 research studies i.e. Science Direct = 74, ERIC = 34, and EBSCO = 21, out of these only 22 studies which met the criteria were included to conduct the systematic review. The summary of those studies can be seen in Table 1.

Table 1: Summary of Research Studies Included for Systematic Review

References	AI Tools	AI Applications	Teacher Education Topics
Science Direct (Total 74)			
Kaufmann, E. (2021). Algorithm appreciation or aversion? Comparing in-service and pre-service teachers' acceptance of computerized expert models. Computers and Education: Artificial Intelligence, 2, 100028.	Computer	Computerized expert models	Acceptance of EdTech
Cao, Q., Hao, H., Sabitha, R., & Thanjai, V. (2021). Occupational stress management of college English teachers under flipped classroom teaching model. Aggression and Violent Behavior, 101712.	Flipped Classroom	Flipped Learning Network with AI	Stress Management of English Teachers
Pérez-Torregrosa, A. B., Díaz-Martín, C., & Ibáñez-Cubillas, P. (2017). The use of video annotation tools in teacher training.	Video	Video Annotation Tools	Teacher Preparation and

			Reflective Teaching
Vartiainen, H., Tedre, M., & Valtonen, T. (2020). Learning machine learning with very young children: Who is teaching whom? International journal of child-computer interaction, 25, 100182.	Web-based Teachable Machine	Google's Teachable Machine	Teaching and Learning (Promoting Children Participation)
Dalinger, T., Thomas, K. B., Stansberry, S., & Xiu, Y. (2020). A mixed reality simulation offers strategic practice for pre-service teachers. Computers & Education, 144, 103696.	Simulations	Mixed-Reality Simulations	Teacher Preparation
Ouyang, F., Hu, Y., Zhang, Y., Guo, Y., & Yang, Y. (2021). In-service teachers' knowledge building during face-to-face collaborative learning. Teaching and Teacher Education, 107, 103479.	Web-based	Collaborative Concept mapping activities	Teacher Preparation knowledge building Collaboration
Srisawasdi, N. (2012). The role of TPACK in physics classroom: case studies of preservice physics teachers. Procedia-Social and Behavioral Sciences, 46, 3235-3243.	Computerized laboratory environments	TPACK	Teacher preparation
Sarac, H. S. (2013). Belief, knowledge, and expectations on language instruction via ICT: A close/critical look by experts. Procedia-Social and Behavioral Sciences, 70, 696-701.	Computer	Computer-assisted language learning packages	Learning Environment
Pinner, R. S. (2012). Teachers' attitudes to and motivations for using CALL in and around the language classroom. Procedia-Social and Behavioral Sciences, 34, 188-192.	Computer	Computer-assisted language learning	Attitude and Motivation
Utami, P., Hartanto, R., & Soesanti, I. (2019). A study on facial expression recognition in assessing teaching skills: Datasets and methods. Procedia Computer Science, 161, 544-552.	Facial expressions recognition	Facial expressions recognition	Assessing Teaching Skills
Yahya, A. A., Osman, A., Taleb, A., & Alattab, A. A. (2013). Analyzing the cognitive level of classroom questions using machine learning techniques. Procedia-Social and Behavioral Sciences, 97, 587-595.	Machine Learning Algorithms	Machine Learning Technique	Classroom Questioning
ERIC (Total 34)			

Attwood, A. I., Bruster, B. G., & Bruster, B. G. (2020). An Exploratory Study of Preservice Teacher Perception of Virtual Reality and Artificial Intelligence for Classroom Management Instruction. SRATE Journal, 29(2), n2.	Web-based	Virtual Reality	Classroom Management
Wetcho, S., & Na-Songkhla, J. (2022). An Investigation of Pre-Service Teachers Using Mobile and Wearable Devices for Emotion Recognition and Social Sharing of Emotion to Support Emotion Regulation in mCSCL Environments. Contemporary Educational Technology, 14(2), ep359.	Emotion tracker mobile computer-supported collaborative learning	Emotion Recognition and Social Sharing of Emotion to Support Emotion Regulation	Socio-emotional learning
Ishizuka, H., & Pellerin, M. (2020). Providing quantitative data with AI Mobile COLT to support the reflection process in language teaching and pre-service teacher training: a discussion. CALL for widening participation: short papers from EUROCALL 2020, 125.	Mobile	Mobile Communicative Orientation of Language Teaching (COLT)	Language teaching
Schussler, D., Frank, J., Lee, T. K., & Mahfouz, J. (2017). Using virtual role-play to enhance teacher candidates' skills in responding to bullying. Journal of Technology and Teacher Education, 25(1), 91-120.	Virtual role-play	Virtual role-play	Classroom Bullying
Istenic, A., Bratko, I., & Rosanda, V. (2021). Are pre-service teachers disinclined to utilize embodied humanoid social robots in the classroom? British Journal of Educational Technology, 52(6), 2340-2358.	Robots	Social Robots	Human-computer interaction
Akgün, E., & Demir, M. (2018). Modeling course achievements of elementary education teacher candidates with artificial neural networks. International Journal of Assessment Tools in Education, 5(3), 491-509.	Artificial neural networks	Artificial neural networks	Predicting course achievement
Demir, M. (2015). Predicting pre-service classroom teachers' civil servant recruitment examination's educational sciences test scores using artificial neural networks. Educational Sciences: Theory & Practice,	Artificial neural networks	Artificial neural networks	Predicting course achievement

15(5).			
EBSCO			
Hadjerrouit, S. (2017). ASSESSING THE AFFORDANCES OF SIMREAL+ AND THEIR APPLICABILITY TO SUPPORT THE LEARNING OF MATHEMATICS IN TEACHER EDUCATION. Issues in Informing Science & Information Technology, 14.	Web-based	Simulation	Mathematics Education
McGarr, O. (2021). The use of virtual simulations in teacher education to develop pre-service teachers' behavior and classroom management skills: implications for reflective practice. Journal of Education for Teaching, 47(2), 274-286.	Web-based	Virtual Simulation	Classroom management
Atmacasoy, A., & Aksu, M. (2018). Blended learning at pre-service teacher education in Turkey: A systematic review. Education and Information Technologies, 23(6), 2399-2422.	Web-based	Blended Learning	Technology integration Social interaction
Schugar, J., & Schugar, H. (2018). eTexts and Teacher Education: Considerations for Text Structure and Purpose in Mobile Pedagogy. International Journal of Mobile and Blended Learning (IJMBL), 10(2), 78-87.	Mobile	E-texts	Language learning

Results and Discussion

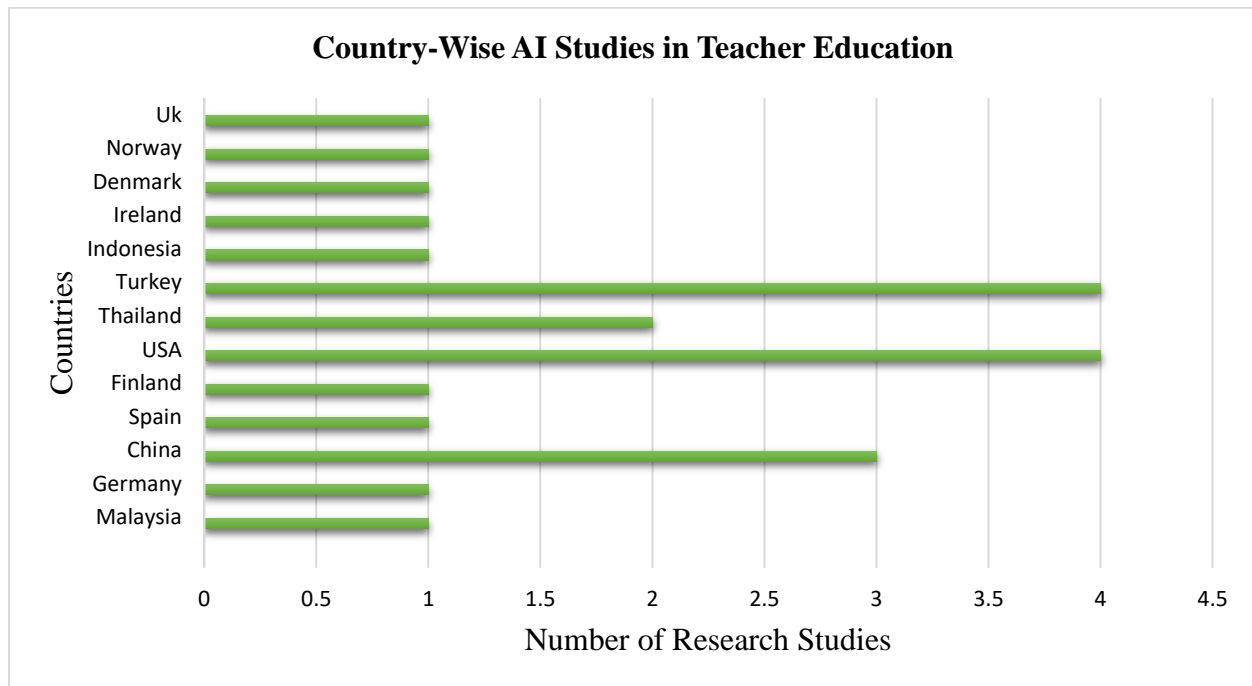**Characteristics of Included Studies for Systematic Review**

Figure 1: Country-Wise AI Studies in Teacher Education

Figure 1 shows the country-wise AI studies in teacher education. It can be seen that the majority of the studies have been conducted in the USA and Turkey followed by China and Thailand.
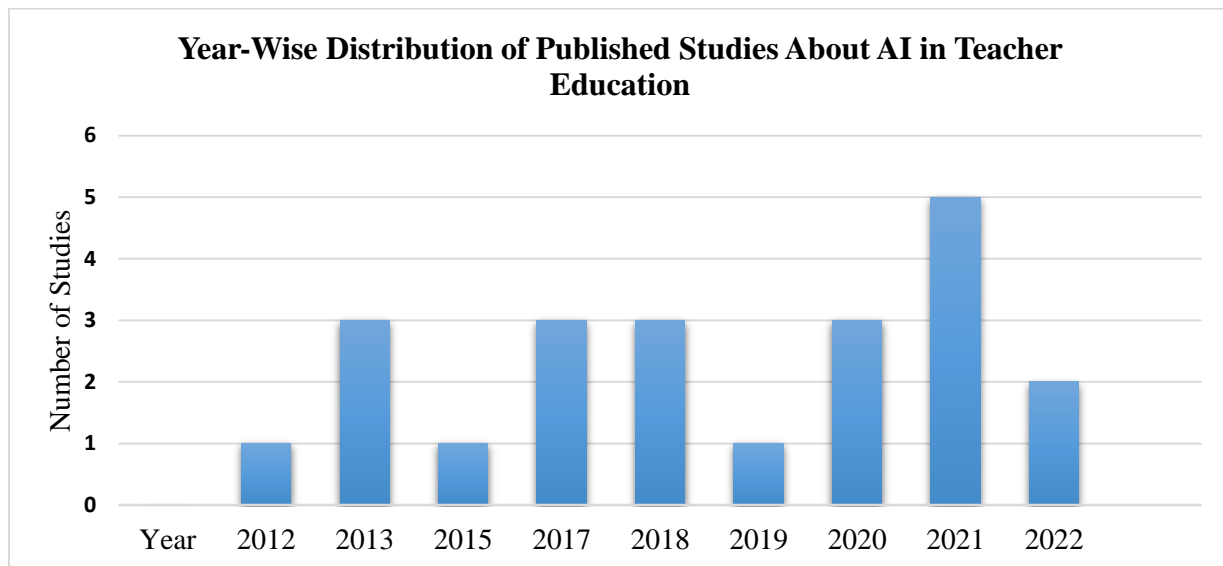

Figure 2: Year-Wise Distribution of Published Studies About AI in Teacher Education

The above figure shows the year-wise distribution of published studies about AI in teacher education. The number of publications on artificial intelligence in teacher education is maximum in 2021, with twelve publications. It can also be seen that number of publications has increased over the years which means that more attention has been given to AI in teacher education.
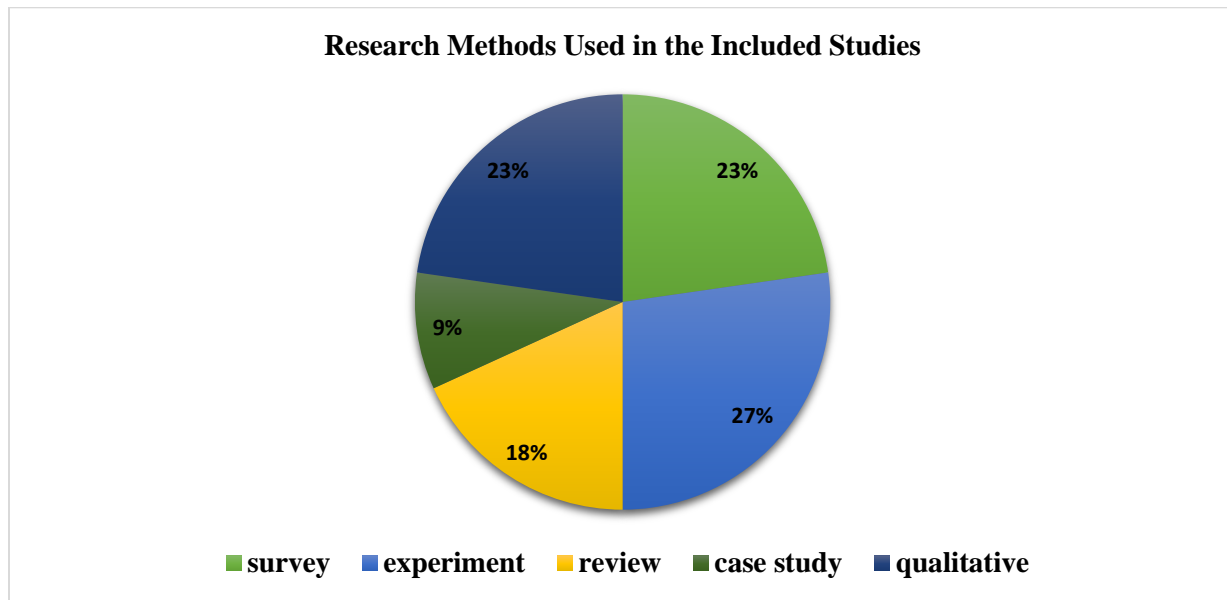

Figure 3: Research Method Used in the Included Studies

The pie chart shows the research methods used in the included studies for systematic review. Most of the studies adopted the experimental method with 27%. Furthermore, survey and qualitative research methods were used in 23% of studies each. However, 18% of included studies were based on review and 9% of studies were conducted by using a case study approach.

RQ1: What are the most common instances of Artificial Intelligence in teacher education programs?

Table 2: Applications of Artificial Intelligence in Teacher Education

Instances of AI Application in TE	Reference of Studies	No. of Studies
Virtual Reality and Simulation	(Attwood, Bruster, & Bruster, 2020; Dalinger, Thomas, Stansberry, & Xiu, 2020; Hadjerrouit, 2017; McGarr, 2021; Schussler, Frank, Lee, & Mahfouz, 2017)	5
Computerized Expert Models and Learning Packages	(Ishizuka & Pellerin, 2020; Kaufmann, 2021; Pinner, 2012; Sarac, 2013; Schugar & Schugar, 2018)	5
Machine Learning and Artificial Neural Network	(Akgün & Demir, 2018; Demir, 2015; Yahya, Osman, Taleb, & Alattab, 2013)	3
Facial Expression	(Utami, Hartanto, & Soesanti, 2019; Wetcho &	2

Recognition	Na-Songkhla, 2022)	
Flipped Learning Network and Blended Learning	(Atmacasoy & Aksu, 2018; Cao, Hao, Sabitha, & Thanjai, 2021)	2
Collaborative Concept Mapping	(Ouyang, Hu, Zhang, Guo, & Yang, 2021)	1
Video Annotation Tools	(Pérez-Torregrosa, Díaz-Martín, & Ibáñez-Cubillas, 2017)	1
Google Teachable Machine	(Vartiainen, Tedre, & Valtonen, 2020)	1
TPACK	(Srisawasdi, 2012)	1
Social Robots	(Istenic, Bratko, & Rosanda, 2021)	1

Through a systematic literature review, ten themes were found about the applications of AI in teacher education. The findings show that virtual reality and simulation computerized expert models and neural networks are mostly being used in teacher education. Virtual reality has been widely adopted in professional training of situational, adaptive, and complex skills within various occupations, yet the field of teacher education has only just started to utilize this technology in the recent decade (Huang, Richter, Kleickmann, & Richter, 2021) virtual reality improves the learners' ability to implement learning strategies, besides boosting their motivation to gain relevant knowledge and skills. As such, virtual reality is seen as a tool through which learning processes can be improved (Hussein & Nätterdal, 2015). Regarding computerized expert models and learning packages Kaufmann (2021) found that though in-service teachers had lack of knowledge about computerized expert models yet, bits of advice from expert models were appreciated and preferred by them over human advice.

The next common themes were machine learning and artificial neural networks, facial expression recognition, flipped learning networks, and blended learning. Machine learning has significant importance in education since it helps in predicting students' performance and helps teachers understand the perceptions of students (Kharb & Singh, 2021). Whereas, Artificial Neural Networks (ANN) are machine learning algorithms based on the model of a human neuron and simulate features of the human brain and its learning processes. So, they are widely used by researchers to solve different problems in optimization, classification, pattern recognition, associative memory, and control. Mining students' data optimally requires predictive data mining tools and machine learning techniques like ANN (Okewu, Adewole, Misra, Maskeliunas, & Damasevicius, 2021) machine learning and ubiquitous computing have become commonplace features of people's everyday lives, and education systems still a long way from realizing them in the classroom (Vartiainen et al., 2020). Apart from this, facial expression recognition is one of the common applications of AI in teacher education. By recognizing expressions, teachers can help students who are not able to communicate or feel hesitant to share anything with teachers. Despite being a useful technique, it is not being utilized in pre-service teacher education (Bellocchi, Ritchie, Tobin, Sandhu, & Sandhu, 2013). Likewise, flipped and blended learning models are widely used in teacher education in which physical and web-based learning are intentionally combined for a quality educational experience. One example of such an AI application is the Learning Management System (LMS). According to the latest research, flipped

and blended learning prepare teachers for the 21st century (Wulandari, 2017) while blended learning implementation can improve quality in higher education and has the potential to improve teacher education (Yi, Rhim, Lee, Narangerel, & Lee, 2017).

However, very limited research has been done on other applications of AI in teacher education as one study on each collaborative concept mapping, video annotation tools, google teachable machine, TPACK framework, and social robots were retrieved. Wang, Cheng, Chen, Mercer, and Kirschner (2017) found that collaborative concept mapping functioned more effectively in facilitating group interaction in the concept-oriented task situation than in the design-oriented task situation in several ways. Concept mapping is a valuable tool to represent knowledge about environmental education, encourage reflexive and collaborative learning, improve teaching communicative abilities, and use effectively ICT in the classroom (Pontes-Pedrajas & Varo-Martínez, 2014). Likewise, video annotation tools offer the potential to support both the reflection and analysis of one's own teaching with minimal video editing as well as the ability to associate captured video with related student and teaching evidence (Rich & Hannafin, 2009) video annotated technology-based supervision method is feasible and effective if paired with effective training and technical support (Ardley & Johnson, 2019). On the other hand, the Google teachable machine is an example of training a computer to recognize your own images, sounds, & poses and it is widely used in STEM education. The trained machine-learning models are lightweight and computationally efficient, and the applications are usable even with low-end mobile devices (Toivonen et al., 2020). Contrary to this, Technological, Pedagogical Content Knowledge (TPACK) is not a web-based thing or any other tool but, it is a framework that enables teachers to integrate ICT and is widely known in the field of teacher education. Finally, social robots are very helpful in teacher education because interaction is encouraged to improve communication skills and socialization. Acceptance of interaction between humans and robots is more complicated than human-computer interaction acceptance of social robots are radical innovation, harder for potential users to accept in human social spaces than are incremental innovations (Istenic et al., 2021) teacher education needs to follow the development of robots and prepare students and teachers in applying robotic technology in teaching.

RQ2: Which tools and techniques of Artificial Intelligence are being used in teacher preparation programs?

Table 3: Artificial Intelligence Tools/Techniques Used in Teacher Education

Tools/Techniques	Reference	No. of Studies
Web-based	(Atmacasoy & Aksu, 2018; Attwood et al., 2020; Hadjerrouit, 2017; McGarr, 2021; Ouyang et al., 2021; Vartiainen et al., 2020)	6
Computer	(Kaufmann, 2021; Pinner, 2012; Sarac, 2013; Srisawasdi, 2012)	4
Simulations and Virtual Role Play	(Dalinger et al., 2020; Schussler et al., 2017)	2
Mobile	(Ishizuka & Pellerin, 2020; Srisawasdi, 2012)	2

Artificial Neural Networks	(Akgün & Demir, 2018; Demir, 2015)	2
Facial Expression Recognizer	(Utami et al., 2019; Wetcho & Na-Songkhla, 2022)	2
Flipped Classroom	(Cao et al., 2021)	1
Videos	(Pérez-Torregrosa et al., 2017)	1
Machine Learning	(Yahya et al., 2013)	1
Robots	(Istenic et al., 2021)	1

Out of 22 studies that were included in the current study for systematic review, 6 studies used web-based tools and techniques, 4 studies used computers as tools, 2 studies each employed simulations, virtual role plays, mobile, artificial neural network, and facial expression recognizer. Besides, one study each adopted flipped classrooms, videos machine learning, and robots as tools and techniques of AI in teacher education.

For example, web-based techniques and tools were adopted for blended learning (Atmacasoy & Aksu, 2018), virtual reality and simulation classrooms (Attwood et al., 2020; McGarr, 2021), and using interactive visualization tools (Hadjerrouit, 2017). The computer was used as a tool to implement computerized expert models (Kaufmann, 2021), and for computerized assisted language learning (Pinner, 2012). Similarly, simulations and virtual role-plays were used to let pre-service teachers practice strategically (Dalinger et al., 2020) and to enhance their skills to respond to bullying (Schussler et al., 2017). Ishizuka and Pellerin (2020) used AI mobile COLT to support the reflection process in language teaching of pre-service teachers. Other examples of using Artificial Neural Network technique include its use to model pre-service teachers' course achievement (Akgün & Demir, 2018) and model educational test scores of pre-service teachers for recruitment (Demir, 2015). Additionally, the facial expression recognizing technique was used by (Utami et al., 2019) to assess the teaching skills of teachers and (Wetcho & Na-Songkhla, 2022) to study emotional regulation by teachers. Interestingly, Yahya et al. (2013) used machine learning techniques to analyze the cognitive level of questions in the classroom. In the same way, robots can also be a great support to teachers as diversity can be developed according to the needs of students and purpose (Newton & Newton, 2019). These results show that the mentioned techniques are used to get pre-service teachers to practice teaching in real situations through simulations, use computer and mobile to reinforce content-related concepts, predict and model success through artificial neural network, analyze cognitive level of questions by using an interesting AI technique and use facial expression recognition to study and support affect related notions.

RQ3: Which topics of teacher education are being focused on in artificial intelligence applications?

Table 4: Teacher Education Topics in which Artificial Intelligence is Used

TE Topics	Reference	No. of Studies
Affective Skills (Attitude, Stress Management, beliefs, motivation, socio-emotional learning, and bullying)	(Cao et al., 2021; Istenic et al., 2021; Kaufmann, 2021; Pinner, 2012; Sarac, 2013; Schussler et al., 2017; Wetcho & Na-Songkhla, 2022)	7
Teacher Preparation (Reflective Teaching, promoting participation, and knowledge building)	(Dalinger et al., 2020; Ouyang et al., 2021; Pérez-Torregrosa et al., 2017; Srisawasdi, 2012; Vartiainen et al., 2020)	5
Classroom Management	(Attwood et al., 2020; McGarr, 2021)	2
Language teaching	(Ishizuka & Pellerin, 2020; Srisawasdi, 2012)	2
Predicting Achievement	(Akgün & Demir, 2018; Demir, 2015)	2
Assessing Teaching Skills	(Utami et al., 2019)	1
Classroom Questioning	(Yahya et al., 2013)	1
Mathematics Education	(Hadjerrouit, 2017)	1
Collaboration	(Atmacasoy & Aksu, 2018)	1

From the above table, it can be seen that by using AI tools and techniques major affective-related concepts are studied including attitude, stress management, beliefs, motivation, socio-emotional learning, and coping with bullying. Within teacher preparation, AI is used to support reflective teaching, promote the participation of future teachers, and build knowledge. Followed by, AI is also used in teacher education for language teaching, predicting achievement, assessing teaching skills, analyzing the level of classroom questioning, reinforcing mathematical concepts, and facilitating collaboration and communication.

Most studies were related to affective domains this is because emotions shape objectives linked which contribute to consciousness, concentration, memory, knowledge convey, and application. Understanding how developmental processes take place over time and interact in different contexts can promote more supportive designs for learning environments. Central suggestions for educators are that this consolidated and dynamic developmental system is immaculately supported when all aspects of the educational environment support all the dimensions of children's development. This calls for a deeply integrated approach to practice that contributes to

the whole child in schools and classrooms that function consequent and consistently to build strong relationships and learning communities; support social, emotional, and cognitive development; and provide a system of support as required for healthy development, productive relationships, and pedagogical progress. In teacher education, reflection plays a vital role and the promotion of reflective teaching will require something other than an additive approach to teacher education; therefore, AI could be a great tool for that (Phillips, Saleh, & Ozogul, 2022). Similarly, Classroom management involves the practical application and integration of much of the foundational knowledge and skills that can be gained by using AI. The study of Mahon, Bryant, Brown, and Kim (2010) also found that the simulations proved to be a great tool to enhance the learning experience and classroom management of pre-service teachers and put them in situations that forced them to think on their feet. Not only this but AI has the potential to make digital language learning truly personalized to each learner. In literature, many such examples can be found which illustrate that AI helps in teacher preparation in better ways and help them meet the 21st century demands.

Overall, the current study provides an important insight into the status of research on AI in teacher education. The results can be summarized as follows: first, there are many applications of AI in teacher education for the preparation of both pre-service teachers and the professional development of in-service teachers. However, to use AI in teacher education, much resources, manpower, and change in attitude will be required as teacher education is regarded as a social science subject and AI is considered to be used by engineers and computer science-related people. Despite this, the present research has unfolded many ways in which integration of AI is possible in teacher education, as well, A few examples of that include simulations, computer expert models, artificial neural networks, facial expression recognition, blended learning, videos, and robots. However, with this an important responsibility to maintain digital integrity also comes; therefore, teacher education programs need to teach these things. After COVID-19, the need to integrate technology has significantly increased, and pre-and in-service teachers need to provide instructions on the use of technology. A similar thing is supported by Carrier and Nye (2017) who highlighted that technology empowers educators and enhances their teaching by supporting the learning experiences of students. Second, the systematic review revealed notable techniques and tools of AI that are being used in teacher education. For instance, web-based tools, virtual role plays, computers, mobile, videos, and robots are found to be useful to employ in teacher education. However, for all these to be integrated and utilized in teacher education, pre-and in-service teachers should be taught about TPACK (Srisawasdi, 2012) as without technological, pedagogical, and content knowledge, AI or any other technology incorporation will not be possible. Lastly, the final research question was about teacher education topics being studied by using AI. The review showed that affective skills, teacher preparation, classroom management, language teaching, predicting success, assessing teaching skills, classroom questioning, mathematics education and collaboration was being studied by using AI in teacher education.

This systematic review has revealed several applications, tools, techniques, and topics that are being studied in teacher education by using AI. However, the study is limited because it was done only on teacher education studies around the world, if one geographical area was chosen

then it could have given a greater understanding of the context in which AI is being implemented in teacher education. Second, the current study's focus was on AI applications, tools, techniques, and topics, in future studies the scope can be extended to other aspects. Finally, it cannot be assured that all relevant articles were included since four authors had done work and everyone saw things from their perspective and interpreted research studies accordingly; nonetheless, the study has significance as it has given an overview and present status of AI in teacher education. Keeping this study as a base, future surveys and experiments can be conducted to demonstrate and verify the results.

Conclusions, Implications, and Recommendations

The primary purpose of the current study was to systematically review the applications, tools, techniques, and topics that are being studied in teacher education by using AI. To achieve this purpose, three databases were searched i.e. Science Direct, ERIC, and EBSCO. Keywords, Teacher Education, AND Artificial Intelligence were searched in all three databases and suitable filters were applied to yield all relevant studies from 2012 to 2021. The search generated 129 studies and out of those 22 relevant studies were included for systematic review. The applications of AI in teacher education are: virtual reality and simulation, computerized expert models and learning packages, machine learning and artificial neural networks, facial expression recognition, flipped learning network and blended learning, collaborative concept mapping, video annotation tools, google teachable machine, TPACK and social robots. Tools that are being used to integrate AI in teacher education are: web-based, computer, mobile, and robots, and the techniques include, simulations, virtual role plays, artificial neural networks, facial recognition, blended classrooms, and machine learning. All these applications, tools, and techniques are being used to study affective skills, prepare teachers, manage classrooms, teach language, predict achievement, assess teaching skills, analyze cognitive levels of questions in classrooms, teach mathematics, and encourage collaboration.

The findings have several implications for policymakers, teacher education departments, curriculum developers, trainers, software developers, and teachers themselves. Policymakers need to incorporate the technology and use of IT in teacher education policies and teacher professional standards. Likewise, teacher education departments need to have a digital lab dedicated to teachers in which modern AI equipment is kept to analyze, assess, and improve the teaching skills of teachers. Not only this but teachers should be taught to use technology and incorporate AI techniques and tools to teach students. Furthermore, courses like programming, machine learning, and robotics should be included by curriculum developers in teacher training and preparation programs. Since, many web-based tools, applications, and techniques are and will be utilized by teachers; therefore, software developers need to develop user-friendly and education-related tools and techniques with the concern of teachers. Finally, teachers also need to keep their selves updated to survive and meet the needs and demands of 21st-century students.

Based on the findings discussed above, it is recommended that further empirical research should be done on the use of AI in teacher education. The world is making progress with the use of technology hence its use in teacher education should not be an exception. The concept of AI in teacher education is naïve and may not be accepted unless the attitude of people towards the

teaching profession is changed it is also considered a scientific discipline in which facials are needed to be recognized, achievement is needed to be predicted and robots are used to assist teachers and students.

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Appendix I: Databases Search Links

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https://eric.ed.gov/?q=(%22Artificial+Intelligence%22)+AND+(%22Teacher+Education%22)&ff1=dtySince_2012

https://essentials.ebsco.com/search/eds?query=AND%20%20%28%22Artificial%20Intelligence%22%29%20AllFields%20AND%20%28%22Teacher%20Education%22%29%20Title%20&group%5B0%5D%5Blookfor%5D=%20%28%22Artificial%20Intelligence%22%29&group%5B0%5D%5Btype%5D=AllFields&group%5B0%5D%5Bbool%5D=AND&group%5B1%5D%5Bbool%5D=AND&group%5B1%5D%5Blookfor%5D=%28%22Teacher%20Education%22%29&group%5B1%5D%5Btype%5D=Title&limit=25&ff%5B0%5D=Language%3Aenglish