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Artificial Intelligence Applications in K-12 Education: A Systematic Literature Review

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ABSTRACT Education is a vital part of the development of society and it is changing over time in terms of methods, content, concepts, and models. Recently, it has been increasingly prevalent to benefit from the potentialities of Artificial Intelligence (AI) in addressing educational issues. In this research, the current state of the art of the integration of AI in K-12 education was provided. Specifically, different parts of education in which AI was employed along with the related AI categories were discussed according to different K-12 grades and courses. Additionally, technologies and environments that contributed to employing AI in education were discussed. To this end, a systematic literature review was conducted on articles and conference papers published between 2011 and 2021 in the Web of Science and Scopus databases. As the result of the initial search, 2075 documents were extracted and based on inclusive criteria and 210 documents were identified for further investigation. AI applications were categorized into Student performance, Teaching, Selection, and Behavior tasks, and Other. Machine Learning (ML) and Intelligent Tutoring System (ITS) were the most common approaches among AI categories. Furthermore, high school-related applications were more frequent and STEM courses were substantially targeted by AI. In conclusion, the remarkable impact of AI on education was concluded. The current study reveals information about the potentialities offered by AI in K-12 education which aids researchers in implementing AI-based education systems. As for future works, other databases such as ACM library and Google Scholar can be investigated as well. Furthermore, exploring the 95 papers that were excluded due to inaccessibility to their full texts can be taken into account. Finally, the papers can be also investigated in terms of pedagogical approaches or development tools.

INDEX TERMS Artificial intelligence, machine learning, education, educational technology, review.

I. INTRODUCTION

Artificial Intelligence (AI) has had a noticeable impact on different industries among them education. This branch of science, studying the development of machines that can simulate the thinking process of humans, has changed the interaction between elements of education namely learner, instructor, and institution. Bringing AI in current systems can simply enhance human works in terms of time efficiency, energy efficiency, ease of access, and other positive effects. On the other hand, education is considered a crucial part of humans' lives and their resolution which involves seeking a better future [1]. This is not just about learning. Education improves decision-making skills, problem-solving, and critical thinking [2]; this highlights the considerable importance of education. Besides, the ultimate goal of all educational institutions would be to improve the students' performance and to enhance the quality of education [3], [4]. However, teaching methods are usually traditional and theory-based. This often causes people who are accustomed to learning through experience to fail to learn [5], [6]. The growing demand in education and the introduction of certain national policies have introduced a new and thriving research field that integrates AI and education, resulting in an expansion of

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existing literature on Educational Artificial Intelligence [7]. Therefore, the integration of AI and education is considered an active topic among researchers. The prediction by Market Research Engine which illustrates that the involvement of AI in the education market will reach $5.80 billion by 2025, can be a testimony to the considerable influence of AI on education. The great potential of AI makes it a wonderful tool to be used in education systems in order to enhance the functionalities of such systems. The resulted system is called Artificial Intelligence education system (AIEd).

By scrutinizing the studies on the integration of AI and education, the current state-of-the-art of this matter can be seen from two aspects, namely benefits for students and benefits for instructors or institutions. As for some forms of enhancements made by AI, task automation and personalized learning can be named. AI will most likely be used in the classroom of the future to personalize learning for each individual student. Students can receive insightful feedback and supplementary support from AI coaches [8]. They can feel comfortable in doing mistakes to learn and receive immediate feedback to progress individually [9]. Currently, there are many Intelligent Tutoring Systems (ITS) powered by AI that have been provided for students. Also, these systems adjust the educational content with the ability of the student [10], so, the learning experience becomes more enjoyable for them [11]. Students may also benefit from the use of AI to do certain learning activities simpler. Additionally, it is believed that the students of today will work in the future where AI is integrated into different parts of their everyday life, and it is of paramount importance that educational institutions start to add AI into their courses. Moreover, one of the most beneficial uses of AI for institutions and instructors is that it performs the evaluation tasks accurately and rapidly. This evaluation involves assessing the work of students [12], evaluating teachers and student performance [9]. This helps improve teachers' efficiency and changes the role of teachers in education [13]. AI software that understands and adapts to each student's unique needs, on the other hand, allows teachers to assist students precisely when they are required, and it tailors the learning environment so that no student falls behind. Automation works on making routine assignments easier for both students and teachers.

Many studies have been done on the integration of AI and education from different aspects. They were either general or focused on specific areas. Ref [14] explored the adoption of AI in education in terms of challenges, opportunities, and benefits from 2010 to 2019. That said, no criteria regarding the education sector were considered in their work. Therefore, no in-depth investigation on the involvement of AI in different education sectors was provided. On the other hand, although Refs such as [15] provided a research overview on AI applications in education, they focused on higher education rather than the K-12. On a final note, there were also other systematic reviews only focusing on specific learning areas such as mathematics [16] and health [17]. In a like manner, some studies limited their research field by focusing on one education topic such as student assessment [18]. After all, no similar studies targeting AI adoption in K-12 education in terms of investigating the applications and providing classification for different ways of employing AI in this education sector were found.

The present systematic research is performed with the aim of investigating the role and the impact of AI on K-12 education. In the first step, studies discussing AI in k-12 education are extracted. The results of this investigation will be analyzed to find any relation between the way AI is being used in education. In particular, the educational tasks that are done by AI and the type of this AI will be analyzed. Also, the focus of this integration on which topics and educational levels, as well as the modern technologies, will be examined. Based on previous studies, it is considered that the potential of AI can be beneficial in addressing different issues available in education systems. The main novelty of this paper is to investigate the adoption of AI for education purposes in terms of 1) Applications, 2) AI Categories, 3) Level (education sector), 4) Lecture (the target course), and 5) assistive technologies.

The following questions were considered for this paper:

1- What are the applications AIEd in education and which type of AI has had a lot of benefits for education?
2- How is the distribution of AI applications at different levels and in which courses, AI has been frequently involved?
3- Which technologies and devices are employed to implement AI in education?

The rest of the paper is as follows. The background information is provided in part A of the Introduction Section. The methodology of the research is discussed in section 2. Section 3 gives information about the results of the study. In section 4, the discussion is provided and finally, the conclusion is illustrated in section 5.

A. ARTIFICIAL INTELLIGENCE

Alan Turing's simple question, 'Can a machine think?' paved the way to establish the fundamentals of Artificial Intelligence (AI) [19], [20]. The term Artificial refers to computational devices on which some techniques are performed [21]. In addition, the term Intelligence relates to the computational part of the ability to satisfy the aims [22], [23]. Specifically, intelligence in AI denotes the way an entity deals with different types of input in order to present a suitable outcome [24]. Therefore, AI can be defined as developing human-like intelligence in machines [25]. In other words, AI is a branch of science, trying to simulate human intelligence and mimic their actions on computational devices [21]. Performing intelligent tasks contains intellectual processes such as reasoning, discovering meaning, or learning from past experiences. Hence, learning, reasoning, and perception can be considered as the main goals of AI.

With the developments of technologies associated with computing and robots, a tendency toward embodied intelligence products and services has been noticed [26]. AI covers a wide range of applications in domains such as

agriculture [27], healthcare [28], and business [29]. In addition to the mentioned domains, Ref [30] highlights two branches of AI in medicine namely virtual and physical medicine. The former explores methods of deep learning in order to be used in controlling health management systems. The latter, that is physical medicine, discusses mainly the involvement of robots to assist patient or surgeons. The functionalities offered by AI has encouraged researchers and practitioners to explore solutions for building a safe, reliable and efficient transportation system [31]. For instance, AI can be beneficial in planning transportation services which identifies the demands related to transportation along with considering economic, environmental factors. For computer games, AI is involved as a subsystem in the development process which is dependent on concrete details of the game environment [32]. The engagement of AI in Games can enhance the gamers' experience by facing them with more clever characters in the game [33].

A significant amount of research has been done on AI for the past few decades [34], [35]. Besides, with the advancement in technologies involved in AI, it is difficult to classify this field based on time or subject [26]. Brief descriptions of different AI and AI-Educational terms are provided in the following.

1) MACHINE LEARNING

The development of new learning algorithms along with accessibility to a large amount of online data resulted in major advancements in Machine Learning (ML) [36]. The ultimate goal of ML is to learn from data and teach machines how to deal with the data effectively [37]. ML discusses approaches to train mathematical models with context-related data in order to be used in machines that suffer a lack of information about all components of the problem [38]. The available techniques and approaches in ML are discussed a lot and categorized differently [37]–[39].

2) DEEP LEARNING

Deep Learning (DL) is obtained by adding more complexity or depth into ML models [40]. The different types of functions exploited in DL enable data representations in a hierarchal way [41]. In DL, due to the existence of several levels of abstraction, the input data of each level is converted into a more abstract one as an input for the next level [42]. Therefore, the benefit of feature extraction is obtained in DL.

3) INTELLIGENT TUTORING SYSTEM/EXPERT SYSTEM

Most Intelligent Tutoring Systems (ITS) are implemented with expert system technology and corresponding computer models. ITS was introduced in the 1970s. It includes subcategories of educational technology that integrate object-oriented systems, databases, communications, and AI techniques. These systems can teach students without human intervention [43].

4) DATA MINING

Data mining is the process of converting raw data into helpful information. In educational applications, it is called educational data mining (EDM). Using ML algorithms in data mining, it is possible to discover patterns and information automatically in the dataset. A major contribution of such algorithms is that human intervention is not required any longer [44], [45].

5) NLP

Natural language processing (NLP) enables humans to interact and talk to machines. In a like manner, it is an AI branch that provides computers with capabilities to read, decipher, understand and manipulate human language [46].

6) ROBOT

Robotics involves the design, construction, and use of machines to perform tasks that were done traditionally by human beings. Robotics can play several roles in education by varying levels of involvement in teaching/learning tasks. For instance, robots can support learning processes and be considered as ''CO-Learner''[47].

7) RECOMMENDATION SYSTEM

AI-based Recommendation systems (RS) provide quick recommendations tailored to the needs and preferences of the user. For education-related purposes, RS plays the role of supporting teaching and learning activities through enhanced information retrieval [48].

II. MATERIALS AND METHODS

In this systematic review, the integration of AI and k-12 education is being investigated in terms of the application of the proposed systems, the role and type of AI, and targeted course and level. According to the questions of this study, the inclusion criteria were obtained to define which studies should be included in the review.

A. SEARCH STRATEGY

The workflow of the study was based on PRISMA 4-phase diagram and is indicated in Fig1. The four stages of the study were identification, screening, eligibility, and included. In the identification stage, the Scopus and Web of Science databases were chosen in order to perform the search because they both cover a considerable number of related topics. The authors accessed these databases through institutional access. Additionally, other databases are somehow considered inappropriate or time-consuming for systematic reviews. For instance, some may only cover specific fields or some may lack offering search operations such as Boolean ones [49]. The reason why these databases were selected is that a combination of their results provides high coverage of related articles to the topic of this research, and by considering both, the chance of missing any relevant paper can be reduced [50]. The search was conducted using Boolean operators AND/OR

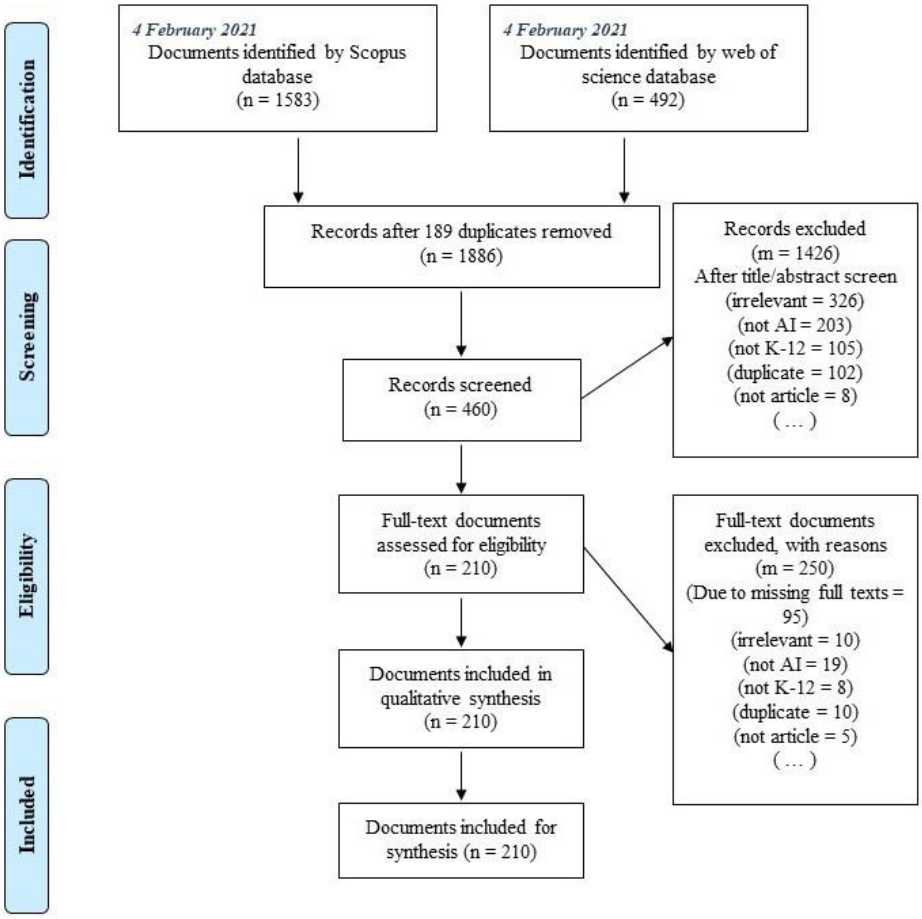

FIGURE 1. PRISMA flow diagram of the study [51].

along with the keywords indicated in Table1. The documents included in this paper are English articles or conference papers that were published from 2011 to February 2021. The reason behind choosing 2011 was the fact that noticeable headways had been made into educational purposes by AI near this year [52], [53]. At first, by employing mentioned keywords, 2967 studies were selected according to their titles, abstracts, and keywords. The results declined to 2075 after considering the criteria and the records of each study such as Title, Author(s), Abstract, Keyword, Publisher, Publish Year, Affiliations were extracted. Results of the Scopus and Web of Science database consisted of 1089 articles and 987 conference papers. In order to omit the duplicate papers in the screening phase, the extracted data was imported in Endnote which resulted in 1886 studies after deleting duplicates.

B. SCREENING STUDIES

The aim of this section is to identify relationships, inconsistencies, and the current subtopics in the selected literature and map them to provide a conceptual synthesis for future studies. In this regard, Rayyan - www.rayyan.ai -, a website providing a powerful collaboration research tool to perform systematic research, was chosen for further investigation of the data. This website enables the researchers to label studies and categorize them into three different groups namely, Included, Excluded, and Maybe. As shown in Fig1, the keywords used to filter the studies were ''irrelevant'', ''not AI'', ''duplicate'', and ''not article''. With the help of Rayyan, the screening process was done manually by the authors. During the examination, the authors came up with mentioned keywords to label the paper so that the reasons for exclusion can be discussed. The labeling was done by reading the abstract of papers. That is to say, if the abstract of a paper provided enough information, the paper was assigned to either Included or Excluded groups. On the other hand, if a decision cannot be reached, the paper was assigned to Maybe group in order to be investigated by examining the full text. Finally, a total of 1426 studies were excluded due to the following reasons. Firstly, 326 studies that had not covered any relevant topics in AI and education were labeled as ''irrelevant''. The label ''Not AI'' was assigned to 203 papers not benefiting from AI in their studies. The third most frequent reason was not focusing on K-12

TABLE 1. Search string and document results.

	Topic	Code	doc results
Scopus	AI	TITLE-ABS-KEY (“artificial intelligence" OR " machine learning" OR " deep learning" OR " neural networks" OR " Educational artificial intelligence" OR " Assessment Intelligent tutor system" OR " Intelligent tutoring systems" OR " machine intelligence" OR " intelligent support" OR " intelligent virtual reality" OR " chat bot" OR " automated tutor" OR " personal tutor*" OR " intelligent agent*" OR" expert system" OR " natural language processing")	1177804
	K-12	TITLE-ABS-KEY (“K-12" OR " kindergarten*" OR " primary school*" OR " middle school*" OR " high school*" OR " elementary school*" OR " pre-school" OR " primary education" OR " secondary school" OR " secondary education" OR " pre-primary" OR " elementary education" OR " K-12 education")	309871
	AI + K-12	#AI AND #K-12	2285
	AI + K-12 + Refine	#AI AND #K-12 AND (LIMIT-TO (LANGUAGE, “English")) AND (LIMIT-TO (DOCTYPE, "cp") OR LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (PUBYEAR, 2021) OR . . . OR LIMIT-TO (PUBYEAR, 2011))	1583
WoS	AI	TITLE-ABS-KEY ("artificial intelligence" OR "machine learning" OR " deep learning" OR " neural networks" OR " Educational artificial intelligence" OR " Assessment Intelligent tutor system" OR " Intelligent tutoring systems" OR " machine intelligence" OR " intelligent support" OR " intelligent virtual reality" OR " chat bot" OR " automated tutor" OR " personal tutor*" OR " intelligent agent*" OR " expert system" OR " natural language processing")	368644
	K-12	TITLE-ABS-KEY ("K-12" OR " kindergarten*" OR " primary school*" OR " middle school*" OR " high school*" OR " elementary school*" OR " pre-school" OR " primary education" OR " secondary school" OR " secondary education" OR " pre-primary" OR " elementary education" OR " K-12 education")	202784
	AI + K-12	#AI AND #K-12	682
	AI + K-12 + Refine	#AI AND #K-12 Refined by: LANGUAGES: (ENGLISH) AND DOCUMENT TYPES: (ARTICLE) AND PUBLICATION YEARS: (2021 OR 2013 OR 2020 OR 2012 OR 2019 OR 2011 OR 2018 OR 2017 OR 2016 OR 2015 OR 2014)	492

issues which resulted in 105 studies labeled as ‘‘Not K-12’’. After that, 8 articles were attributed as ‘‘Not Article’’ because of not being a journal or conference paper. The matching-finder software was not able to recognize 102 duplicates simply because some of the studies contained more or fewer punctuation marks compared to their original ones. Finally, a total of 460 studies discussing the integration of AI and K-12 education were selected to investigate for further analysis. In the following stage, the full text of each paper was explored so as to extract information.

C. CODING, DATA EXTRACTION, AND ANALYSIS STUDIES

In order to extract information, the 460 included studies were exported from Rayyan. To do so, each study was scrutinized in terms of 26 questions. These questions were designed to include not only the research questions, but also further possible information. The list of the main questions is as follows:

1. The number of students who took part in each study,
2. The technologies or devices employed by researchers along with AI,
3. About which grade the research was conducted,
4. Which course is being investigated,
5. The domain in which AI is used to face problems,
6. What type of AI is used in the experiment?
7. If ML or DL is employed in the study,
   a. What algorithm did the author(s) use?
   b. The accuracy?
   c. The amount of data?
   d. Input features?
   e. Validation Techniques
8. What was the learning environment?

Other questions were excluded due to the fact that the studies did not provide clear answers for them. Those questions targeted topics such as pedagogical strategies and building tools. During the process of examining the full texts of papers, some were excluded according to Fig1 with the labels mentioned earlier. Also, the full texts of the 95 of the studies were not available to the public, therefore they were excluded as well. As the final result of this stage, 210 studies were selected after their full texts were investigated. The results consisted of 85 and 125 journal and conference papers respectively. Because of a wide variety of applications and the use of AI, as expected, answers to some of the questions were not presented in all studies. Therefore, those studies were not considered for further investigations. The gathered information was stored in Microsoft Excel and each column (i.e., The extracted feature) was examined by itself and also along with other columns in order to recognize any patterns connecting the information.

III. RESULTS

A. ARTICLE PER YEAR

Fig2 Compares all identified studies along with the 210 included studies in terms of the publishing year. The line graph, the lower section of Fig1, indicates all papers ($n = 1886$) in each year studying the integration of AI and K-12, whereas the bar chart reveals information about the articles after being filtered. As illustrated in Fig2, the identified articles cover a good sample of articles published each year, compared to the total number of publications shown in the bar graph in Fig2. This would result in a more reliable conclusion due to the fact that the included studies are properly spread during the 10-year-period between 2011 and 2021. Fig2 highlights a general rise in the number of papers between

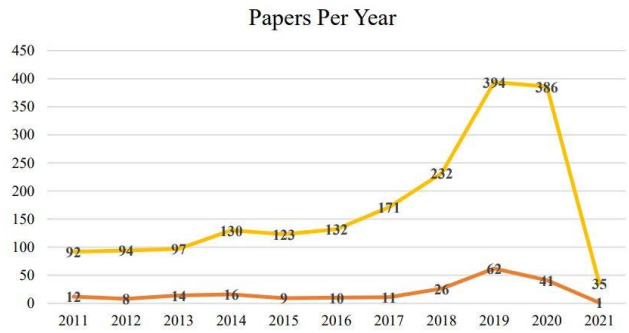

FIGURE 2. The gold line graph shows the total number of articles (n = 1886) published per year and the orange line indicates the number of included articles (n = 210) published per year.

TABLE 2. Journals with the highest number of publications among the included articles (n = 85).

Journal title	N
Computers and Education	7
IEEE Access	4
Education and Information Technologies	4
Journal of Science Education and Technology	3
International Journal of Artificial Intelligence in Education	3
Sustainability (Switzerland)	2
IEEE Transactions on Learning Technologies	2
Interactive Learning Environments	2
Other	58

2011 and 2017. This is in accordance with Ref [54] asserted about the steady pace of AI-Education research. Moreover, there has been a noticeable increase in 2018, and the total number of papers almost doubled. This, in turn, makes it a good opportunity to investigate papers published after 2017. On a final note, a slight fall has been indicated in 2020 probably due to the previous rise which made exploring this field with enough novelty a bit tough.

B. AUTHORS

No exclusion criteria were considered for filtering journals in order to examine the reflection of AI in different areas of education. The number of identified studies in each journal is indicated in Table2. The journal with the most share of articles, Computers, and Education, mainly discussed periodicals focus on AI-based education systems like ITSs along with the integration of computer-based technologies such as Augmented Reality (AR) and Virtual Reality (VR). IEEE Access and Education and Information Technologies covered macro concerns and major projects in specific educational applications. Also, they examined various challenges in terms of student, instructor, and institution-based. The total figure of the first three journals (n = 15) is considered low compared to the total number of papers (n = 85), and the reason behind it is the one-time presence of a wide range of journals that are categorized into Other.

The variety of journals can be considered a positive point because journals normally have different aim and scopes; therefore, different ideas and implementations are being taken into account for performing these studies which can result in more comprehensive results.

C. AI APPLICATION IN EDUCATION

The integration of AI and education covers a wide range of applications such as dropout prediction, assessing essays, aiding teachers in classrooms. A thorough analysis revealed that the purposes of the papers in this study can be categorized into five groups namely: Student Performance, Teaching, Behavior, Selection, and Other. Simply put, this categorization was obtained by scrutinizing the papers for their ultimate goal. After the goals were gathered, the authors categorized them into the mentioned groups. Each group consists of some sub-application which is shown in Table3.

The $*$ in Table3 indicates the fact that although the mentioned sub-categories exist, a clear boundary in related studies has not been expressed; therefore, the number of studies in these groups is not computed. As illustrated in Table3, researchers have explored different areas in order to tackle the challenges in education by means of AI. The first category mainly covers the issues in teaching such as methods to improve it [55]–[57], training teachers [58], providing personalized teaching systems for students [59]–[61]. Ref [62] tried to improve the teaching methods for supporting the dyslexic students' music learning process. By using AI, they designed software to help students avoid making the same errors by monitoring their actions. Ref [63] studied the application of ML agents in students' learning in an online game environment. This study tried to help students with learning a subject by teaching that specific topic by themselves. Ref [58] proposed a DL-based solution combined with the help of NLP to train primary school teachers. Ref [59] stated a shift from traditional predefined steps for educating students to adaptive learning systems. In this paper, an emotion-based learning system to suggest learning material was designed considering the emotional and psychological characteristics of students. The student performance section is concerned with evaluating the performance of students in various areas such as Dropout Prediction [64], [65], Grading [66], [67], Reading Abilities [68], [69], and Engagement [70], [71] according to different criteria. Ref [72] studied the risk of dropping a course out by examining the scores of each student. In fact, this study used the information of 9th grade in order to predict the dropout of high school students by ML. Ref [66] proposed a writing test scoring system that automatically grades and gives feedback to students' tests. The system took English sentences as inputs and processed them using NLP to detect errors. Ref [70] studied the tracking of students' eyes to realize mind wandering in a biology class. This is to find about the shift of students' minds to unrelated topics. Therefore, this study can be attributed as engagement that involves the evaluation of a student's engagement in a class. The applications related to choosing an appropriate major [23], [73]

TABLE 3. The AI application categorization along with the frequency of articles in each category.

Main Category	Sub-category	N	Main Category	Sub-category	N
Teaching - 86	Teaching-aid	15	Selection - 11	Major	4
	Teaching Quality	5			
	Pedagogical Agents	*		University	*
	Training of Teachers	*			
	Personalized Teaching	4		Career	4
	Improving Teaching	11			
Student Performance - 86	Dropout Prediction	12	Behaviour - 16	Recognition	*
	Assessment	2			
	Cognitive Diagnosis	2		Mode Choice	*
	Achievements	3			
	Grading	11		Dyslexia Detection	*
	Reading Ability	5			
	Creativity	2		Sentiment Analysis	*
	Engagement	4			
	Feedback	2		Characteristics	2
	Argumentation	*			
Others - 11					

or university [74] for students are involved in the selection category. Ref [23] studied the prediction of directing students toward subjects like science, business studies, and humanities by using ML and data mining algorithms. Besides, there were papers predicting future careers for students based on their performance [75], [76]. The studies in the Behavior section investigated the issues related to a student's behavior and characteristics. Ref [77] compared the logistic regression and multi perceptron neural networks in the mode choice behavior of high school students. Finally, the last section, Others, covers some less-frequent issues such as optimizing the route for school buses [78].

D. AI CATEGORIES

As mentioned earlier, one aspect of the study is to investigate the role of AI in education. Therefore, a classification of the types of the AI being used in studies is provided to study how different types of AI influenced the education systems. Various papers have been categorizing AI algorithms in general. The majority of them consider DL a sub-branch of ML, or as ML/DL is used in NLP, some of them consider a relation between ML/DL and NLP as well. Having said that, as this study aimed to provide in-depth analysis, the authors decided to separate these types of AI and provide further investigation on each category individually. Furthermore, the frequency of these AI types in the investigated papers was another reason behind presenting such classification. Fig3 highlights the number and combination of different categories. The overlay parts of Fig3 indicate the joint employment of categories. A general perspective from Fig3 reveals that ML has been dominating and involved in all other categories except the

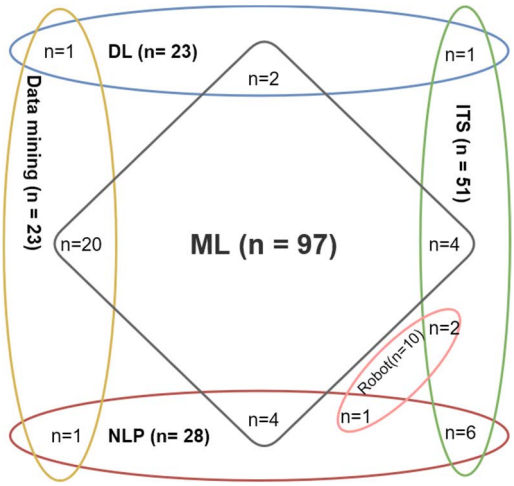

FIGURE 3. Relations between different types of AI in education.

Robot category. Moreover, the columns of Table4 indicate the eight categories of AI-Education which were employed in the identified results.

As an overall overview, it is stated in Table4 that ML took the lead while RS was employed the least in papers. Another general perspective reveals that student performance and teaching were more targeted compared to other applications. That is to say, ML, Data Mining, and DL were mostly used in the student performance category. Moreover, the teaching category were mostly explored with the help of ITS, ML, and NLP.

As indicated in Table4, ITS was normally used for teaching purposes. Besides, it was also beneficial in applications like behavior or student performance. For instance,

TABLE 4. The number of each AI category being used in different AIEd applications.

	ML	DL	ITS	Data Mining	ANN	NLP	Robot	RS
Student Performance	51	10	6	13	4	9	0	2
Teaching	26	9	34	4	1	16	9	2
Behavior	9	1	6	1	0	2	1	0
Selection	6	2	4	4	0	0	0	0
Other	5	1	1	1	1	1	0	0
Sum	97	23	51	23	6	28	10	4

Refs [79]–[81] assessed cognitive diagnosis which is classified in behavior and in student performance. Some studies also used ITS for tasks other than teaching such as Grading [66], Engagement [70], and feedback [82]. One of the major challenges in teaching is how to take appropriate learning approaches for students with different characteristics. The diversity in characteristics and behavior leads to having different learning paces in students which some might find a topic boring while others may have difficulties in learning the same topic. The capabilities of AI make it suitable to address this issue by personalizing learning systems. That is, to adjust the education system so that students with different needs can benefit from that system. In other words, a personalized educating system would consider the learning pace, level of knowledge, and other parameters in order to offer a suitable education system for students [83]. Moving forward with further detailed analysis, ITS in teaching purposes explored the possibilities to improve the learning process in 7 studies which five of them were targeting mathematics problems.

Ref [84] proposed an interactive learning environment so as to improve problem-solving skills. Refs [56], [62], [85] tried to promote the efficiency of such systems. Six studies in ITS were considered for teaching-aid purposes that facilitated the teaching process for instructors. In the investigated documents, ITS was widely used in Mathematics (n = 23, 49%) – indicated in Table6 –, by 19 studies in high schools, and 14 in primary schools.

With the rapid spread of datasets containing different features, ML has been widely used in order to recognize different patterns among data. ML algorithms can be beneficial while choosing an appropriate major or university for students based on their interests and performance. Besides, it can help teachers with evaluating the quality of knowledge acquisition by students. Therefore, teachers would enhance their teaching methods so that it would be much easier for students to acquire knowledge.

According to Table4, ML and DL algorithms were mostly used to study student performance applications each being employed in 51 and 10 respectively. Issues such as dropout prediction (n = 14), grading (n = 12), and reading quality assessment (n = 4) were addressed with the help of ML or DL. A total of 26 studies employed ML algorithms in the teaching category, whereas only 9 studies used DL. Among these studies, 12 of them were analyzing techniques in order to improve teaching, and 16 of the papers were benefiting AI to act as an aid to teachers and teaching methods. Besides, just 4 articles studied the quality of teaching using these algorithms. Furthermore, there have been 8 papers lying in the selection category, mainly discussing career (n = 4) purposes and college and university majors (n = 3). As a final note indicated in Table4, the behavior category contained 10 studies employing ML and DL working on related topics. In a like manner, a total of 10 papers employed the other six categories in the behavior category.

For further investigation in the ML category, the name, number and average accuracy of ML algorithms used in the documents are shown in Table5 in terms of the four main applications discussed above.

Table5 illustrates information about ML algorithms that have been used frequently in our dataset. The ''non'' values in the Table state that a specific algorithm was used only once in the application shown on the same row but no information on the accuracy was provided in the papers. The most popular algorithm used in AIEd were RF, SVM, and DT and these algorithms generally provided high accuracy comparing the other algorithms in Table 5. For tasks that were categorized in student performance class, SVM and RF provided the highest average accuracy. It is also worth to highlight that all of the considered algorithms were employed in this category. For teaching and behavior categories, ANN resulted in the highest average accuracy compared to other algorithms in the dataset. That said, in these two categories, SVM and LR had the lowest average accuracy respectively. On a final note, RF and SVM resulted in the highest and lowest accuracy for selection category. Other algorithms were used for different tasks, such as XGBoost algorithm which was used for Dropout [86] and Grading [87], [88]. Moreover, Decision Tree [89], Support Vector Machine [68], and linear regression [90] were used for Reading ability.

ML input features (input Data) are diverse and depending on the application, require different types of inputs. Inputs such as ''unauthorized absence, time of self-regulated activity, time of club activity, time of volunteer work, time of career development features'' have been using for Dropout prediction [91], [92] and ''audio recording'' for reading ability [89], [90]. Moreover, ''monthly family income, travel time to school, and parents' education level'' have been used as input features for mode choice [77]. Another example of inputs would be ''Essays'' which are used for grading [93], [94].

Other inputs are used in most studies in the common forms such as ''personal data, background data, interaction data, including access data, use of resources (learning resources), and performance'' [65], [98], [102]. Input features in

TABLE 5. The average accuracy of the algorithms implemented in each application.

References	Applications	LR	NB	RF	K	ANN	SVM	BN	DT
[95, 96]	Student performance	77.5	83.5	86.8	85.74	84	89	65.86	79.67
[97, 98]	Teaching	-	75.40	-	non	99.00	71.26	71.28	82.00
[99, 100]	Behavior	70.01	non	78.24	non	91.21	80.23	-	non
[23, 101]	Selection	78.04	77.88	81.45	-	-	75.44	-	-
Sum		13	16	23	6	21	25	3	25

Logistic Regression (LR), Naïve Bayes (NB), Random Forest (RF), KNN/K-means(K), Artificial Neural Network (ANN), Support Vector Machine (SVM), Bayesian Network (BN), Decision Tree (DT)

DL-based papers consist of images [57], [103]–[105], textual data [106], [107] and Essays [67].

The full potential of using data in data-driven education decision-making is being investigated owing to the unprecedented student performance [108]. In comparison with ITS, data mining techniques were used to extract information related to the performance of students. The number of studies employing data mining techniques using ML and DL was 20 and 3 as well. Ref [75] used DL along with data mining algorithms while Ref [109] employed NLP instead of DL.

Moving forward with further analysis of Table4, NLP was used mostly for teaching purposes (n = 16, 57%). This category of AI is capable of being combined with other types of AI presented in the AI category to improve the efficiency of the education systems. 6 and 4 of the studies used the NLP with ITS and ML respectively. Moreover, the number of studies in primary schools, 12 studies, was higher compared to those of elementary and high school which was 5.

All other studies in robotics performed teaching tasks such as ref [110] which studied teaching aid topics in science class high school. However, Ref [111], aimed to solve mathematics problems utilizing rapport-building linguistic strategies in middle school, and was assigned in the behavior category. Also, robotics was employed for Language Training. For instance, primary school Japanese students learned English with the help of robots [112].

E. LEVEL AND LECTURE

AI has targeted different levels of education in different lectures. This section covers the number of studies in each level of education. To begin with, high school-related applications led the pack by being investigated by 73 studies. 53 and 52 articles targeted middle schools and elementary school applications respectively. Moreover, only 8 papers discussed challenges jointly related to elementary and middle schools and took the last place. On a final note, a total of 24 articles were assigned to the Others category illustrating issues such as those related to vocational schools and kindergarten.

Some interesting points can be obtained about the role of AI in different levels of education by studying the identified papers. There is a significant difference in how studies targeted student performance and teaching in AIEd systems. At the elementary level, 48% of papers studied teaching issues while only 25% decided to work on evaluating students. However, this is almost the opposite in high school-related studies. Nearly 22% of papers focused on teaching, whereas a percentage of 43 studied students' performance in high schools. This is true because the numbers of studies concerning dropout prediction and grading were larger by 2.5 and 8 times compared to those of elementary school. Another analysis states that the number of papers targeting teaching-aid purposes was 6 times higher than those in high schools; therefore, that could be the reason behind why the percentage of teaching topics is higher in elementary schools. Continuing with comparing studies related to elementary and high school, 5 and 9 of the studies were based on selection [73], [113] and behavior [114], [115] topics respectively. The figures for middle school were 29% for teaching, 37% for student performance, 4% for selection, and only 2% for behavior.

Table 6 indicates which AI category is used in each course. It can be understood from this table that ITS and ML played great roles in mathematics. In science, ML was employed the most, and DL and ITS took the second place, each by being used 5 times. Moreover, papers used ML in Engineering and Language related courses more than other AI categories. For technology related courses, ML, ITS, and Robots were used equally. Despite the above, DL was not employed by researchers in the engineering field. Moving forward with taking levels into account, in elementary school, studies targeted mathematics (n = 17), science (n = 9), language learning (n = 10), and STEM (n = 5). For instance, Ref [116] by using a web-based ITS in a mathematics class,

TABLE 6. The frequency of using each AI category in different courses.

	ML	Data mining	DL	ITS	NLP	Robot
Mathematic	14	3	3	23	5	3
Science	11	3	5	5	4	2
Engineering	5	1	0	1	0	0
Language	7	1	2	2	5	1
Technology	2	0	1	2	0	2
STEM	3	0	2	1	4	1

and Ref [117] with the help of AR in English class helped teachers evaluate students. In middle school, targeted lectures were mathematics (n = 10) and science (n = 8). AI has been implemented at the high school level for different courses such as mathematics (n = 13), science (n = 11), and language (n = 5). Some studies have conducted student performance tasks in specific lectures. About 50% of all studies in the lecture section, such as engineering, mathematics, and science, have addressed student performance tasks.

With regard to Table6, Fig4 can be a testimony to the high number of studies covering topics in mathematics and science. Subjects are categorized into some sub-subjects in each group in Fig4, each color in this figure indicates a group of similar subjects. In Fig4, as also shown in Table6, Science and Mathematics were more dominant among other subjects.

F. LEARNING ENVIRONMENTS AND ASSISTIVE TECHNOLOGIES

Learning environments play a significant role in learning and teaching. It has a direct relationship with training. That is to say, better learning environment provides better understanding. Compelling reasons to use learning environments are provided in different papers, asserting positive outcomes in student learning compared to traditional instructional methods [118], [119]. An effective learning environment increases concentration and supports a student's behavior and emotions. Different learning environments have been noticed among the reviewed papers such as classrooms, laboratory environments (n = 1), animation (n = 1), and e-learning (n = 2). Also, one of the most popular environments used by the reviewed papers was gaming environments (n = 14). In these kinds of learning environments, technologies such as AR [120], ActiGraph GT3X+ accelerometer [120], and Web [57] were employed which resulted in appealing environments. Some of these technologies are indicated in Fig5. Game-based learning is considered an approach for education, in which learners explore a relevant aspect of games in a learning context designed by instructors. Game-based learning environments provide students a higher level of engagement in problem-solving which improves student learning [121]. Gamification takes game elements (such as points, badges, leaderboards, competition, and achievements) and applies them to a non-game setting. Since the past decade, there have been significant developments in game-based learning. In such environments, various concepts can be taught such as mathematics (n = 3) [63], [122], [123] and science (n = 5) [57], [121], [124]–[126] effectively and influentially. By benefiting from LOT [127] and LEGO [113] the output of adopting artificial intelligence in education is enhanced. Technologies and techniques such as ultrasonic sensor [128], screening model [129], RC-Car platform [130], perceptual computing technology [71], human-driven approach [131], and crowdsource – robotics [132] were also used in the reviewed papers. Virtual Reality (VR) as an immersive technology enables users to experience events that are not possible or cost significantly to be simulated in the real world. Therefore, this technology offers a safer environment for learning different topics especially practical ones. This is also beneficial for those who are unable to take school, as it also encourages overseas students to study courses that are not available in their home countries, allowing a much larger number of students to participate. A noticeable number of learning materials are now available on the Internet and these web-based systems can be accessed from everywhere. Technologies such as VR and Robotics have provided various opportunities to be taken about education purposes. The potentials of robotics to realize engaging multidisciplinary activities in education have made robotics a suitable solution to be employed in STEM activities [128]. The use of technologies such as Web/WWW (n = 10), Extended Reality – describing different combination of real-world and virtual worlds – (which includes VR (n = 2), AR (n = 4) and MR (n = 1)) and Mobile (n = 5) resulted in creating a suitable learning environment. A more precious implementation of different scenarios is obtained by employing these kinds of technologies; that in turn will result in enhancements in education and learning systems. Besides, a decrease in cost is reached by removing the physical barriers such as the classroom itself while using these kinds of technologies.

G. AI TEACHING

In the foreseeable future, due to the rapid increase in AI-based systems and products, a deep knowledge of AI is bound to play a major role in a wide range of professions. Moreover, learning AI courses will be of paramount importance just like basic literacy forming the abilities to read and write. The knowledge acquisition of AI would help people to have a higher level of understanding of AI techniques in AI-based products [133]. The involvement of AI in everyday life has made policymakers add AI courses in education systems. Therefore, this section briefly discusses papers that considered AI as a teaching subject. There were 8 papers discussing AI subjects as training materials. This has been detached at

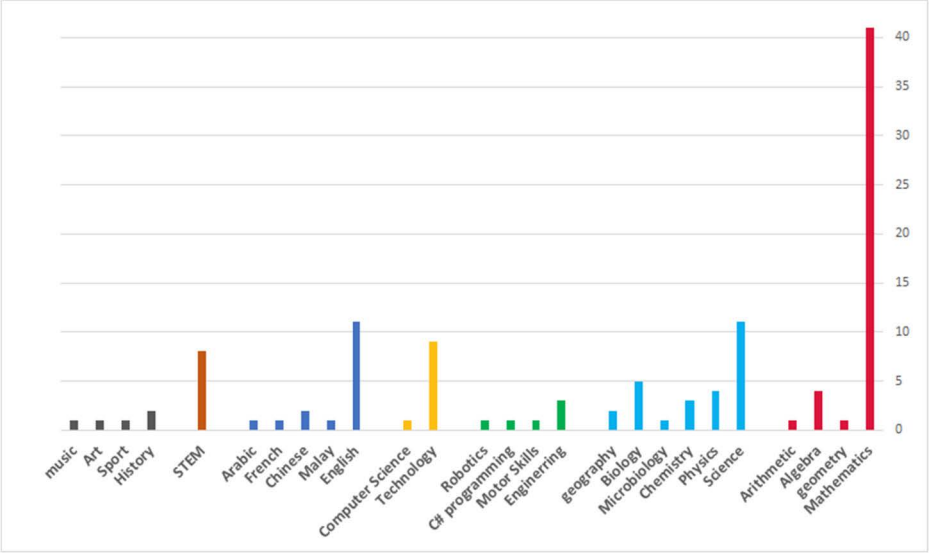

FIGURE 4. The number of studies targeting different courses.

FIGURE 5. A: RC-Car; B: perceptual computing technology; C: ActiGraph GT3X; D: virtual reality headset; E: ultrasonic sensor; F: LEGO.

high school (n = 4) and middle school (n = 2). Ref [134] developed a novel AI education concept for different age groups on different educational levels (kindergarten/primary school, middle school, high school, university).

IV. DISCUSSION

With the rapid development of AI technology in recent years, especially in Computer Vision, Speech Recognition, National Language Processing, the applications of AI are increasing in different domains which have led to a noticeable impact on education. This fast spread of AI not only helps students with learning different topics but also plays a major role in improving personal skills, providing deeper learning, and acquiring qualifications for future jobs. This systematic literature review investigated the role of AI in k-12 education during the last decade in terms of recognizing different relations existing among the findings. Two of the largest databases called Scopus and Web of Science were used in this study and according to the keywords, all studies related to this paper's objectives were extracted. The keywords covered different aspects of education including the scopes, and levels. Finally, the number of identified studies equaled 2075 which 210 of them were selected for further investigation.

Considering research question #1, a specific analysis revealed that AIEd has been applied in different institutions for various purposes including the automation of administrative tasks, timetabling, defining curriculums and instructions, and the learning process of students. These applications have many benefits and have been able to help different parts of education such as students, teachers and institutions to enhance education. Students can have a more convenient and suitable learning path and supplementary support with the help of AIEd. Also, it helps teachers and institutions to monitor the process of students' learning in real-time and support them when they need help. AI has improved the efficiency of administrative tasks such as evaluating students' performance, ranking students, and presenting feedback about assignments by means of automating these tasks in web-based or computer programs. Furthermore, the majority of these tasks were performed by ML and DL algorithms which highlights the noticeable efficiency and importance of these AI techniques in education. According to the first row of table 5 that represents these tasks, ML models resulted in proper and reliable accuracy for various problems. Particularly, RF and SVM were mostly used in student performance topics each by 6 times. These algorithms are so efficient in

such tasks and they are able to provide high performance. ANN is also a famous algorithm that has been used in many studies and carried out a significant performance in various AIEd tasks such as personalized teaching [59]. These algorithms bettered others in this application. Moreover, one contribution of ML would be its capability to be integrated with other AI categories such as datamining which further extends the performance of the resulted system. Hence, ML and DL enable data mining techniques to automatically extract valuable information through educational databases such as that related to dropout predictions which lead to improvements in efficiency [45]. Therefore, these AI techniques were the most valuable in terms of frequency of usage and efficiency for K-12 education.

Moving forward with adding application into the discussion on research question #2, for the lectures being targeted by reviewed paper, it can be stated that the most frequent algorithms being employed in teaching and particularly STEM courses were NLP and ITS. To be specific, ITS has been used more than NLP. A large proportion of studies, equal to 50%, benefiting from ITS targeted mathematics which compared to the figures for STEM illustrated a noticeable difference. The figures for science, technology, and engineering are respectively 19%, 20%, and 16%. It is acclaimed that the use of computer systems and ITSs dramatically improves the performance of students in mathematics and reduces the cost of studying [135], [136]. It was found that researchers used AI in mathematics, by 40%, which was the largest proportion among other lectures. In addition to Mathematics, courses such as Science, Technology, and Engineering, comprising STEM, were targeted by 75% of studies; this is a testimony to the potential offered by AI in STEM courses. AI has provided so many benefits for STEM education, from designing and developing concepts to assessing the understanding of these concepts by students. For instance, for proper learning and understanding of STEM concepts, students need a lot of resources to study and exercise. Assembling these requirements is costly, however, AI algorithms such as NLP have the ability to produce similar content based on the original content appropriately. STEM learning is a substantial and fundamental approach in education and every student should have an understanding of this matter. The best time to learn STEM is in early childhood and students should learn it during K-12 education. That would be another reason behind the fact that the majority of investigated papers discussed courses in STEM. Furthermore, investigating AI adoption in terms of levels in education, as we get closer to higher education, the adoption of AI gets more noticeable. Simply put, high school-related applications were more frequent compared to middle school and elementary applications. As a result, it can be inferred that employing AI in lower levels is still in its early stages. In elementary schools, students have faced learning challenges of literacy for reading and writing. They need to spend many hours practicing this and receiving feedback. NLP systems can easily fulfill this time-consuming and repetitive task so implementing the system

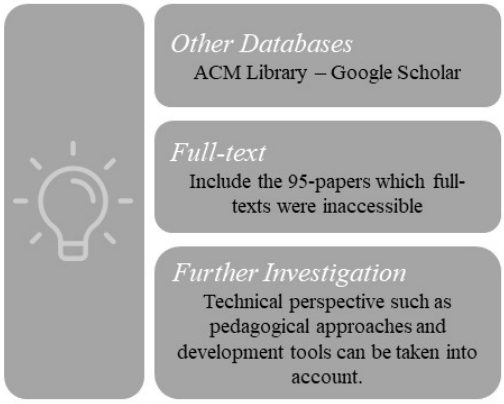

FIGURE 6. Future research ideas.

in this section of education is welcomed by researchers. Our findings acknowledge this. Further investigation revealed the usage of NLP in elementary schools by two times more than in middle schools and high schools. That said, as mentioned earlier, still the adoption of different types of AI in elementary and middle schools is less frequent than in high schools.

As discussion on research question #3, AI enhances the experience of learning by offering students practical or experimental learning; and this enhancement is more drastic while being integrated with other technologies such as VR, 3D games, and simulations. In other words, AI can be easily executed in education with the help of implementing tools and technologies in order to employ all the potential of AI. By integrating other technologies, the weaknesses of each are covered and the ability to provide content increases. These technologies use educational games to integrate educational concepts and structured games to facilitate student thinking and learning. Consequently, the learning process becomes a more enjoyable atmosphere for them. Generally, AI has been considered almost a blanket solution for different challenges in education. In recent years, with the development of VR technology, some wearing gadgets are being used in education which presents positive outcomes. Plus, the involvement of technologies in AI contributes to entertainment and creativity in education systems [11].

Overall, a machine is capable of repeating the same task over and over again, but only in random conditions, it can be creative in doing its duties. Therefore, machines can help teachers in terms of reducing the time spent on assessing students and analyzing their behavior. Furthermore, teachers have more time to improve their own knowledge to present the materials in a more effective way. Promoting thinking and improving the learning process are the ultimate goals of the involvement of technology in education. However, some challenges exist in benefiting from AI in education. Examining first, AI is not able to compete with teachers since education is a human-center task, not a technology-center one. That said, technology is no longer considered a simple assistance tool and is integrated with deeper learning which is illustrated as

an indispensable part of learning behavior [137]. Ref [138] highlights the impact of cognitive beliefs on their knowledge acquisition; hence, this should be taken into consideration in order to implement a more efficient education system.

V. CONCLUSION AND IMPLICATIONS FOR FUTURE RESEARCH

This systematic literature review investigates studies conducted in artificial intelligence and K-12 Education. The results were discussed in several sections based on the evaluation of various aspects of the studies. In section 4.1. we sought the different roles of AI in Education which in summary, we divided into four main categories of student performance, teaching, behavior, selection, and 24 sub-categories. Each category was discussed in other sections from the aspect of that section. Types of AI systems include Intelligence Tutoring System, machine learning, deep learning, natural language processing, Datamining, Robotics, and recommendation system were examined individually from various Properties such as diversity, number, accuracy, and tasks. In this section, various types of AI systems were compared with different categories of AIEd in terms of number and type of use. various types of input data to AI and their features were discussed in this section. the type of AI in each lecture and each level of K-12 education was compared and determined. New technologies (such as XR) and old (such as web or logo), which were assisted to improve AI in education as a physical space or virtual space were mentioned and the benefits of using these technologies were discussed. Some studies have addressed the necessity for AI training for students and teachers. Overall, the relationships between different viewpoints of AIEd documents in the results section of our paper are as follows: App-AI category, AI category-lecture, AI category -level, ML-APP, level-lecture, level-Application, lecture - AI category, environment-lecture, AI teaching-level.

The integration of AI and education has shown a remarkable effect on the educational system. These systems can be trained in a way that would offer more intelligence; then, they can address different difficult issues, including motivation, emotions, principles, ethics, and nature. The development of personal computers along with the improvements in computational systems have made AI more pervasive that its involvement in different sectors is now noticeable. Besides, the ability to integrate computer-based technologies with different equipment or machines has also played a considerable role in making AI being used widespread.

The findings of the deep review of literature in the AIEd field identify all aspects of the integration of AI and education and the current state-of-the-art of the studies conducted in this field were determined. Moreover, the benefits of using different AI algorithms in various tasks were revealed and it was indicated how the integration of AI and education can help improve student outcomes and achievement. Therefore, researchers can use this valuable information and conduct their work more purposeful and useful for further research. Furthermore, the present study added helpful information to existing literature. AI has a high potential and in the current review, it was highlighted where it is used and what it can do for educational purposes. Therefore, according to the information obtained from this study, policymakers and stakeholders should think of an arrangement to make learning easier and more efficient by embedding AI systems in different parts of education. This helps students to have a more high-quality learning process and helps teachers to be more efficient in schools.

As for the limitations of this review, indicated in Fig6, three main topics can be considered. First of all, other databases such as ACM library and Google Scholar can be taken into account to retrieve appropriate papers. Moreover, in the eligibility stage of this systematic review, 95 papers were excluded due to the fact that the full texts of those papers were not accessible. Finally, as mentioned earlier, some of the papers did not provide explicit answers for some technical terms such as pedagogical approaches. However, researchers might find the answers with a thorough in-depth analysis so that the integration of AI and Education could be investigated in terms of pedagogical approaches or development tools. Considering these three limitations can aid researchers in future works on the adoption of AI in K-12 education. This, in turn, would result in a more general and well-rounded conclusion.

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