Global Scientific Landscape of AI and Fuzzy Logic in Education: A Bibliometric and Thematic Evolution Analysis

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Abstract

This study examines 568 documents indexed in Scopus to reveal the evolution and current status of AI-enabled fuzzy logic in education. The study shows that scientific production in this field has increased significantly since 2013, with the highest productivity in 2023 and 2024. China, Greece, Turkey, India, and the USA are identified as the most active countries, with Greece standing out in terms of both productivity and citation impact. Collaborative authorship is highest, with an average of 2.88 authors per document and an international collaboration rate of 14.26%. Leading researchers such as Maria Virvou and Konstantina Chrysafiadi have been the most contributing authors in this field. Frequently used keywords (such as fuzzy logic, students, education, and AI) indicate a strong emphasis on adaptive learning, intelligent systems, and student-centered pedagogies. Despite its popularity, challenges remain regarding implementation, teacher preparation, and ethical considerations. This analysis, global trends, and key contributors will serve as a guide for future research on AI-fuzzy logic integration. Another result obtained from the research is that the most relevant source for the field is "LECTURE NOTES IN COMPUTER SCIENCE (INCLUDING SUBSERIES LECTURE NOTES IN ARTIFICIAL INTELLIGENCE AND LECTURE NOTES IN BIOINFORMATICS".

Keywords

Fuzzy Logic, Artificial Intelligence, Bibliometric Analysis

1. Introduction

Today, Artificial Intelligence (AI) has begun to be used at all levels of education from preschool to higher education and lifelong learning, and has become indispensable for individuals at all levels [1]. Technology integration in education also constantly adds AI to lifelong learning environments and emerges as an advantage [2]. The use of artificial intelligence in education is not limited to a single discipline, but also has a global impact. Along with interdisciplinary studies on AI and Fuzzy Logic in Education, early research on AI in Education has focused on technical areas, and journals such as Computers & Education have included these publications [3]. Studies on themes such as intelligent tutoring systems, adaptive learning environments, educational robotics, and AI-supported assessment are also increasing, showing that the themes have increasingly evolved from computer-aided education to personalized learning and learning analytics between 2000 and 2020 [4]. Another trend in studies is the desire to include AI in curriculum design, and many educators, such as AI literacy [4]. These developments also bring ethical concerns, such as privacy issues and access inequalities to the fore [5]. As a complementary AI method, fuzzy logic plays a unique role in addressing uncertainty in education and training. Fuzzy logic allows for the modeling of uncertain or imprecise data, which is generally more suitable for evaluating learning outcomes than binary logic [6].

1.1. Related Research

Artificial intelligence (AI) is having a significant impact on our lives, from improving education, healthcare and transportation to transforming the way we work and learn [7]. Artificial intelligence-

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focused tools such as virtual assistants and chat robots are becoming more common, used by more and more users, and their diversity is increasing day by day. Artificial intelligence also automates certain tasks in the business world and opens up new areas, offering new opportunities in fields such as data science and robotics [8]. The development of personalized and adaptive learning systems that use artificial intelligence applications and algorithms to tailor education to students' needs and abilities is an important area of change [9]. Chiu et al. [10] argue that one of the most important concerns in educational research is to harness the role that artificial intelligence can play in promoting the next generation of pedagogical methods and curricular initiatives. The importance of this area of research has also been emphasized by Ouyang et al. [11].

In the study that evaluates the opportunities and risks of artificial intelligence in higher education and examines the effects of GenAI tools (ChatGPT, Codex, etc.) on teaching, learning, and research, it is clearly stated that Artificial intelligence offers significant application potential in areas such as personalized learning, evaluation, data analytics, and academic success [12].

In the study, which examined academicians' self-efficacy, perceived benefits, difficulties encountered, usage situations, and professional development needs regarding artificial intelligence, four different faculty member profiles were identified (optimistic, critical, critical reflective, and neutral), and the lack of artificial intelligence literacy stood out as one of the biggest challenges. Increasing equality in education was seen as the most important benefit. The findings indicate that supporting services need to be developed for digital transformation [13].

Another study examining undergraduate students' tendencies to adopt artificial intelligence based on the UTAUT model aims to investigate the effects of performance expectation, social influence, and supportive conditions on attitudes and behavior [14]. Another study introduces the artificial intelligence-supported intelligent assistant framework called AIIA, developed for personalized and adaptive learning. AIIA supports interaction, access to information, and assessment processes by providing learning paths tailored to student needs [15]. At a private university in Latin America, the impact of artificial intelligence tools on learning was evaluated according to students' opinions. The research, which was analyzed in five dimensions, including ChatGPT, emphasizes that artificial intelligence positively affects the academic experience [16].

In another study advocating the use of ethical artificial intelligence in higher education, AI teachers examine the interaction between human instructors and students with Third Generation Activity Theory [17]. In the context of entrepreneurship education at the business school, it has been researched how students use and perceive artificial intelligence tools and their benefits, such as productivity and personalization. It emphasizes the importance of balanced and ethical use by revealing concerns such as academic honesty and overdependence [18].

Another study examining the adoption of artificial intelligence applications in universities in India found findings based on technology acceptance models, showing that self-efficacy, perceived usefulness, organizational support, and risk perception are important in understanding AI integration [19]. The study examining the impact of cultural values on the ethical use of artificial intelligence tools on graduate students in the USA and the UAE shows that ethical perceptions differ according to cultural clusters, emphasizing the importance of cultural sensitivity and AI integration in higher education [20]. Another study affecting information and communication technologies (ICT) in higher education is that ICT aims to increase the efficiency of communication and management processes by supporting student-centered learning. Thus, faculty members can focus more on learning design and student support [21].

By examining the perception and usage levels of university students towards productive artificial intelligence such as ChatGPT, it was found that the students had high knowledge, positive attitudes, and a strong intention to use. However, it has been revealed that they have a moderate level of concern about artificial intelligence [22]. Another study examines the challenges and benefits faculty members encounter with the integration of artificial intelligence tools in higher education. The study shows that the use of artificial intelligence contributes to the development of innovative and effective learning experiences [23].

This study was conducted to reveal the scientific production structure of AI and fuzzy logic in

education. To achieve the research purpose, the following questions were sought:

1. What is the basic information on artificial intelligence-supported fuzzy logic studies in education?
2. What is the distribution of annual scientific production in this field?
3. How has the publication output of countries changed over time?
4. Who are the most relevant authors in the field?
5. What are the most frequently used keywords in the studies?
6. What are the most relevant academic sources (journals) for this field?

2. Method

This study aims to determine the distribution of AI-supported Fuzzy Logic studies in education by year, the most productive countries and their citations in the field, the most relevant authors in the field, and the most frequently used words. The research data were obtained from the Scopus database[1] on June 17, 2025, using the keywords "AI* AND Fuzzy Logic in Education*". The search was limited to the "article title, abstract, keywords" in the search section of the Scopus database. In this context, studies that included the phrases "AI* AND Fuzzy Logic in Education" in the title, abstract, and keywords of documents published in Scopus were included in the analysis. In the analysis of the data, Bibliometrix, which is an open-source tool for scientific measurement and quantitative research in bibliometrics, including bibliometric analysis methods, was preferred. Developed by Aria and Cuccurullo [24], "Bibliometrix is a tool developed in the R language for statistical calculation and graphics according to the bibliometric workflow"[2]. In the study, the Biblioshiny web application[3], which provides a web interface for Bibliometrix and is described as a bright application, was used. Biblioshiny was preferred especially because it is easy to use and practical. In addition, bibliometrix; It was used to provide structured analysis to a large amount of information, to determine trends and researched themes over time, to identify the most productive countries, to identify the most relevant authors, to determine the distribution of studies by year, and to reveal the general picture of AI-supported Fuzzy Logic studies in education [24]. 568 documents related to AI-supported Fuzzy Logic studies in education were obtained from the Scopus database. The documents were published in a total of 390 sources. 267 of the analyzed studies were articles, 4 were books, 17 were book chapters, 220 were conference papers, 46 were conference reviews, 2 were retracted, 11 were reviews, and 1 was a short survey document. When the authors' quantitative data were examined, it was determined that a total of 1440 researchers published in this field, and 65 researchers were the authors of single-authored documents. When the collaboration between the authors was examined, it was determined that 67 documents had a single author, the number of co-authors per document was 2.88, and the international co-authorship was 14.26%. The findings show that researchers working in this field attach importance to collaborative work.

3. Findings

In this section of the study, the findings obtained from the research are included.

3.1. Basic Information on Artificial Intelligence Supported Fuzzy Logic Studies in Education

Main information about artificial intelligence-supported Fuzzy Logic studies in education in the Scopus database is given in Table 1.

[1]Scopus https://www.scopus.com/home.uri
[2]Bibliometrix https://www.bibliometrix.org/home/index.php/layout/bibliometrix
[3]Biblioshiny https://www.bibliometrix.org/home/index.php/layout/biblioshiny

Table 1
Main Information on Artificial Intelligence Supported Fuzzy Logic Studies.

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	1988:2025
Sources (Journals, Books, etc)	390
Documents	568
Annual Growth Rate %	10,25
Document Average Age	7,83
Average citations per doc	9,875
References	16543
Keywords Plus (ID)	3788
DOCUMENT CONTENTS	
Author's Keywords (DE)	1569
AUTHORS	
Authors	1440
Authors of single-authored docs	65
AUTHORS COLLABORATION	
Single-authored docs	67
Co-Authors per Doc	2,88
International co-authorships %	14,26
DOCUMENT TYPES	
Article	267
Book	4
book chapter	17
conference paper	220
conference review	46
Retracted	2
Review	11
short survey	1

As seen in Table 1, there are 568 documents in the Scopus database regarding artificial intelligence-supported Fuzzy Logic studies in education. The studies were published in a total of 390 sources.

When the authors' quantitative data were examined, it was determined that a total of 1440 researchers published in this field, and 65 researchers were authors of single-authored documents. When the collaboration between authors was examined, it was determined that 67 documents had a single author, the number of co-authors per document was 2.88, and international co-authorship was 14.26%. The findings show that researchers working in this field attach importance to collaborative studies.

3.2. Findings for Annual Scientific Production

The distribution of artificial intelligence-supported Fuzzy Logic studies in education published in the Scopus database by year is given in Figure 1.

As seen in Figure 1, studies on Fuzzy Logic supported by artificial intelligence in education started in 1988, and only one study was included in the Scopus database in this year. There were no studies published in this field in the Scopus database in 1989, 1990, and 1991. It was determined that studies on Fuzzy Logic supported by artificial intelligence in education started to be published in the Scopus database again in the 2000s, and that the studies increased quantitatively as of 2013. The most productive years were 2023 with 63 documents and 2024 with 61 documents. It is seen that 37 documents were published in the Scopus database in 2025. However, it is thought that this number will increase towards the end of the year.

The years in which artificial intelligence-supported Fuzzy Logic studies in education were published and the distribution of publications by year are detailed in Table 2.

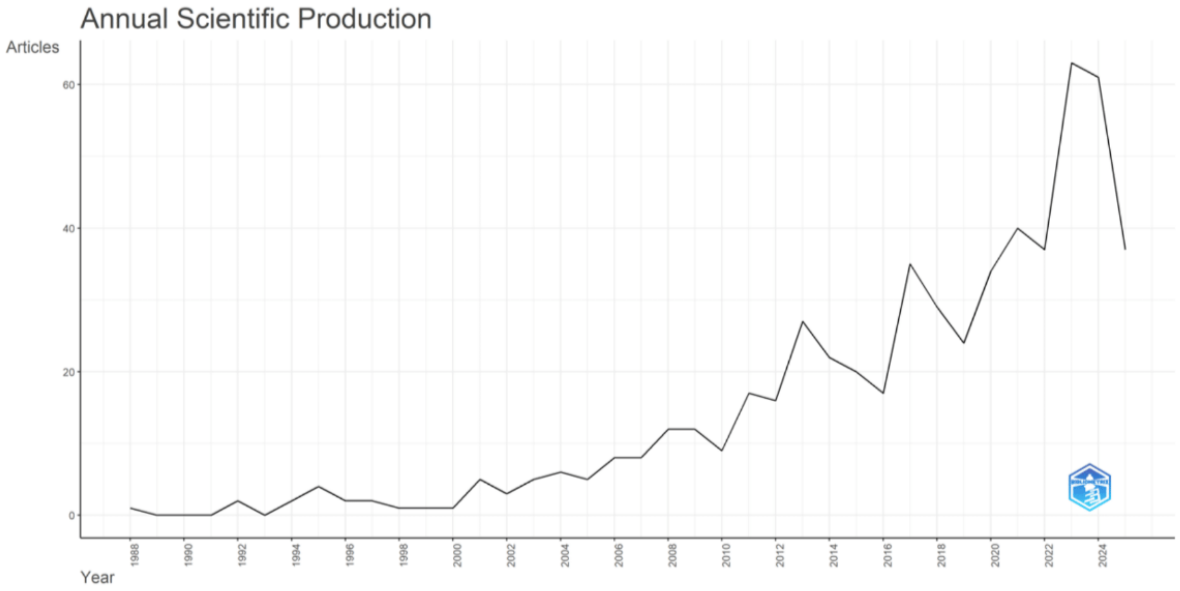

Figure 1: Annual Scientific Production

3.3. Publishing production of countries over time and their citation analysis

The findings regarding the production over time of the countries where artificial intelligence-supported Fuzzy Logic studies in education are published in the Scopus database are given in Figure 2.

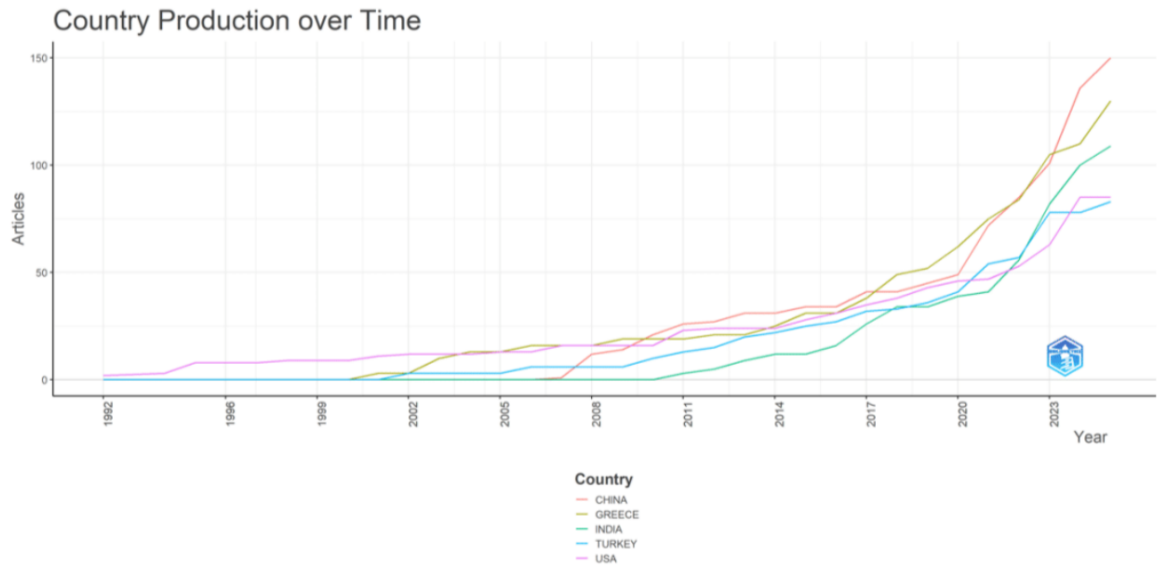

Figure 2: Country Production over Time

The 568 documents analyzed were conducted in “China”, “Greece”, “India”, “Turkey” and “USA”. It was determined that the artificial intelligence-supported Fuzzy Logic studies in education published in the Scopus database were conducted in the 5 countries shown in the graph between 1992-2023. When the production years of the countries were examined, it was determined that a limited number of studies were conducted only in the USA in the 1990s and that quantitative production in 5 countries started in the 2000s. In particular, it can be said that there was an increase in the scientific production of the countries in 2015 and after, and that the studies became more intense after 2023. The countries that received the most citations for artificial intelligence-supported Fuzzy Logic studies are given in Table 3.

Table 2
Main Information on Artificial Intelligence Supported Fuzzy Logic Studies.

Year	Articles
1988	1
1989	0
1990	0
1991	0
1992	2
1993	0
1994	2
1995	4
1996	2
1997	2
1998	1
1999	1
2000	1
2001	5
2002	3
2003	5
2004	6
2005	5
2006	8
2007	8
2008	12
2009	12
2010	9
2011	17
2012	16
2013	27
2014	22
2015	20
2016	17
2017	35
2018	29
2019	24
2020	34
2021	40
2022	37
2023	63
2024	61
2025	37

Table 3
Most Cited Countries

Country	TC	Average Article Citations
GREECE	869	36,20
CHINA	699	11,10
TURKEY	469	19,50
SPAIN	394	23,20
SINGAPORE	316	79,00

The study also aimed to determine the most productive and most cited countries in terms of AI-supported Fuzzy Logic studies in education. The findings reveal the reputation and influence of these countries in the field of AI-supported Fuzzy Logic.

3.4. Findings for Most Relevant Authors

The study also aimed to determine the top 10 researchers who are most interested in the field of artificial intelligence-supported Fuzzy Logic. The findings of the research are given in Table 4.

Table 4
Most Relevant Authors

Authors	Articles	Articles Fractionalized
VIRVOU M	13	5,42
CHRYSAFIADI K	11	5,75
TROUSSAS C	11	2,93
SGOUROPOULOU C	10	2,60
HAGRAS H	9	2,60
KROUSKA A	9	2,27
ALMOHAMMADI K	6	1,95
DIAS SB	6	1,92
PAPADIMITRIOU S	6	2,25
BARRÓN-ESTRADA ML	5	1,02

When Table 4 is examined, the first 10 most relevant researchers in the field of artificial intelligence who supported Fuzzy logic in education were determined as "VIRVOU, MARIA", who has the most studies and 13 studies published in the Scopus database. The other 2 most relevant researchers with 11 articles each are "CHRYSAFIADI, KONSTANTINA" and "TROUSSAS, CHRISTOS". Another most relevant researcher with 10 documents in the Scopus database was determined as "SGOUROPOULOU, CLEO". The other most relevant researchers in the field were determined as "HAGRAS, HANI" ($n = 9$), "KROUSKA, AKRIVI" ($n = 9$), "ALMOHAMMADI, KHALID" ($n = 6$), "DIAS, SOFIA B." ($n = 6$), "PAPADIMITRIOU, SPYROS" ($n = 6$), and "BARRÓN-ESTRADA, M.L." ($n = 5$). It is believed that the studies published by the aforementioned authors will provide basic resources and guidance to researchers who plan to conduct studies on Fuzzy Logic supported by artificial intelligence in the field of education.

3.5. Findings regarding the most frequently used words in the studies

The distribution of the most frequently used words in the 568 documents analyzed in the study is given in Table 5.

Table 5
Most Frequent Words

Words	Occurrences
fuzzy logic	348
students	120
computer circuits	115
computer aided instruction	103
learning systems	91
education	83
artificial intelligence	78
fuzzy-logic	76
education computing	74
teaching	71

As seen in Table 5, the most frequently used keywords by researchers in their studies were determined as "fuzzy logic" (Occurrences=348), "students" (Occurrences=120), "computer circuits" (Occurrences=115), "computer aided instruction" (Occurrences=103), "learning systems" (Occurrences=91), "education" (Occurrences=83), "artificial intelligence" (Occurrences=78), "fuzzy-logic" (Occurrences=76), "educa-tion computing" (Occurrences=74) and "teaching" (Occurrences=71). The findings obtained

will shed light on researchers who will conduct studies in this field, especially during the literature review process. Researchers will be able to easily access effective studies in this field by using the most frequently used keywords.

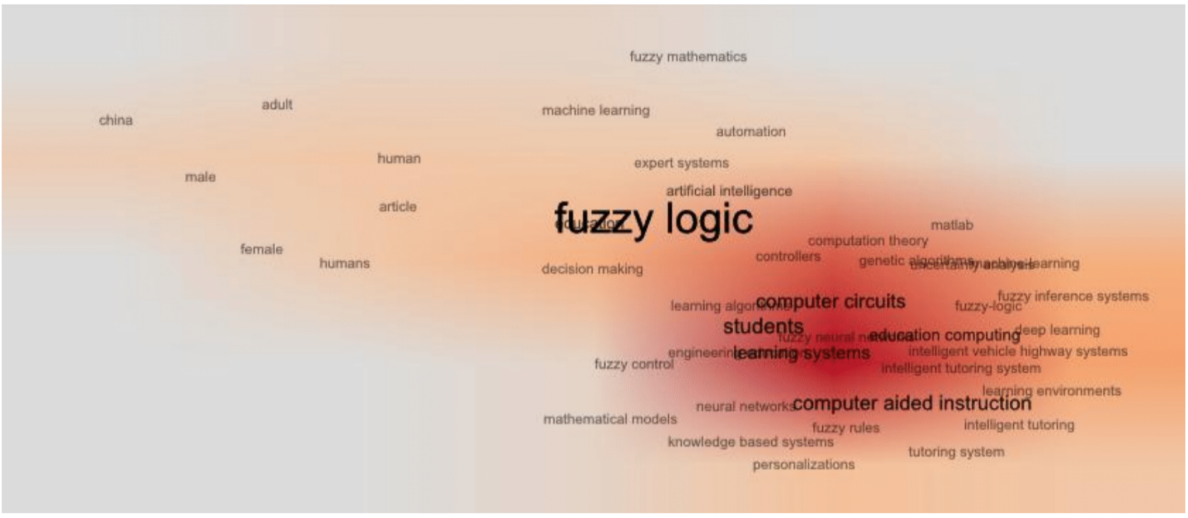

Figure 3: Chart of most frequently used words in documents

3.6. Distribution of the most relevant sources for the field

The distribution of the sources where the most published studies on artificial intelligence-supported Fuzzy Logic in education are given in Table 6.

Table 6
Most Relevant Sources

Sources	Articles
LECTURE NOTES IN COMPUTER SCIENCE (INCLUDING SUBSERIES LECTURE NOTES IN ARTIFICIAL INTELLIGENCE AND LECTURE NOTES IN BIOINFORMATICS)	23
COMMUNICATIONS IN COMPUTER AND INFORMATION SCIENCE	15
LECTURE NOTES IN NETWORKS AND SYSTEMS	12
COMPUTER APPLICATIONS IN ENGINEERING EDUCATION	10
ADVANCES IN INTELLIGENT SYSTEMS AND COMPUTING	9
IEEE INTERNATIONAL CONFERENCE ON FUZZY SYSTEMS	8
JOURNAL OF INTELLIGENT AND FUZZY SYSTEMS	7
CEUR WORKSHOP PROCEEDINGS	6
PLOS ONE	6

As seen in Table 6, the source with the most publications in this field was determined as “LECTURE NOTES IN COMPUTER SCIENCE (INCLUDING SUBSERIES LECTURE NOTES IN ARTIFICIAL INTELLIGENCE AND LECTURE NOTES IN BIOINFORMATICS)” with 23 articles. The other source with the most publications was “COMMUNICATIONS IN COMPUTER AND INFORMATION SCIENCE” ($n = 15$), and the other sources were as follows, respectively; “LECTURE NOTES IN NETWORKS AND SYSTEMS” ($n = 12$), “COMPUTER APPLICATIONS IN ENGINEERING EDUCATION” ($n = 10$), “ADVANCES IN INTELLIGENT SYSTEMS AND COMPUTING” ($n = 9$), “EXPERT SYSTEMS WITH APPLICATIONS” ($n = 8$), “IEEE INTERNATIONAL CONFERENCE ON FUZZY SYSTEMS” ($n = 8$), “JOURNAL OF INTELLIGENT AND FUZZY SYSTEMS” ($n = 7$), “CEUR WORKSHOP PROCEEDINGS” and “PLOS ONE” ($n = 6$).

4. Discussions and conclusions

The study examines 568 documents indexed in Scopus to reveal the evolution and current status of AI-supported fuzzy logic in education. The study shows that the studies has increased significantly since 2013, with the highest productivity in 2023 and 2024. China, Greece, Turkey, India, and the USA are the most active countries, with Greece standing out in terms of both productivity and citation impact. Collaborative authorship is the highest, with an average of 2.88 authors per document and an international collaboration rate of 14.26%. Leading researchers such as Maria Virvou and Konstantina Chrysafiadi have been the authors who contributed the most to this field. The most used keywords (such as fuzzy logic, students, education, and AI) indicate the need to focus on adaptive learning, intelligent systems, and student-centered pedagogies. Chrysafiadi and Virvou [25] stated that fuzzy logic integration in learning environments increases student satisfaction. Despite these developments, as stated in the studies of [26, 27], it has not been actively used due to ethical concerns such as system complexity, teacher preparation, data privacy, and algorithmic bias. The distribution in the study shows us that studies on AI and Fuzzy logic in particular need to be increased. It is recommended that research in future studies focus not only on citations but also on pedagogical integration, accessibility, and integration of smart technologies.

Declaration on Generative AI

The authors have not employed any Generative AI tools.

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