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Research Article

AI-Based Applications Enhancing Computer Science Teaching in Higher Education

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ABSTRACT

The incorporation of Artificial Intelligence (AI) in higher education has gained significant attention as it presents new opportunities to improve the teaching and learning process. This paper aims to analyze how AI applications can support the teaching and learning of computer science in higher education. By reviewing various scientific publications, this paper offers an in-depth analysis of how AI-driven tools and applications have been successfully integrated into computer science courses. Key AI applications considered include intelligent tutoring systems, assessment, performance prediction, academic management, educational innovation, and adaptive learning. These tools have been shown to increase student engagement, provide tailored instruction, offer timely feedback, and enable the scalability of high-quality education. Also, the paper addresses the challenges associated with AI in education, such as diversity of educational contexts, security and data privacy, algorithmic bias, and the importance of faculty preparation. This article emphasizes the transformative potential of AI to enhance computer science education in the context of higher education and identifies mechanisms for research and practice to take full advantage of AI capabilities in designing effective and inclusive learning environments, guided by a comprehensive synthesis of current research and case studies.

Keywords: Artificial Intelligence, Computer Science, Higher Education, Learning analytics, Systematic review.

INTRODUCTION

The rapid advancement of technology has deeply reshaped the learning-teaching process in higher education, changing traditional classrooms into interactive, student-centered, and dynamic settings [1]. Digital tools and online platforms have revolutionized knowledge delivery and acquisition, enabling access to massive resources, fostering collaborative learning, and facilitating personalized instruction [2]. Innovations such as Learning Management Systems (LMS), and Massive Open Online Courses (MOOC), have democratized education [3], providing learners from diverse backgrounds with access to high-quality education regardless of geographical restraints. The addition of technology in education has also introduced innovative methods of instruction, such as flipped classrooms and blended learning models [4], which combine face-to-face and online sessions to enhance student learning experiences. Furthermore, technology has facilitated new arrangements of collaboration and interaction among students and educators. Online discussion forums, collaborative software, and video conferencing tools enable learners to work together and share knowledge beyond the confines of the traditional classroom. Online education has accelerated the use of technology in the learning-teaching process and shown how useful it could be to support flexible and resilient education systems [5-7].

Artificial Intelligence (AI) represents a promisor technical advancement that holds great significance for education. AI has the capability to address the difficulties faced by modern education and revolutionize existing methods of teaching and learning. AI-based applications facilitate customized learning experiences by analyzing student performance information to detect learning gaps and recommend targeted interventions, and consequently enhancing the overall effectiveness of the learning-teaching process [8]. Similarly, AI-driven adaptive educational systems can modify the difficulty level of tasks based on individual student progress, ensuring that learners are

constantly challenged yet not overwhelmed [9].

AI's potential extends beyond personalized learning. It can facilitate the introduction of intelligent tutoring systems that simulate the function of a human as tutor by offering tailored assistance. These systems can advantage students to develop analytical skills and increase their consensus of complex materials. Also, AI can assist in creating intelligent content, such as digital textbooks with multimedia elements and simulations, which can improve student engagement and comprehension [10].

In higher education, the use of AI is particularly impactful in subjects such as computer science, where the demand for skilled professionals keeps increasing. AI tools can support computer science instruction by automating assessment and grading, providing real-time coding assistance, and enabling personalized learning pathways. These tools can also support educators manage large classes more effectively by detecting students who may need further help and providing insights into overall class performance [11].

The rapid and robust advancement of AI, coupled with the elevated interest of educators in this field, requires additional academic examination of the employment of AI. This paper analyzes the way AI technologies can enhance the teaching of computer science in higher education. It explores how AI provide assistance to both the students and educators to overcome some challenges in computer science courses. Through a widespread literature review which study recent advancements and applications of AI in education, this research focuses on shedding light on the potential of AI to improve computer science education and contribute to the knowledge of those techniques and tools that are most successful in improving learning-teaching environments.

Despite the significant advancements present in AI's use in education; there are however, limited research conducted in its specific use and evidence is present only for general education context. Existing research have however, attempted to assess AI's potential use in improving educational efforts but is conducted in broad scope only. This lack of a comprehensive, domain specific analysis results in a major gap in understanding the full potential of AI tools to tackle the existing pedagogical issues in computer science education.

This paper makes several key contributions to address this gap. It first presents the recent progress of AI driven applications tailored for Higher Education Institutions as computer science education purposes. Second, it organises the identified AI tools and techniques by their primary applications, which included adaptive learning systems, automated assessment, and performance prediction. Third, the paper describes the challenges and limitations of using AI based solutions for education, especially for data privacy, algorithmic bias, and environmental consideration. It then proposes actionable insights, recommendations, and suggestions for educators, researchers, and policy makers, on how to successfully integrate AI into computer science curricula.

RELATED WORKS

The scientific community has become growing interested in studying the advantages of AI in education in recent years. Several research publications have specially focused on the ways AI-tools might assist in the subject of computer science education. Rongxin Liu et al. [12] study the integration of AI techniques into CS50, which is a Harvard's opening computer science course. The authors analyze the potential benefits and difficulties associated with utilizing AI for the objectives of grading, delivering feedback, and giving personalized aid to students. The authors highlight the value of AI tools such as GitHub, Copilot, and ChatGPT in enhancing students' grasp of programming ideas. However, they also express concern about the risk of these AI tools being excessively supportive, which might undermine the students' learning process. The study highlights the significance of formulating policies and methods to accomplish a harmonious equilibrium between AI help and autonomous student learning. In their study, Brent R. et al. [13] study the efficacy of AI-assisted code generation models in solving Parson's problems, which are a particular form of programming exercise employed in computer science instruction. The study investigates the performance of several AI-based models when are exposed to small differences in prompts and evaluates their potential to assist inexperienced programmers in gaining coding skills. According to authors, the results reveal that AI models can importantly improve the learning process by offering precise solutions, hence helping students in comprehending programming logic and structure more efficiently. Regarding the fact that these studies provide highly pertinent data, it is evident that a more comprehensive review is needed to identify general trends and best practices in the usage of AI for computer science education, rather than relying on isolated efforts.

Shuchen et al. [14], investigated the general trends and impacts of AI in the field of education over the past decade. The research areas identified are intelligent tutoring systems, automated grading, and adapted learning environments. The review highlighted the collaboration among researchers and stressed the difficulties related to data protection and the need for additional multidisciplinary studies. In this instance, the article focused on five education topics: science, technology, engineering, and mathematics (STEM) as well as language disciplines. The literature review conducted by Jerry C. S. et al. [15] examines the incorporation of AI-tools to improve the learning strategies and self-regulation of students. The results demonstrates that AI-based visualizations enhance students' engagement and academic performance by facilitating a more comprehensive understanding of their learning progress. The review also addresses the impact of adaptive learning tools in the facility of tailored learning experiences. Lastly, the study in [16] offers a systematic examination of the applications of AI in education. It

addressed a diversity of AI-powered tools, such as virtual teaching assistants, automated feedback tools, and intelligent tutoring systems. This review emphasized the advantages of these technologies in improving the efficiency of learning and the personalized nature of education, as well as the ethical implications and future orientations of AI in the field of education. These reviews are favorably beneficial for gaining perspective on the role of AI in the field of education; however, they are not exclusive to any one discipline and are rather general in nature.

There have been a lot of studies about the education side which deals with the integration of artificial intelligence integrated into the education. For example, Liu et al. [74] investigated AI tool such as GitHub Copilot and ChatGPT can be used in introductory computer science courses, demonstrating how these AI tool can offer real time feedback and personalised learning support. In doing so, however, their work focused mainly on immediate pedagogical benefits and did not investigate long term outcomes or in the broader scope of scalability and use of these tools in diverse institutional contexts. In addition, Brent et al. (2023) studied the effectiveness of AI augmented code generation models in solving Parson's problems, a type of computer science education problems often used in computer science education. While their work showed that these models proved efficacious to help novices, it was based on a limited area of educational tasks and lacked a coherent way to integrate AI across other learning activities.

Moreover, a comprehensive review such as the one performed by Shuchen et al. [14] on several areas of AI education applications was also offered including adaptive learning, intelligent tutoring systems, and automatic grading. However, their analysis drew on a broad range of disciplines, but not on domain specific insights for computer science education. Likewise, in Jerry et al. (2023), AI based visualisation tools were used for enhancing students' self-regulation strategies. The study highlighted the importance of the use of adaptive tools in increasing learning engagement, without focusing on how these strategies could be applied to the particular challenges of computer science, including algorithmic thinking and problem solving at scale.

Different from these studies, the current research is domain specific and investigates only the AI-driven applications for computer science education in higher education setting. Unlike most prior works that apply on isolated AI tools or offer generic overview, this study systematically divides AI applications into the following six main areas: adaptive systems, automated assessment, intelligent tutoring, educational innovation, performance prediction and academic management. Finally, this research critically explores the practical limitations and constraints of rolling out AI solutions, including issues of privacy, algorithmic bias, and faculty preparedness, typically ignored in previous research.

OBJECTIVES AND RESEARCH QUESTIONS

The objective of this article is to systematically examine an important number of publications pertaining to the utilization of AI-based tools in the subject of computer science, with the purpose of identifying the essential contributions provided by AI-based tools and methods in enhancing current educational systems. The aim is to conduct a widespread evaluation of AI applications used in the field of computer science education and provide an overview of the impacts and benefits found in current research. Also, this article identifies certain flaws and deficiencies in existing research and highlights the potential of AI technology for computer science instruction within the context of higher education. This paper particularly answers the following research questions:

Q1) What are the potential applications of AI in the field of computer science in higher education to enhance teaching?

Q2) Which AI techniques and algorithms are utilized to enhance computer science education?

Q3) While using AI methods and techniques in computer science education, what problems and issues have educators and learners faced?

METHODOLOGY

The study methodology is a systematic review of currently existing literature concerning AI driven applications in computer science education and within higher education. Specific criteria were established for selection of the data sources to ensure comprehensive coverage and high quality of a suggested evidence. The datasets primarily consisted of peer reviewed journal articles published from 2014 till 2024. We included publications on AI applications in higher education focusing in particular on computer science instruction. We excluded articles that merely covered nonacademic uses of AI, or were based on fields other than computer science. Moreover, only primary research written in English from peer reviewed and published articles were taken into account, but the review articles, conference proceedings and book chapters were discarded to avoid being inconsistent and unrealistic.

This study accomplishes an analysis aimed at solving the research questions outlined in the earlier section, employing criteria to decide which papers will be included or excluded. [17]. Establishing systematic and reproducible search criteria is necessary to accomplish this objective. We then determine the research findings by conducting an exhaustive analysis of the study's included papers. Our study includes 66 articles that pertain to the enhancement of computer science in higher education using AI applications.

In table 1; careful consideration was given to designing the search strategy to yield the maximum number of potentially relevant studies. A variety of publications were then gathered by querying three prominent academic databases—Scopus, Web of Science (WoS) and IEEE Xplore. A combination of keywords and Boolean operators such as, 'Artificial Intelligence', 'Machine Learning', 'AI based applications', 'Higher Education', 'University' and 'Computer Science' was used to search. The search was done using the titles, abstracts, and keywords in order to retrieve only relevant publications. In addition, philtres were employed to restrict the findings to journal articles published in the relevant time frame. After removing duplicates, an initial screening through titles and abstract was performed. Full text review of articles included in the study was carried out to ensure that they were relevant to the research questions and objectives of the study.

Table 1. Original search query

Subject	**Search string**
Artificial Intelligence	"Artificial intelligence" OR "Machine Learning" OR "AI-based applications"
AND	
Education degree	"Higher education" OR "College" OR "University"
AND	
Topic of interest	"Computer science" OR "Informatics"

A. Identification of pertinent research

The original search query (Table 1) and criteria (Table 2) for this systematic review include papers that documented the use of AI in education, specifically focusing on enhancing the instruction of computer science within the context of higher education. Analyzed papers were queried in three prominent international databases: Scopus, Web of Science (WoS), and IEEE (IEEE Xplore). The search was conducted by using the title, abstract, and keyword fields of the publications, and it was restricted to original research publications, published in peer-reviewed journals within the past decade (2014–2024), with the review articles being excluded.

Table 2. Criteria for inclusion and exclusion

Inclusion criteria	**Exclusion criteria**
Year of publication (2014-2024)	Before 2014
English language	Not in English language
Education level (Higher education)	Not Higher education
Rigorous review process (journals)	Not a journal article
Original research paper	Not primary research (e.g. review)
AI improving education	Not academic objectives
Computer science subject	Other subjects

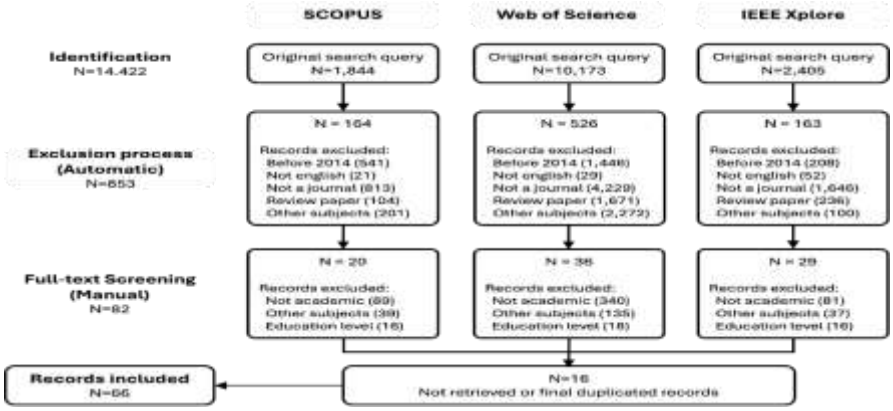

Fig. 1. Flowchart for determining the records included

Fig. 1 presents the flowchart for determining the included records in our study. A total of 14,422 records were located in the initial search: 1,844 from Scopus, 10,173 from WoS, and 2,405 from IEEE.

B. Records exclusion process

The initial procedure of excluding records was performed utilizing the filters available on the websites of each database, allowing for automated exclusion. The first stage consisted of five exclusion criteria: the year of publication of the article, that they were published in English, which was the filter with the lowest number of excluded records, and that the work was published in peer-reviewed journals, which, in contrast to the previous one, was the condition with the highest quantity of omitted records, principally in the WoS database. Note that a relevant number of the records are articles published as book chapters or in proceedings of international congresses. While there are questions regarding the peer-review processes in the scientific community, this work only includes publications published in peer-reviewed journals. This was done because such journals are generally considered legitimate in academia since it goes through a more rigorous review process. The last criteria matched review papers and works that did not align with computer science subject. At the end of the exclusion process, a total of 13,569 records were omitted: 1,680 from Scopus, 9,647 from WoS, and 2,242 from IEEE, leaving a total of 853 records for the next phase.

C. Screening process

The subsequent phase implemented the screening process where both the study's title and abstract are focused upon at in this step. We employed the Rayyan tool [18] to conduct the screening, which involved including the metadata of the 853 records for inspection. In contrast to the previous procedure, which was entirely automated, this one necessitated manual review.

Articles with an emphasis on non-academic subjects were initially excluded. In this instance, we can locate papers that include keywords such as AI or computer science, but which are papers that implement AI-tools based on certain computer technologies for industrial or commercial purposes. Besides, papers with research goals to enhance certain AI techniques for classification, expert systems, neural networks, robotics, and other purposes are excluded. A total of 510 records were excluded based on this initial criterion.

During the screening process, we also recognized research publications that, while centered on academic subjects aimed at enhancing instruction using AI-tools, did not manly focus on computer science. Medicine and biology are extensively researched subjects when it comes to applying AI to improve academic practices. Also, it is frequently observed that there are articles that specifically aim to enhance instruction in the fields of science, technology, engineering, and mathematics (STEM). However, as our target is only focused on teaching computer science, we removed a total of 211 records during this second inspection. We also identified published works that primarily concentrated on teaching computer science at the high school or elementary school level. We retained only records related to higher education, as the educational topics pursue different objectives. This third criterion excluded 50 more records.

Following the accomplishment of the screening process, we obtained a total of 82 records. We then downloaded these papers and conducted an additional screening process that considered the full text. During this review, we found papers that exhibited similar content, and with a review approach, even though it was assumed as original works. Consequently, we excluded 16 records, which led to the inclusion of a total of 66 publications in this research evaluation.

RESULTS AND DISCUSSION

D. Number of articles published annually

The quantity of articles published annually from 2014 to 2024 is illustrated in Fig. 2, where it can be realized that the publication of articles is on the rise. In the current era, there has been an increasing attention and concentration in doing research that studies the impact of using AI techniques in computer science courses within higher education.

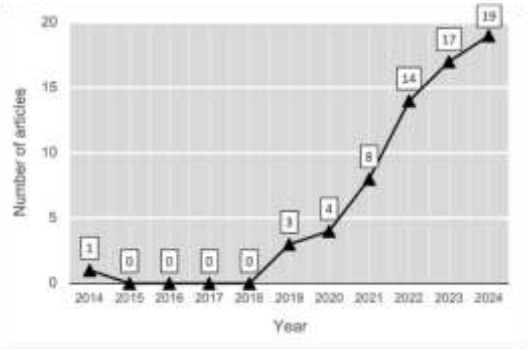

Fig. 2. Annual total number of included articles.

E. Journals

The articles included as part of this study were published in 28 distinct journals. The journal *IEEE Access* possessed the maximum amount of published articles (n=29), then *Informatics in Education* (n=5), and the *Journal on Advanced Science, Engineering and Information Technology* (n=3). Table 3 lists the journals where two or more articles were published.

Table 3. Journal-based categorization of the included articles

Rank	Journal	n
1	IEEE Access	29
2	Informatics in Education	5
3	Journal on Advanced Science, Engineering and Inf Tech	3
4	Data in Brief	2
	Egyptian Informatics Journal	2
	Journal of Universal Computer Science	2
	PeerJ Computer Science	2
5	Journals with one published article	21
	Total	**66**

F. Countries

Based on the nationality of the first author of each paper, Table 4 displays the geographical distribution by country for the papers included in this study. Table 4 reveals a significant variation in the countries of origin of the authors, totaling 32 different countries. Saudi Arabia has the highest number of papers (n=12), signifying 18.2%, followed by Pakistan (n=7) contributing 10.6%. Each of China, India, and Spain provides four papers, totaling 18.3% together. Three articles have been published by the United States, accounting for 4.5% of the total. Following this, a total of 26 countries have published two or fewer publications.

G. Affiliation of the authors

The first author is utilized to categorize their affiliation in a similar way to the geographical distribution by country, as shown in Table 5.

Table 4. Geographical distribution by country of included papers

Country	n	%	Country	n	%
Saudi Arabia	12	18.2	Egypt	1	1.5
Pakistan	7	10.6	Greece	1	1.5
China	4	6.1	Indonesia	1	1.5
India	4	6.1	Italy	1	1.5
Spain	4	6.1	Japan	1	1.5
United States	3	4.5	Kazakhstan	1	1.5
Algeria	2	3.0	Mexico	1	1.5
Bangladesh	2	3.0	Morrocco	1	1.5
Brazil	2	3.0	Peru	1	1.5
Finland	2	3.0	Poland	1	1.5
Malaysia	2	3.0	Republic of Korea	1	1.5
Nigeria	2	3.0	South Africa	1	1.5
Australia	1	1.5	Sweden	1	1.5
Belgium	1	1.5	Taiwan	1	1.5
Bulgaria	1	1.5	Thailand	1	1.5
Chile	1	1.5	Vietnam	1	1.5
			Total	**66**	**100**

In this case, as expected, 43.9% of the authors are affiliated with the Computer Science Department of their Educational Institutions, while 24.2% are affiliated with the Informatics Engineering Department. These two affiliations, despite their distinct names, have similar curricula and together account for approximately 68% of all publications. The remaining 32% is disseminated among correlated departments such as basic sciences, software and electrical engineering, etc.

H. Applications of AI in Computer Science

Regarding the first research question of this study (Q1), the included articles have been categorized based on the specific AI-based application used in the subject of computer science within the context of higher education. Table 6 illustrates the outcome of this categorization. We found six main AI-based applications to enhance computer science teaching process: 1) Adaptive systems and personalization, 2) Assessment and evaluation, 3) Educational innovation, 4) Intelligent Tutoring Systems, 5) Academic management, and 6) Performance prediction. Below is a detailed explanation of each of the six AI-based applications aimed to enhance the computer science teaching process. In addition, a brief description of the most representative works within each of them is included, since although they belong to the same classification, the included works have been implemented with particular methodologies and objectives.

Table 5. Classification by first author's affiliation

Affiliation	**n**	**%**
Computer Science	29	43.9
Informatics Engineering	16	24.2
Electrical Engineering	6	9.1
Software Engineering	5	7.6
Mechatronic	3	4.5
Mathematics	2	3.0
Applied Sciences	2	3.0
Data Science	2	3.0
Geospatial sciences	1	1.5
Total	**66**	**100**

Table 6. Categorization of included articles regarding AI-based applications

Study	Application	Study	Application
Kaleem et al. [21]	Adaptive Systems and Personalization	Roy and Farid [24]	Performance prediction
Lee and Cho [28]		Alwarthan et al. [25]	
Khan et al. [29]		Shi et al. [26]	
Lokkila et al. [30]		Qu et al. [31]	
Jahr et el. [34]		Haerani et al. [33]	
Kawamura et al. [38]		Tao et al. [35]	
Chao et al. [54]		Alruwais [37]	
Mehenaoui et al. [55]		Alboaneen et el. [39]	
Butt et al. [65]		Alhazmi and Sheneamer [40]	
Sayed et al. [66]		Alamgir et al. [45]	
Alruwais and Zakariah [76]		Raji et al. [47]	
Kopec et al. [80]		Veerasamy et al. [49]	
Guerrero-Higueras et al. [22]	Assessment and evaluation	Rafique et al. [53]	
Alkhatib [23]		Latif et al. [56]	
Jain et al. [27]		Almadhor et al. [57]	
Humble et al. [32]		Ahmad et al. [58]	
Zaman et el. [36]		Bujang et al. [59]	
Ramzan et al. [42]		Van Petegem et al. [64]	
Charytanowicz [62]		Adnan et al. [67]	
Mamatnabiyev et al. [19]	Educational innovation	Ahajjam et al. [68]	
Silva et al. [44]		Parida et al. [69]	
Pyae et al. [48]		Guerrero-Higueras et al. [70]	
Salas-Rueda [51]		Sabri et al. [71]	
Campbell and Atagana [52]		Vives et al. [72]	
Okonkwo and Ade-Ibijola [77]		Almiman and Ben Othman [73]	
Hsu and Chen [78]		Liu et al. [74]	
Pereira et al. [81]		Adekitan and Salau [79]	
Nauman et al. [50]	Academic management	Cooper et al. [83]	
Nacheva and Jansone [60]		Boudjehem and Lafifi [20]	Intelligent Tutoring Systems
Kathirisetty et al. [61]		Prada et al. [41]	
Kathirisetty et al. [75]		Verdejo et al. [43]	
Mengash [82]		Chrysafiadi et al. [46]	
Li [84]		Nalli et al. [63]	

1) Adaptive systems and personalization

Within this section, there exist three main applications that relate to the capacity of AI to analyze and classify data based on specific criteria. AI can help to improve the teaching and learning process by providing adaptive feedback, identifying students' learning styles, and enhancing curricula.

a) Adaptive feedback

By utilizing the data obtained from student's interactions, whether during the course or before to it, AI-based methods can help us to categorize them based on specific criteria. The ultimate goal of this classification is to determine the level of assistance needed by specific groups of students and adapt or personalize key learning elements

to enhance their academic performance. Kaleem et al. [21] aims to assess programming students based on their computational thinking (CT) skills. A machine learning algorithm was used to group these students according to their abilities. Thus, a specific development plan was created for the groups that showed certain deficiencies in their skills. A model for categorizing students giving to their prior programming knowledge is presented by Lokkila et al. [30]. The objective is to prove that the programming behavior of students can be represented as a Markov process. Once the initial programming level of the student is determined, the content can be adapted to align with the rest of the class.

However, the classification of students should not be only based on their academic skills. In Santiago, Chile, Jahr et al. [34] categorize students according to their motivation in the programming course. Motivation profiles were made through clustering, and the profiles students were evaluated, thereby enabling the creation of course-based motivation trajectories. Based on multimodal data generated from face recognition, seat pressure, and heart rate, Kawamura et al. [38] generate a model to detect students' wakefulness. Data from students in a blended computer science course undergoes two analyses. Initially, they group features according to the wakefulness labels of learners that are generated by human raters through statistical analysis. Secondly, machine learning models are trained to automatically identify the wakefulness states of students. Lastly, Alruwais and Zakariah [76] developed novel deep learning-based algorithms that continuously monitor a student's mood, which includes feelings such as *contempt, dread, happiness, sorrow, rage, and surprise*. It can be provided more effective assistance to students by better understanding their behavior and providing specialized and personalized support, thereby enhancing academic performance and activity evaluation, by using these techniques.

b) Detection of Learning Styles

The development of personalized academic resources for students can be helped by the recognition of learning styles, that are based on their preferences and experiences [55, 66]. Kan et al. [29] suggest an automatic method for detecting learning styles and affective states in a web-based learning environment. By using this methodology, the learning styles and affective states of students are automatically estimated based on their learning preferences and behavior throughout a course. The study's findings demonstrate that an automated AI-based method outperforms learning styles questionnaires. Thus, employing this methodology, a tool has been created that educators can utilize to discern the learning styles and emotional states of their students.

c) Personalization of curriculum

AI has the potential to enhance and refine curriculum. Lee and Cho [28] applied AI to analyze the curricula of computer science departments at prominent universities worldwide, as well as expert databases. Course titles, curricula, and learning objectives comprised the data that was refined and analyzed. A curriculum that was personalized to the requirements of a complete comprehension of computer science was suggested in response to the findings of these AI-based analyses. This study illustrates that universities can be supported in the development of more systematic specialization curricula, which will result in educational enhancements for the future.

2) Assessment and evaluation

This application encompasses the use of machine learning algorithms and other AI tools to examine students' work data and activities to automate their academic assessment.

a)Automatic assessment

AI-based automatic assessment in education encompasses the usage of AI to analyze data and provide grades to student performance without human intervention. Guerrero-Higueras et al. [22] employ machine learning models to automatically evaluate student performance. The aim is to establish a direct relationship between the degree of interaction with a version control system and the probability of a student successfully completing a computer-related course. Based on this study, there is an important correlation between the extent to which each student interacts with a version control system and the grades they achieve. Jain et al. [27] propose an AI-based tool to assess students' comprehension of a specific topic through concept maps. The suggested tool calculates the probability distribution of the concepts listed in the concept map created by the student. The assessment of a student's comprehension of the subject is guided by examining the curve of the graph created by the tool. This strategy aids teachers in recognizing and evaluating their capability to increase understanding of subjects and enhance their pedagogical techniques.

b) Automated cheating detection

AI-based automated cheating detection involves the use of AI techniques to recognize and mitigate dishonest behaviors in diverse settings, such as academic assessments and online evaluations [32]. The proposed method of Ramzan et al. [42] is designed to prevent students from engaging in unethical conduct or cheating by identifying and recognizing unusual behavior in an academic setting, such as online exams. The method uses several deep learning-based models to segment 4 categories of cheating by analyzing frames from a video exam. The method conducted exhaustive experiments with pre-trained and as a result has developed a real dataset of cheating behaviors.

3) Educational innovation

AI-based educational innovation is defined as the process of including AI technologies into daily academic activities to create attractive learning experiences. These activities intend to enhance the interest, efficacy, and relevance of learning for students.

a) Educational robots

Robots are intelligent machines that can execute complex sequences of actions and software and machine learning models primarily drive their functionality. The principal purpose of educational robots is supporting teaching, intending to pique learners' interest in learning topics such as math, engineering, technology, and science. Mamatnabiyev et al. [19] suggest for a comprehensive strategy on the use of programmed robots for the purpose pertaining to higher education. To develop auxiliary learning materials and activities, open-source educational robot is employed for some areas within a computer science program. The activities promote computational and creative thinking by including the design and assembly of the robot, and the management of its hardware and software. This method provides a complete learning experience that permits students to apply academic concepts in practical situations, so increasing their creativity and motivation.

b) Metaverse

The metaverse, an interactive virtual space, employs AI to develop dynamic and immersive educational settings. These can be real-world events or fantasy worlds in which students can participate in hands-on learning. Pyae et al. [48] propose a metaverse-based learning system, originally designed for medical students and adapted for undergraduate computer science and engineering students. The study results found that the metaverse offers an engaged and dynamic learning environment. However, it still has usability issues that can be addressed in the future. The study's findings also highlight the significant potential that metaverse systems must advance higher education on a global scale.

c) Gamification

AI-based gamification applied in the context of education combines game concepts and AI tools to enhance educational activities by making them more interesting, interactive, and tailored to individual needs. Hsu and Chen [78] carried out a study that allowed students to train a model, enhancing their comprehension of the machine learning process and applying this model to a game-based competency in CT. The primary objective is to incorporate gamification into the computer science curriculum to increase student engagement while also facilitating the conception of a speech recognition application using AI. The study revealed significant student acceptance of the activity, which effectively supplied them with useful AI learning materials, promoted their creative thinking, and retained their engagement during class.

4) Academic management

Higher education institutions have undergone a significant transformation in their operations and service delivery as a result of the potential of AI techniques to renew and enhance a variety of processes. The administrative sector is one of the main areas in which AI tools have had a significant impact.

a) Job placement

AI technologies may considerably enhance the efficiency of university job placement areas through process automation, data-driven insights, and support for students. Kathirisetty et al. [61] conduct a study to determine the correlation between academic accomplishment and students' IQ to facilitate their job placement. This study used machine learning techniques to forecast students' IQ based on several characteristics. As a result, the assessment of students' IQ can have an impact on their definitive determination of suitable work positions. Ultimately, the firm assessed the student's final IQ score on a specified scale, projected an appropriate wage package for the student, and gained a clear understanding of the student's capabilities. The study presented in [75] aims to evaluate the emotional quotient of students for job placement purposes. This research categorizes the different elements of academic performance that help a student's employment by a company. This study's primary contribution is the development of a student's emotional calculus, including a methodology for its evaluation and the related challenges.

b) Admission system

An AI-assisted admissions system can ease the selection of applicants who are likely to get favorable academic outcomes at higher education organizations. Mengash [82] presented a study aimed at assisting universities in performing admission decisions through data mining tools to forecast the academic performance of candidates. To validate the proposed method, a dataset of more than two thousand students enrolled in the Faculty of Computer Science at a Saudi public institution was utilized. The employed AI technology was artificial neural networks, which achieved a superior accuracy rate compared to other evaluated categorization methods. The findings indicate that it

is feasible to forecast candidates' university performance prior to admission using specific pre-admission factors, including high school grade average, standardized admission test scores, and general aptitude test scores.

c) Resource optimization

The multiplying of teaching resources in universities has drawn attention to their optimization and distribution. Li et al. [84] present an enhanced adaptive genetic algorithm mixed with a neural network to optimize educational resources, such as classroom and laboratory utilization. The neural network is improved and then integrated into the wireless network to ease data gathering, processing, and transfer. The proposed study conducted numerous tests demonstrating the potential of AI to enhance the optimization of academic resources.

5) Performance prediction

The availability of data-driven on students' performance through AI-based prediction enhances the teaching process, thereby facilitating personalized and proactive interventions. In general, we can find two classifications of performance prediction: early intervention and performance tracking.

a) Early intervention

AI-based early prediction of student performance involves the use of data analytics and machine learning algorithms to predict students' academic success. To make this estimation, these approaches often evaluate historical academic data. For instance, Haerani et al.'s study [33], which employs a model to forecast students' graduation timing, uses graduation data from Computer Science Engineering students from 2011 to 2018. Alhazmi and Sheneamer [40] made an early prediction model for students' performance in higher education. This model incorporates historical course grades and admission test scores in its data training. The data used lifetime can even span over a decade. Alamgir et al. [45] proposed an approach to forecast the future performance of undergraduate students and to identify at-risk students proactively. This investigation examines the impact of 15 years of historical academic data on the performance of Computer Science university students.

Behavioral patterns are also examined as data to predict the students' academic performance. Shi et al. [26] conducted an analysis of university students' learning behaviors and determined how to estimate their learning by developing a predictive model based on the literacy learning behaviors. Qu et al. [31] mix student behavioral data with textual data from comments on computer science courses to forecast academic performance. This study is noteworthy since it is one of the few that integrates historical performance data with textual attributes to enhance the efficacy of classification algorithms.

At the end, the main objective of early prediction models is to identify students who may need supplementary support or interventions before their performance suffers a significant decline. This approach may offer potential benefits such as to provide customized learning [53, 68-70, 74], identification of at-risk or underperforming students [39, 47, 49, 58, 64, 67, 72, 83], and objective decision-making [33, 79].

b) Performance tracking

AI tools are capable of monitoring and evaluating student performance over time, which can assist in the identification of trends and areas that require improvement. Almiman and Ben Othman [73] utilize machine learning and data mining methods to forecast the educational performance of computer science students. This study intends to identify performance levels across different knowledge domains and semesters with a nine-year data analysis. The recognition of knowledge areas with a high rate of prediction confirms the curriculum's alignment with student achievements, while areas of lower accuracy indicate potential deficiencies in curriculum or pedagogy, providing essential insights for educators and curriculum designers to enhance educational strategies and resources for better student outcomes.

6) Intelligent Tutoring Systems

A specific type of educational software program known as Intelligent Tutoring Systems (ITS) simulates the cognitive abilities and learning requirements of pupils in individual capacity for a customized learning experience. ITS integrates AI technologies to adapt the learning process to each learner's unique requirements, thereby improving the learning process. ITS is important within the context of computer science discipline, where the learners usually have a diverse background, as it models the students' characteristics and requirements and emulates the way a human tutor thinks and reacts within the teaching process.

Prada et al. [41] introduce a web based ITS solution aimed at support engineering students, with no previous knowledge of data science required for its use. This program focuses on analyzing students' success based on observable scores and course completion. To achieve that goal, it employs a dataset consisting exclusively of attributes commonly collected by academic managers regarding students and their disciplines. Clustering and visualization techniques help data analysts identify patterns and facilitate the preliminary profiling of students. Chrysafiadi et al. [46] evaluate an ITS that instructs computer programming. The tested ITS uses a fuzzy system mechanism to measure the learners' current knowledge level and learning requirements, and then adapts the lesson flow accordingly. The assessment encompasses factors such as efficiency, accuracy, usability, and effectiveness. Positive evaluation results

significantly impact the learning process. In particular, the fuzzy-based ITS significantly improves learners' performance and enables them to complete the lessons and achieve the learning objective with a reduced number of interactions with the system.

AI TECHNIQUES EMPLOYED IN COMPUTER SCIENCE

The previous section reviewed the extensive variety of AI applications that facilitate computer science teaching in the context of higher education. In this section, we will discuss what techniques and algorithms are used to implement those applications. In this way, we will address the second research question (Q2).

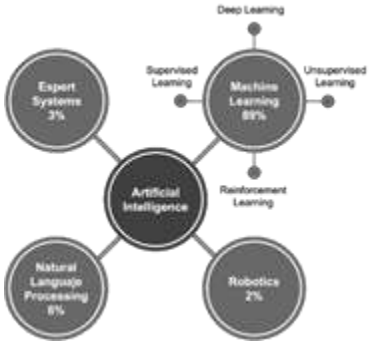

Fig. 3. AI-based techniques used in reviewed publications

Fig. 3 presents the classification of AI-based techniques used in the publications included in this study. After leading a detailed examination, we found four mainly IA techniques used in applications targeted at enhancing computer science teaching in the realm of higher education: Machine Learning, Expert Systems, Robotics, and Natural Language Processing. Fig. 3 also includes the percentage of articles utilizing each technique. In this way, Robotics technique is utilized by just one study, totaling 2%; two publications use Expert Systems, representing 3%; Natural Language Processing is employed by four papers, signifying 6%; and Machine Learning is the leading technique, utilized in 89% of the works in this study.

Due to its significance, Machine Learning is further divide into four techniques: Deep Learning, Supervised Learning, Unsupervised Learning, and Reinforcement Learning. Table 7 presents the quantity of publications employing each of the mentioned learning techniques as well as their corresponding percentage contributions. The results indicate that supervised learning is predominantly utilized with 70%, followed by deep learning with 18%, unsupervised learning with 9%, and reinforcement learning with a mere 3%.

Table 7. Machine Learning algorithms used in reviewed publications

Machine Learning algorithm	**n**	**%**
Deep Learning	14	18
Artificial Neuronal Networks	14	18
Supervised Learning	56	70
Random Forrest	14	18
Support vector machine	12	15
Linear Regression	10	12
Decision Trees	9	11
Naïve Bayes	4	5
Bagging	3	4
Markov Chains	2	3
Boosting	1	1
Adaboost	1	1
Unsupervised Learning	7	9
K-Means	7	9
Reinforcement Learning	2	3
Markov Decision Processes	2	3

Furthermore, Table 7 presents the algorithms employed in each learning technique. Table 7 suggests that the most often employed AI algorithms are Artificial Neural Networks and Random Forrest, each utilized in 14 reviewed

publications. Artificial Neural Networks are an essential component of AI, with their primary usage being the modeling and resolution of difficult problems that encompass classification and pattern recognition [85]. Random Forrest, on the other hand, is an AI robust ensemble learning method employed for classification and regression. By aggregating the predictions from multiple decision trees, this algorithm can accomplish high predictive performance, thereby reducing the risk of overfitting that is frequently associated with single decision trees [86]. Support Vector Machines and Regression are two additional common strategies that are utilized in 12 and 10 studies, respectively. Support Vector Machines operate as effective methodologies for facing a wide array of general AI problems, especially in classification and regression [87]. This algorithm is notably effective for binary classification tasks, which involve the distinguishing of two classes [88]. Linear regression is a core machine learning algorithm that is employed to characterize the relationship between a dependent variable and one or more independent variables. It is primarily employed to solve regression problems, which involve predicting a continuous outcome using one or more predictors [89, 90]. The rest of the algorithms are presented in Table 7, which are utilized in nine or fewer publications.

Finally, please note that in Table 7, the value of *n* denotes the number of publications using a technique or algorithm. However, the sum of these values surpasses the total number of publications. This indicates that some papers incorporate multiple techniques or algorithms, leading to their inclusion in the count.

I. Issues faced while using IA in Computer Science

Thus far, the development of several kinds of applications and the usage of a variety of algorithms and techniques have demonstrated that AI can facilitate the implementation of enhancement strategies in the teaching of computer science at higher education. However, these solutions face constraints and issues that will be examined in this section to address the third research question (Q3).

The study in [43] enumerates actions by higher education institutions that, if neglected, may obstruct the development of AI-based technical solutions. The effective application of changes in response to AI-based implementations could be obstructed by the failure to consider faculty and university management as a team. To enable the efficient adoption of AI-based solutions, it is necessary to eliminate tedious and complex administrative and regulatory processes. Constant coaching for educators by professionals from the industrial and business sectors will create the essential circumstances for the adoption of AI-based solutions. Promote collaboration among universities and industries to meet the demands for AI-based solutions and tailor courses to student needs.

Meanwhile, Chao et al. [54] suggest that AI literacy should be a factor to consider in the training of skilled professionals to ensure that IT students have the necessary knowledge and skills in AI to adopt technological solutions. Additionally, it is important to contemplate how non-technical students can enhance their understanding of AI and its applications in their respective fields.

Almadhor et al. [57], discusses the aspect of diversity of educational contexts and student populations. The diversity of educational contexts can influence the implementation of AI-based solutions in higher education, conditioning both their effectiveness and adoption [91]. Several aspects should be considered in this regard. Institutions with different levels of funding and resources may encounter varying capacities to incorporate AI solutions. Certain institutions may possess the financial capability to acquire advanced AI systems, whereas others may struggle with basic implementations. [92]. The existing technological infrastructure can affect how well AI solutions perform. Institutions with outdated infrastructure might find it challenging to implement advanced AI systems effectively [93]. The diversity in curricula across institutions can also affect the AI's role in teaching and learning [94]. Educational contexts can vary across regions and cultures. AI solutions must consider linguistic diversity, cultural nuances, and local didactic practices to be effective and inclusive [95].

Alruwais and Zakariah [76] analyze how studies could induce biases. To recommend or make decisions, AI systems frequently depend on historical data. The AI may perpetuate some prejudices in its recommendations if the data used to train these systems reflects existing biases [96]. Furthermore, students from excluded communities or those with unique learning requirements may not receive the necessary support, which could potentially exacerbate educational inequities rather than addressing them [97]. AI systems employed for grading and assessment may demonstrate biases rooted in their training data. This may result in unfair grading methods, wherein certain students are disadvantaged not due to their actual performance, but because of intrinsic biases within the assessment system [98].

The challenges that both teachers and students face during the development of AI-based solutions to enhance teaching require the consideration of an additional aspect related to privacy and data security. AI-based applications frequently require the collection and analysis of considerable amounts of data, including sensitive and confidential information about students. Protecting this data from unauthorized usage and breaches is an important challenge [99]. It is imperative to implement data privacy and security controls; however, this is a complex endeavor.

J. Addressing research questions

This study findings clearly address the research questions, providing essential understandings for the application, techniques and challenges, if Artificial Intelligence driven tools will be used in Computer Science education. Regarding the first research question (What are the potential applications of AI in the field of computer science in

higher education to enhance teaching?), the study identified six primary application areas: Educational innovation with adaptive systems, automated assessment, intelligent tutoring systems; performance prediction and academic management. These categories include particular AI methodologies and tools that have proven to greatly enhance student engagement, offering personalised learning paths, and making administrative work a breeze. Specifically, adaptive systems proved capable of tailoring instructional content to the needs of individual learners and improving academic performance and performance prediction models were able to identify at risk students and engage these students before they fall behind.

Answering the second research question (Which AI techniques and algorithms are utilized to enhance computer science education?), the results indicated that machine learning is the main technique utilised, with supervised learning, deep learning, and unsupervised learning being the main approaches applied. Among these, one can name supervised learning models which included random forests and support vector machines in order to provide automated grading, and to predict performance. In addition, expert systems and natural language processing were discovered to be significant techniques in the construction of intelligent tutoring systems and automated feedback tools.

To answer the third research question (While using AI methods and techniques in computer science education, what problems and issues have educators and learners faced?), the study presents a number of such challenges. However, these include concern regarding information protectiveness and security, algorithmic prejudice, and variety of educational contexts among others. We found that although AI tools present great advantages, they fail to take root due to challenges such as lacking infrastructure, scant faculty expertise, and divergent levels of institutional support. Further, the dangers of AI assessment tools being biased and the requirement for transparent and interpretable AI systems were identified as significant problems to overcome so that equitable learning results can be achieved. Through relating these findings with research questions, this study satisfies its objectives and represents a road map for future research as well as suggests a course of action for practical application in the field.

CONCLUSION

This article presents a comprehensive review of AI's contributions to enhancing the teaching process, specifically in computer science within higher education. We conducted a systematic search and applied some exclusion criteria using the Scopus, Web of Science, and IEEE Xplore databases, resulting in the inclusion of 66 publications. The analysis of publication patterns reveals an important increment in the number of publications on this topic over the past decade. The IEEE Access journal, with 29 publications, accounted for most of the publications distributed across 28 different publishers. The analysis of countries of origin revealed that Saudi Arabia had the highest quantity of published works, followed by Pakistan, China, India, and Spain, based on the nationality of the first author of the papers. We examined publications from 31 distinct countries, demonstrating the extensive diversity.

More importantly, this study has offered a comprehensive overview of the variety of prospective AI-based applications in higher education that can be used to assist students, faculty members, and administrators. They were grouped into six areas: adaptive systems and personalization, assessment and evaluation, academic management, educational innovation, and alongside intelligent tutoring systems and performance prediction. The latter is the most extensively applied in the works examined in this study. In addition to this primary classification, we identified a subclassification of 13 specific applications that enable a practical and daily understanding of the application of AI within the educational process.

Following the research goals, the specific AI techniques utilized to implement the aforementioned applications were determined. Four AI techniques were recognized from the studied papers: expert systems, natural language processing, robotics, and machine learning. About 90% of the included papers use machine learning, leading to a subclassification that identified artificial neural networks, random forests, support vector machines, and linear regression as the most prevalent algorithms.

Educators and learners encountered certain challenges in implementing AI-based solutions to enhance the instructional process. The main problems include complex administrative and regulatory procedures, inadequate collaboration between academia and industry, the need for enhanced training for educators and non-technical students, the heterogeneity of educational contexts and student demographics, an increase in biases, and concerns about data privacy and security.

This research has enabled the identification of the potential for IA to revolutionize educational practices by modifying the roles of both students and teachers. The challenge posed by numerous students requiring attention for relatively few teachers in the traditional learning mode can be addressed by AI applications, which can provide differentiated instruction to students. The growing prevalence of AI technologies may enable the teacher's role to transition from the primary source of knowledge to that of a learning coach, providing guidance and feedback as students engage with personalized adaptive learning experiences.

The complete effects of AI growth are unpredictable at present; however, it seems probable that AI applications will emerge as a predominant concern in educational technology over the next two decades. AI technologies and services

possess significant potential to assist students, instructors, and administrators across the student lifecycle.

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