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A SYSTEMATIC LITERATURE REVIEW ON COMPUTER-AIDED TEACHING: ASSESSING TRENDS, TECHNOLOGIES AND LEARNING OUTCOMES

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Abstract
Computer-Aided Teaching (CAT) is a new and innovative approach to teaching and learning that is gaining popularity in modern educational institutions. It is a technology-driven and flexible approach to teaching and learning that is highly interactive and results in improved student engagement and knowledge retention. The objective of this paper is to examine the technologies, approaches, and impacts, as well as the challenges, associated with Computer-Aided Teaching. To accomplish this objective, a systematic literature review was conducted, and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach was followed. The literature was retrieved through the Scopus database to ensure that all relevant literature was included. Sixty-seven studies that met the inclusion criteria for this systematic literature review are included in this study. The results of this systematic literature review revealed that Computer-Aided Teaching is widely implemented through computer-assisted teaching systems, information and communication technology, simulation, virtual and augmented reality, artificial intelligence, and multimedia technology, among other technologies. The results revealed that computer-aided teaching is highly effective and results in improved student engagement and performance, among other positive outcomes. The results also revealed that the implementation of computer-aided teaching is associated with several challenges, including lack of infrastructure, lack of digital competency among students and teachers, software availability, and teaching approaches. The results also revealed that computer-aided teaching is associated with several challenges, including the lack of evaluation approaches for knowledge retention and student performance, among other concerns. The results revealed that computer-aided teaching is highly effective and results in improved student engagement and performance if implemented with appropriate teaching approaches and technology infrastructure.

KEYWORDS: Computer Aided Teaching, Computer Assisted Teaching, ICT Based Teaching, Higher education, Tools, Technology, Trends, Instructional approaches, Academic Performance.

1. INTRODUCTION

In today's information-driven world, digital technologies are changing the way schools work all over the world. They are moving away from traditional teaching methods and toward learning environments that use technology. Education is increasingly regarded as a fundamental catalyst for societal and economic advancement, requiring innovative pedagogical approaches that improve learning efficacy and accessibility. Computer-Aided Teaching (CAT), also known as computer-assisted instruction or computer-aided education, has become a popular way to teach that makes learning more interactive and focused on the student (Chen et al., 2023). CAT allows students to interact directly with digital platforms by using multimedia content, simulations, and adaptive learning systems. This makes learning more interactive instead of just receiving information passively (Meng & Yang, 2025; H. Wang, 2024).

The significance of CAT resides in its capacity to improve the efficiency and sustainability of the educational system, as research demonstrates that computer-aided teaching and learning systems can attain performance rates up to 94.43%, a benchmark frequently elusive through conventional methods (Chen et al., 2023). CAT is not meant to take the place of teachers; instead, it is meant to work with traditional teaching by providing personalized instruction, real-time feedback, and flexible learning paths (Svetsky et al., 2018). The theoretical basis of CAT is closely associated with constructivist learning principles, which highlight active learner engagement and

knowledge construction through interaction with digital tools (Chen et al., 2023; Rakhmetova et al., 2023). Furthermore, instructional design models such as ASSURE and ARCS have contributed to the development of effective computer-aided materials that enhance both student motivation and academic achievement (Rakhmetova et al., 2023).

In specialized domains such as agriculture and food science, CAT has demonstrated significant efficacy in imparting complex and abstract concepts that are frequently challenging to comprehend in conventional educational environments. For example, computer-based modules and augmented reality games have been successfully used to teach enzyme kinetics related to making high fructose corn syrup. This is a cheaper and less resource-intensive way to do it than using expensive and resource-intensive wet chemistry labs (Crandall et al., 2015). Educational software has also been employed to integrate and personalize knowledge about cultivated habitats and living communities, connecting natural sciences with mathematical modeling to address real-world issues (Ćurčić et al., 2018; Tezer & Cumhur, 2019).By utilizing simulations and interactive animations, CAT helps students overcome the barriers of abstract disciplines by providing a more intuitive and visual understanding of agricultural and biological processes (ÇelIk et al., 2020; Crandall et al., 2015).

Even with these benefits, there are problems with putting CAT into practice, such as not having enough technology infrastructure, teachers not being very good with computers, and problems with how the lessons are designed (Saleh et al., 2024). This study employs a Systematic Literature Review to analyze the evolving trends, technologies, and pedagogical methodologies of Computer-Assisted Teaching. This review seeks to synthesize findings from various research studies to enhance comprehension of the role of CAT in contemporary education, particularly emphasizing its effects on performance and its practical applications in technical domains such as agriculture, while also delineating prospective avenues for future research.

RQ1 What are the key publication trends, technologies, tools, and instructional approaches that are commonly used in CAT systems?

RQ2 What impact does CAT have on students' learning outcomes, engagement, and academic performance?

RQ3 What challenges & limitations exist in the implementation of Computer-Aided Teaching?

2. METHODOLOGY

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021) (See Fig. 1) were followed to conduct a systematic literature review on the application of Computer Aided Teaching.

2.1. Literature Search Process

The Scopus database was used for the literature search because it covers a wide range of fields and has a strong index of peer-reviewed research in education, technology and human-computer interaction. It made it easy to find relevant studies on Computer-Based Teaching by using reliable and standardized metadata. Even though other databases might have more studies on specific subjects, Scopus was chosen to make sure that the screening process was systematic and consistent. The search used a mix of keywords about Computer-Based Teaching, with a focus on learning outcomes and teaching methods. These terms were used in titles, abstracts, and keywords to find relevant literature.

2.2. Inclusion and Exclusion Criteria

For the first screening, a set of predefined inclusion and exclusion criteria was used (see Table 2) to narrow down the identified list of articles. Peer-reviewed journal articles that were published in English between 2015 and 2025 were considered. The review concentrated on studies published from 2015 to 2025 to encapsulate recent advancements in immersive learning, indicative of swift technological progress and heightened institutional integration of computers in the educational process. This timeframe emphasizes contemporary practices and emerging challenges, notwithstanding the exclusion of prior foundational studies. Conference papers, book chapters, editorials, or studies that weren't based on real-life data were excluded. To systematically filter studies based on publication period, source type, language, accessibility, and relevance to Computer used in education, table 2 was used.

Database	Search terms
Scopus	"Computer Aided Teaching"
	"Computer Assisted Teaching"
	"Computer Based Teaching"
	"Computer Supported Teaching"
	"Technology Assisted Teaching"
	"ICT Based Teaching"

Table 1: Computer Aided Teaching-related search terms and education-related search terms used.

Table 2: Inclusion and exclusion criteria used

Criteria	Inclusion	Exclusion
Time span	2015-2025	<2015
Literature type	Article	Conference papers, Book chapters, review, Editorial
Language	English	Non-English
Source type	Journal	Trade journal
Publication stage	Final	Press
Keywords	Computer Aided Teaching, Teaching, Computer-aided Teaching Systems, Computer Aided Instruction, E-learning, Computer Aided Teaching System	All other keywords
Open access	All open access	Restricted Access
Screening		
Title and abstract	Existence of predefined keywords in the titles and abstracts were included in the study.	
Full text	The relevant papers that have been included in this study are those that discuss the predefined keywords.	

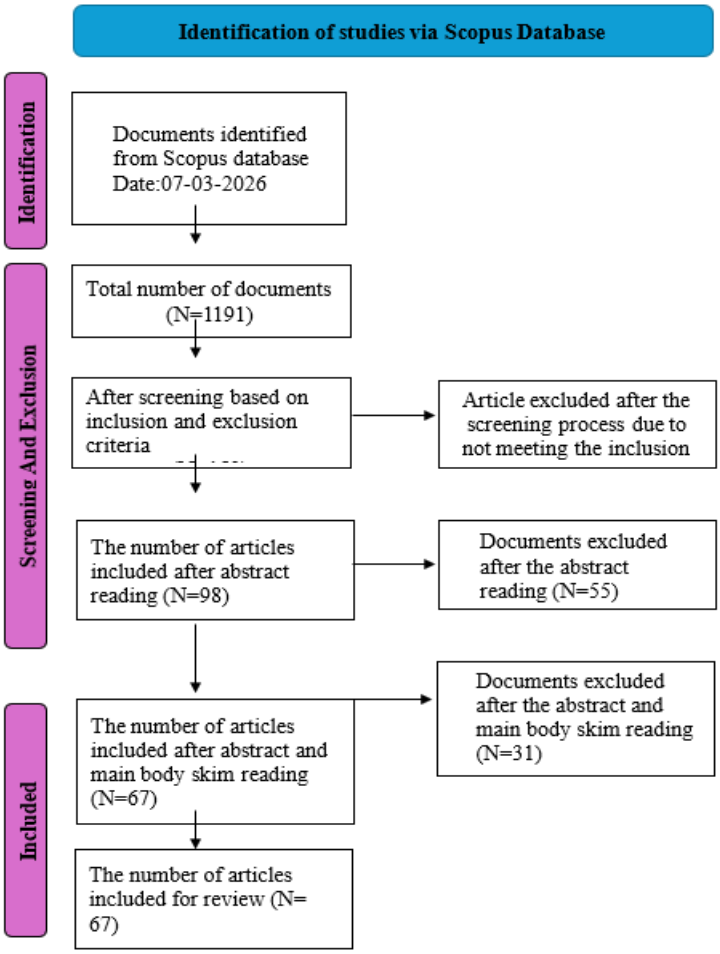

Fig. 1 PRISMA flow diagram

3. RESULT AND DISCUSSION

This section provides a critical examination of the existing studies undertaken to address the stated research questions and reflect on our findings, acknowledge the limitations inherent in our study, and outline directions for future research.

3.1. Key publication trends in Computer Aided Teaching Research (RQ1)

3.1.1. Annual Scientific production

The annual scientific production from 2015 to 2025 reflects a dynamic evolution in Computer-Aided Teaching research. The initial phase (2015-2017) focused on foundational pedagogical effectiveness and overcoming technical barriers, with early applications including the use of augmented reality and computer-based modules to visualize abstract concepts in specialized fields like food chemistry (Crandall et al., 2015). By 2018 and 2019, scholarly interest transitioned toward personalized instruction and subject-specific integration, particularly in mathematics and natural sciences (Ćurčić et al., 2018; Svetsky et al., 2018). During this time, using interactive models to teach geometric objects was shown to greatly improve student performance compared to more traditional methods (Tezer & Cumhur, 2019). From 2020 to 2022, there was a big jump in the number of publications. This was because of the global shift toward web-based teaching and the requirement to use online learning platforms (ÇelIk et al., 2020; H. Wang, 2024). After this peak, research from 2023 to 2025 has shifted to more advanced intelligent systems, like making knowledge graphs and finding the best ways to learn (Meng & Yang, 2025). Recent studies show that these new systems are very effective, with a 94.43% success rate in teaching basic skills and making students more interested in cultural subjects through constructivist-based CAT models.(Chen et al., 2023; Rakhmetova et al., 2023). The demographic analysis shows that the focus of research is mostly in secondary schools (53.85%), then in universities (19.23%), and high schools (15.38%). Nevertheless, a decline in the CAT research at high schools has been reported whereby the traditional computer-based models are being replaced by the mobile and touch-based technological tools. Regardless of these changes, the fact that the concept of algorithmic optimization and digital competencies are still in the limelight does prove that CAT is a crucial and dynamic discipline (Meng & Yang, 2025; Saleh et al., 2024).

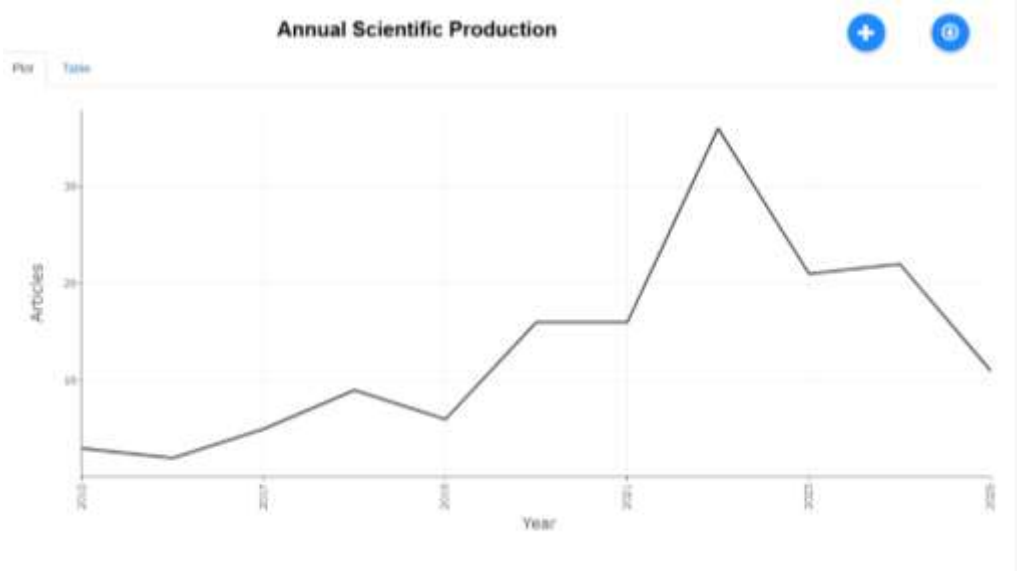

Fig. 2 Annual scientific production of articles

3.1.2. Corresponding Author's Countries

The comparison of the count of the corresponding authors, in their country of residence, demonstrates the clear geographical distribution of the research on Computer-Aided Teaching, with China becoming the most fruitful participant. Much of the Chinese output is single-country publications, and it indicates a strong national interest in implementing technology into the online environment of English, elementary level functions, and sophisticated knowledge graphs(Chen et al., 2023; Meng & Yang, 2025; H. Wang, 2024) . The second most productive country is Turkey where a lot of research studied the impact of computer-mediated analogies and geometric models on educational performance (ÇelIk et al., 2020; Tezer & Cumhur, 2019).Another trend in research is the combined national and international cooperation in different settings. In the US, study has led to the use of interactive simulations and augmented reality to visualize complicated food chemistry processes (Crandall et al., 2015). In the meantime, researchers in Kazakhstan have applied CAT to improve the delivery of folklore and cultural lessons in constructivist approaches (Rakhmetova et al., 2023). The interest of the whole world is also confirmed by contributions of the Middle East and Eastern Europe; examples include evaluative studies of Sohag University to determine the competencies of computer usage in teaching (Saleh et al., 2024), and researchers in Bosnia and Herzegovina to individualize mathematics teaching by using special educational software (Ćurčić et al., 2018).

Other contributions by the countries like Slovakia underline the need to have customized computer support to be adjusted to changing digital world (Svetsky et al., 2018). Although countries like Greece, Ethiopia, Indonesia, and Colombia show lower publication volumes, their involvement underscores a universal trend toward shifting from traditional methods to technology-integrated learning environments. Collectively, this distribution confirms that CAT is a globally recognized pedagogical priority, bridging diverse disciplines from technical engineering to the natural sciences (Chen et al., 2023; Crandall et al., 2015; Ćurčić et al., 2018).

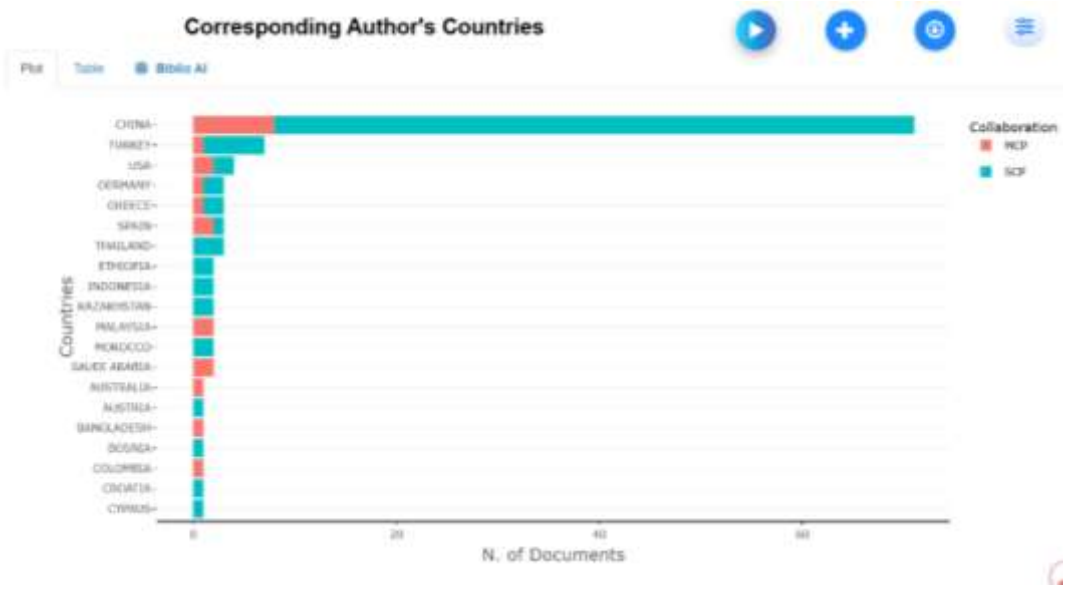

Fig. 3 Corresponding Author's Countries

3.1.3. Major Research Keywords

The keyword analysis shows that much of the field of computer-aided teaching is focused on the keywords viz computer-aided instruction and computer-assisted teaching, as the use of digital technologies to make teaching more effective and interactive is being increasingly integrated (Hu, 2020; Yuan et al., 2023). The popularity of such keywords as students and teaching emphasize the change of the focus to the learner-centered methods, in which informational technology promotes individualized learning and does not focus on the conventional uniform approaches to learning (Yuan et al., 2023).

The study of learning systems and teaching systems is concerned with the creation of more sophisticated platforms, such as those based on Backpropagation neural networks and smart instructional systems, to enhance the fit with particular curricula across disciplines (Hu, 2020; F. Wang, 2020). Meanwhile, the appearance of e-learning and online education underlines the increasing importance of flexible, network-based learning conditions which promote self-directed learning (H. Wang, 2024).

New terms like artificial intelligence and virtual reality suggest that there is an orientation towards more adaptive and immersive technologies, which will increase the efficiency of teaching and the level of interaction in the process of learning (Hu, 2020; H. Wang, 2024). All in all, these keywords indicate that the researchers are interested in applying advanced technologies to enhance student engagement and learning outcomes (F. Wang, 2020; H. Wang, 2024).

Fig. 4 Major Research Keywords

3.1.4. Thematic Map

The thematic map shows the key research themes in the area of computer-aided teaching according to their relevance (centrality) and the level of development (density). Motor themes are highly central and dense, which means that they are not only highly developed but also core to the research area. Such core areas as computer-aided instruction and e-learning belong to this category, and they are backed up by the development of intelligent systems and structured e-learning frameworks (Naveed et al., 2022; Tseng & Chen, 2020; F. Wang, 2020). Basic themes are very central and low density due to being a basis of an area of focus that links with various studies. The meaning of such concepts as students, teaching, and education computing do not vary between the research and are the basis of further development (Batdı, 2015; Ćurčić et al., 2018; Gaviria et al., 2022). Niche themes are more specialized, less interconnected, and deal with specific areas of activity, including engineering education or vocational training, and have less application in general (S. Li et al., 2020; Svetsky et al., 2018).Themes with low centrality and density are emerging or dying. Such directions as virtual reality and knowledge graphs are still in their infancy, whereas such research areas as COVID-19-related research are gradually being transformed into long-term applications (Han & Li, 2022; Lei et al., 2023; Meng & Yang, 2025; Qi, 2024; Yin, 2024).

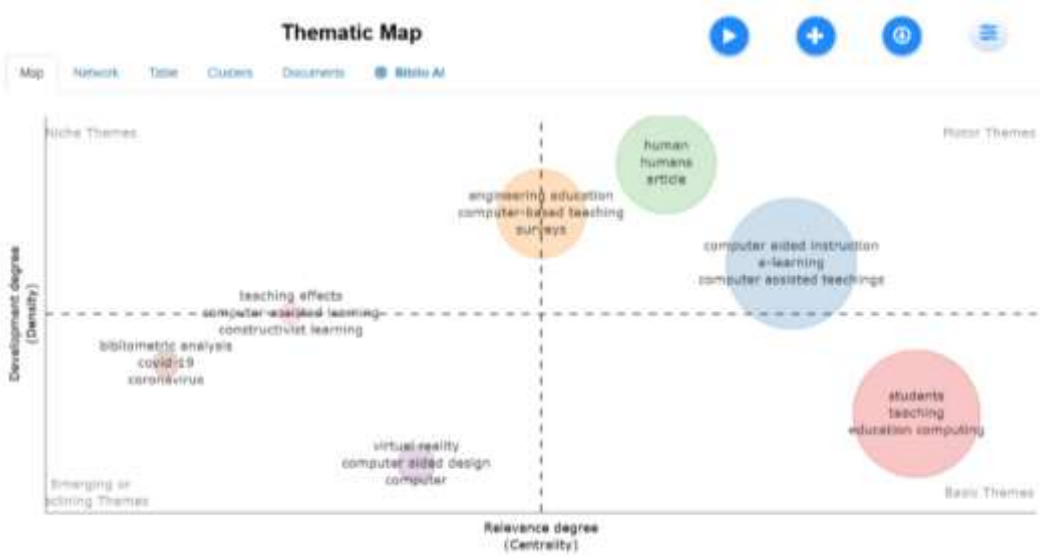

Fig. 5 Thematic Map

3.2. Technologies, tools, and instructional approaches commonly used in Computer-Aided Teaching systems

The major technologies, tools, and instructional approaches in Computer-Aided Teaching research published between 2015 and 2025 were identified through keyword co-occurrence analysis, thematic mapping, and qualitative synthesis of the selected studies included in this systematic literature review. The results indicate several technology, tools & institutional approaches that represent both established and emerging directions in computer-supported education. These technologies include computer-assisted instructional systems, ICT-supported learning environments, simulation-based learning applications, virtual and augmented reality-based learning environments, web-based and online learning platforms, artificial intelligence–supported teaching systems, and multimedia learning environments.

Table 3: Technology, Tools & Institutional Approach

Technology	Tools	Instructional Approach	Author(s)
Computer-Assisted Instruction (CAI) and Computer-Aided Teaching Systems	Computer-aided instructional programs, Multimedia learning platforms and adaptive testing systems, ASSURE instructional design software, Digital learning platforms, Network teaching software, Multimedia simulations	Technology-supported learning, Personalized learning, Constructivist learning, Self-paced learning, Technology-enhanced instruction, Constructivist learning	(Batdı, 2015), (H. Li & Ji, 2021),(Karakis et al., 2016),(Al-Awaysheh et al., 2024), (Pei & Wang, 2022), (ÇelIk et al., 2020)
ICT-Based Teaching and Technology-Enhanced Learning	LMS platforms, online learning tools, Digital textbooks, computers, internet resources, educational software, collaborative platforms, Multimedia tools and computers,	Learner-centered learning, Technology-integrated learning, Collaborative learning, Student-centered learning, Multimedia instruction	(Gupta et al., 2021), (Sumarni et al., 2019), (Svetsky et al., 2018), (Haron et al., 2019), (Deepa et al., 2024)

	Google Classroom, Zoom, Kahoot		
Simulation-Based and Computer Modeling Technologies	MATLAB simulation tools, Engineering simulation software, Simulation software, SQL databases, Surgical planning software	Visualization-based learning, Inquiry-based learning, Skill-based learning, Simulation-based clinical training	(Bait-Suwailam et al., 2023), (Ruíz Rodríguez & Torreglosa, 2020), (Mdletshe et al., 2020), (Zhong et al., 2024)
Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality Technologies	Unity 3D, AR applications, VR headsets and mobile learning apps, HMD devices, 3D visualization, HoloLens devices, Mobile AR learning platforms	Interactive learning, Experiential learning, Immersive learning, Experiential learning, Game-based learning	(L. Li, 2018), (Tai, 2023), (Górski et al., 2017), (Wu et al., 2023), (Crandall et al., 2015)
Web-Based and Online Learning Technologies	Online platforms and video tutorials, Online communication platforms, Virtual classroom platforms, Recorded lectures and digital modules, Multimedia learning objects	Distance learning, Online learning, Remote learning, Self-directed learning	(Tseng & Chen, 2020),(Naveed et al., 2022) , (Santos, 2022) , (Ismail et al., 2021), (Gaviria et al., 2022)
Artificial Intelligence and Intelligent Teaching Systems	Neural networks, AI tutoring systems, Knowledge graph databases, Machine learning models, Data analytics platforms	Adaptive learning, Personalized learning, Intelligent adaptive learning, Project-based learning	(F. Wang, 2020),(Meng & Yang, 2025), (Gu et al., 2022),(Xu, 2024)
Multimedia-Based Teaching Technologies	Video streaming and multimedia systems, Multimedia PowerPoint software, 3D animation software, Video and image processing tools	Multimedia learning, Interactive learning, Visual learning, Demonstration-based learning	(X. Li & Zhang, 2021),(Ćurčić et al., 2018) , (Zhang & Chen, 2020),(He et al., 2025)

3.2.1. Computer-Assisted Instruction (CAI) and Computer-Aided Teaching Systems

The most noticeable research in computer-aided teaching is concerned with the application of computer-aided instructional systems to enhance student learning and engagement. Research indicates that methods like the computer-aided teaching and computer-assisted instruction have a significant positive effect on academic achievement in comparison to other approaches (Batdı, 2015) reported higher achievement, and (H. Li & Ji, 2021) emphasized the effectiveness of personalized learning using CAI systems. Studies also lay stress on self-paced and interactive learning conditions. Computer-aided systems were identified as effective in knowledge retention(Al-Awaysheh et al., 2024), and student engagement was also indicated to be higher because of network-based teaching tools (Pei & Wang, 2022). Moreover, integrating constructivist approaches with computer-aided teaching systems has been shown to significantly improve learners' conceptual understanding (ÇelIk et al., 2020; Karakis et al., 2016)

3.2.2. ICT-Based Teaching and Technology-Enhanced Learning

The results of the chosen articles indicate that the use of ICT-based instruction can play a major role in improving student involvement, motivation, and learning performance. Learning management systems and online platforms are examples of ICT-supported learning environments that facilitate learner-centered learning and enhance participation in general (Gupta et al., 2021). Digital textbooks and internet resources are ICT-based teaching resources that help in building professional competence and integrating technologies effectively by teachers (Sumarni et al., 2019). The interactive learning and knowledge sharing among the students are supported by technology-enhanced learning systems and collaborative platforms (Svetsky et al., 2018). Classroom interaction and student motivation are also improved with the help of the use of technology-assisted teaching aids such as multimedia tools (Haron et al., 2019). Multimedia teaching is supported by ICT-based applications like Google Classroom, Zoom, and Kahoot, which also help develop communications skills, language learning being one of the areas (Deepa et al., 2024).

3.2.3. Simulation-Based and Computer Modeling Technologies

The results suggest that simulation and computer modeling technologies are important in improving the knowledge and applied skills of students. Complex concepts can be visualized with the help of simulation tools and enhance conceptual learning (Bait-Suwailam et al., 2023; Ruíz Rodríguez & Torreglosa, 2020).Additionally, computer-aided simulations provide interactive and skill-based learning environments, particularly in medical and

technical education(Mdletshe et al., 2020). Advanced systems such as dynamic navigation further improve training accuracy and learning outcomes in clinical contexts (Zhong et al., 2024).

3.2.4. Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality Technologies

The analyzed literature shows that Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality technologies can be relevant in improving the process of teaching and learning. The technologies offer participatory and immersive learning experiences that enhance student engagement and participation (L. Li, 2018). VR and AR tools facilitate the process of experiential learning as they allow visualization and spatial comprehension of difficult ideas (Tai, 2023). The VR-based systems are conducive to learning since they enable the development of skills through realistic simulation (Górski et al., 2017), and the mixed reality technologies stimulate better learning results and student satisfaction by combining both real and virtual (Wu et al., 2023). Moreover, AR-based learning games help to obtain higher student motivation and better conceptual understanding(Crandall et al., 2015) .

3.2.5. Web-Based and Online Learning Technologies

The considered literature shows that online and web-based learning technologies are important in ensuring the provision of flexible and accessible learning environments. Through web-based teaching systems and e-learning platforms, students are motivated and offered a chance to learn through distance learning (Naveed et al., 2022; Tseng & Chen, 2020). Such technologies facilitate distance learning enabling students to access learning material at any time or place. Digital modules, virtual classes, and recorded lectures are the forms of online computer-aided learning and teaching methods that allow developing skills (Ismail et al., 2021; Santos, 2022). Virtual learning objects also facilitate self-directed learning through student engagement and motivation (Gaviria et al., 2022).

3.2.6. Artificial Intelligence and Intelligent Teaching Systems

The analysed literature demonstrates that AI and smart teaching applications are important to facilitate individualized and adaptable learning spaces. Neural networks as well as intelligent tutoring systems, which are AI-based teaching systems, improve the efficiency of teaching by customizing learning to individual learner needs (F. Wang, 2020). Graph-based systems that are based on knowledge graphs also facilitate individualized learning by suggesting individualized learning paths that are based on student learning patterns (Meng & Yang, 2025) Moreover, teaching systems based on machine learning enhance the classroom and personalization of learning (Gu et al., 2022). Efficient performance analysis and project-based learning are also supported by the use of big data-supported teaching methods (Xu, 2024).

3.2.7. Multimedia-Based Teaching Technologies

The examined research studies show that the teaching technologies based on multimedia are crucial in developing student engagement and comprehension based on the visual and interactive learning settings. Multimedia network instructional systems, such as video streaming and digital media, enhance the engagement and involvement of students (X. Li & Zhang, 2021). Individualized and interactive learning is facilitated through educational computer software, which incorporates multimedia features (images, animations, and presentations) (Ćurčić et al., 2018). Moreover, computer-aided animation technologies contribute to visual learning, simplifying difficult ideas, especially in professional education, including medical education (Zhang & Chen, 2020). Multimedia network technologies also complement the efficiency of the classroom and learning by demonstrating methods of learning (He et al., 2025).

3.3. Impact of Computer-Aided Teaching on students' learning outcomes, engagement, and academic performance

Computer-Aided Teaching has been highly accepted to be a successful method of improving the learning process of students in a number of educational settings. This review discusses its influence on the important dimensions, such as learning outcomes, student engagement, and academic performance. These effects should be understood to determine whether technology-integrated teaching is effective in the contemporary education systems.

Table 4: Impact of Computer-Aided Teaching on Learning Outcomes, Engagement, and Performance

Dimension	Sub-dimension	Key Findings & Impact	Citations
Learning Outcomes	Professional Competency	Computer-Aided Teaching is a good substitution to conventional education and is particularly useful in areas such as engineering and art to help with such applications like packaging design and interactive animation.	(Lei et al., 2023; S. Li et al., 2020)
	Deep Learning and Skill Acquisition	Encourages more engaged learning in the form of interactive visualization and simulation of abstract concepts, and research has shown a performance rate of 94.43% in learning functional mathematics.	(Chen et al., 2023)

	Standardization	Results in significant improvements in post-test scores as compared to conventional lectures, as well as in the general level of knowledge within various fields.	(Abraham et al., 2022; Batdı, 2015)
Student Engagement	Personalization and Self-Pacing	Favors independent and individual learning, and there is increased engagement when the learner is given personalized support.	(Gaviria et al., 2022; Svetsky et al., 2018)
	Interactive Dialogue	Turns passive learning into a form of interactive experience via real time human computer feedback and results in increased activity in virtual reality-based classrooms.	(Chen et al., 2023; Qi, 2024)
	Satisfaction and Enthusiasm	Despite the improvement in performance, most learners would still want to have a face-to-face interaction to seek clarification, which is a difference between satisfaction and academic results.	(Batdı, 2015; Tseng & Chen, 2020)
Academic Performance	Overall Effectiveness	It has been shown to be more effective than the conventional methods in various studies with a mean effect of 1.13.	(Batdı, 2015)
	Performance Rates	Systems based on technology and structured in this way tend to perform better than traditional teaching, and optimization based on algorithms (e.g., that of Dijkstra) works to improve the learning paths.	(Meng & Yang, 2025; Yin, 2024)
	Grade Level Variation	It depends on the level of development and digital literacy of learners, with higher results obtained in secondary level (1.31) compared to primary level (0.66).	(Batdı, 2015)

3.3.1. Impact on Learning Outcomes

The CAT leads to better learning since it increases knowledge retention and acquisition of theoretical and clinical competence.

3.3.1.1. Clinical Competency

Computer-Aided Teaching is also found to be a successful alternative to conventional lecture-based education in the professional education setting, including oncology nursing. Randomized controlled trials evidence indicates that computer-aided and conventional methods have a significant impact in enhancing the level of knowledge among learners. Nevertheless, the CAT method usually leads to the increased post-test scores, which means that the knowledge acquisition and retention is enhanced. These results indicate that CAT can facilitate flexible, effective, and outcome-based learning in the professional training setting (Al-Awaysheh et al., 2024)

3.3.1.2. Deep Learning and Skill Acquisition

The use of Computer-aided Teaching modules that include simulations, case-based learning, and interactive activities are instrumental in the development of a higher-order cognitive ability in critical thinking, problem-solving, and decision-making (Al-Awaysheh et al., 2024).These interactive features enable students to be more active in their learning and classroom sessions and to use the theoretical knowledge in practice. As an illustration, in mathematics education, visualization tools allow students to perceive abstract concepts in a better way since they can visualize them in dynamic and graphical forms. This method enables the learners to process complex relationships in a more useful way and enhances their logical thinking skills (Chen et al., 2023).

3.3.1.3. Standardization

Computer based Teaching facilitates the presentation of standardized teaching material where there is uniformity in quality of teaching material between institutions and geographical areas. This is especially useful in circumstances where learners are highly fragmented in that it enables them the same access to the same learning resources and quality of learning. With the reduction of the variation in the delivery of teaching, CAT helps to provide equal learning opportunities and high-quality education and training programs on a large scale (Al-Awaysheh et al., 2024).

3.3.2. Impact on Student Engagement and Motivation

The interactive nature of computer-aided systems significantly alters the learner's experience and level of involvement.

3.3.2.1. Personalization and Self-Pacing

Among the greatest contributions of Computer-Aided Teaching to student engagement is that of facilitating self-paced learning. The learners can take charge of their learning process by stopping, revisiting difficult issues and moving at their own pace and comprehension. Moreover, instant feedback that the CAT systems offer consolidates the learning and assists the students in recognizing and rectifying mistakes on the spot. Such flexibility can support

a variety of learning patterns and increase the overall engagement of students and their learning rates (Al-Awaysheh et al., 2024; Chen et al., 2023).

3.3.2.2. Interactive Dialogue

Computer Aided Teaching and Learning systems make the one-way mode of instruction interactive and two-way process of learning. Students are not passive receivers of information and instead, respond to prompts and get real-time and immediate feedback. The interaction that is formed in the process of learning makes the environment dynamic and provides active learning and ensures that the students are not left out during the entire learning process since this is a human computer interaction. Due to this, the learning process becomes more exciting, receptive, and pleasant, and it also allows learners to recognize mistakes and gain a deeper understanding more efficiently (Chen et al., 2023).

3.3.2.3. Satisfaction and Enthusiasm

Computer-Aided Teaching enhances student interest and makes learning more interactive and visually engaging; some studies point to a noticeable gap between learning outcomes and learner satisfaction. Evidence suggests that even when students achieve higher academic performance through CAT, a portion of learners still express a preference for traditional face-to-face instruction. It can be because of the lack of direct contact with instructors, the possibility of immediate clarification, or the lack of experience in digital learning environments. These results imply that although CAT is a successful tool in enhancement of performance, the aspect of student satisfaction and support systems is still significant in implementing the tool successfully (Al-Awaysheh et al., 2024; Batdı, 2015).

3.3.3. Impact on Academic Performance

Studies have always shown that CAT influences student academic achievement in a positive and significant way in any field.

3.3.3.1. Overall Effectiveness

A meta-analysis with 78 studies in an article published between 2006 and 2014 documented a mean effect of 1.13 of the effects of Computer-Aided Teaching on academic achievement (Batdı, 2015). According to Cohen standards, this value is large and significant, which means that CAT has a significant advantage over traditional teaching methods. The results indicate that the combination of computer-aided instructional practices can result in significant improvement of academic achievement of students in various subjects and levels of education (Batdı, 2015).

3.3.3.2. Performance Rates

Differentiated computer assisted instructional programs, especially in subjects like mathematics have shown a very high rate of instructional effectiveness. In one instance, a Computer-Aided Teaching and Learning system reported a performance rate of 94.43, which means that there were good learning results among the students (Chen et al., 2023). This kind of efficiency is a significant sign of the capability of technology-based systems to deliver intricate ideas in an easily understandable and well-organized way, which is in many cases more efficient compared to traditional methods of teaching. These results indicate that properly designed computer-based systems have the potential to significantly increase the learning performance level due to the integration of visualization, interaction, and immediate feedback (Chen et al., 2023).

3.3.3.3. Grade Level Variations

Computer-aided Teaching has varied effects at different education levels. It has been established that the most pronounced effects are realized at the secondary school level with the highest effect size of 1.31, whereas the primary education shows relatively smaller, but still positive, effects at the level of effect size of 0.66 (Batdı, 2015). This difference could be explained by the fact that students have different cognitive development, digital familiarity, and capability of using technology-driven learning environments. These results indicate that CAT will be more effective in the higher education level where learners can more effectively use and take advantage of interactive and self-directed learning systems (Batdı, 2015).

3.3. Challenges & limitations in the implementation of Computer-Aided Teaching (RQ3)

Computer-Aided Teaching has a number of challenges when it comes to its implementation although it has been effective in improving learning outcomes. These issues are associated with technological infrastructure, readiness of the users, and design of instructions. These limitations should be identified in order to facilitate the successful implementation of CAT in various educational settings.

3.3.1. Technical and Infrastructure Barriers

The physical and digital environment remains one of the most significant hurdles to successful CAT adoption.

One of the greatest setbacks in the adoption of the computer-Aided Teaching is the poor access to institutional facilities especially limited access to computer laboratories that are well equipped and have a stable network platform. Studies indicate that without sufficient hardware facilities and stable, high-speed internet connectivity, the effective use of specialized digital teaching tools becomes difficult(Mdletshe et al., 2020). Studies indicate that insufficient infrastructure and limited access to digital tools can hinder the successful adoption of computer-aided learning, particularly in developing or resource-constrained environments (Naveed et al., 2022; Sumarni et al., 2019). Such inadequate infrastructure may limit access to learning resources by students, as well as the overall efficacy of computer-aided instructional systems, particularly in those institutions that have little technological support.

Another significant aspect that affects the performance of Computer-Aided Teaching is accessibility of software. It has been proposed in studies that instructional content and applications must be easily available, downloadable, and exchangeable via the online platform in order to facilitate flexible learning (Karakis et al., 2016). Lack of portability between systems and limited use on only certain devices places software in a restricted state that limits access to students and the possibilities of lifelong learning. These restrictions may adversely influence student engagement and the general learning outcomes, which explains the necessity of highly accessible and convenient CAT systems (Karakis et al., 2016).

The challenge of rapid technological change is a significant issue to the application of Computer-Aided Teaching. The adoption of the mobile and touch-enabled gadgets including tablets and smartphones has led to a technological divide in certain learning institutions. Consequently, older CAT models can be obsolete or less compatible with new platforms and, therefore, become less relevant and used in some situations (Batdı, 2015).This change underlines the necessity of continuous modernization of digital tools and teaching systems so that they can keep up with the changing technologies and provide the effectiveness of computer-based learning environments.

3.3.2. Human Factors and Competency

The competency of the teacher is a major concern in the success of the computer-Aided Teaching. The successful implementation of CAT presupposes that educators should have not only good knowledge in the subject but also sufficient abilities on how to employ digital tools and instructional technologies. Research shows that technological illiteracy or inadequate training of teachers may be a barrier to the adoption of the computer-aided teaching techniques in place of conventional ones (Batdı, 2015). It can result in the inefficient utilization of digital resources and poor learning outcomes and therefore, continuous professional development and training in the technology-enhanced teaching conditions should be emphasized.

Another issue related to the implementation of Computer-Aided Teaching is student readiness. Cat will be effective in case the learners are accustomed to using digital tools and can navigate technology-based learning environments. It has been shown that learners of low technological ability might experience challenges with the utilization of digital interfaces that would divert their attention to the very subject under study (Batdı, 2015). This digital illiteracy may decrease the interaction and impair the results of learning, which is why the simpler technological training and guidance is necessary to guarantee the meaningful usage of computer-aided teaching systems.

Another critical issue in the process of implementing Computer-Aided Teaching is student satisfaction and engagement. Even though CAT can positively influence the learning outcomes and flexibility, certain studies report that learners might report less satisfaction than those who attended the traditional face-to-face instruction (Al-Awaysheh et al., 2024). This can be attributed to the fact that they do not interact directly with instructors and peers as much, and as a result, they might become isolated and less sociable. The lack of direct individual communication and classroom interaction can influence the overall experience of the learning process among the learners, thus the necessity to introduce the interactive and collaborative aspects of the CAT environment to enhance satisfaction (Al-Awaysheh et al., 2024).

3.3.3. Pedagogical and Design Challenges

The digitalization of traditional instructional materials is not a guarantee of a higher quality of education. Computer-Aided Teaching relies on the combination of the proper pedagogical principles, the proper design of instructions, and the meaningful interaction with the learners. In the absence of these components, online materials might not contribute to learning or interaction.

Pedagogical consistency is one of the major issues when incorporating the use of the latest technologies like Web 2.0 tools and artificial intelligence into Computer-Aided Teaching. Even though these technologies are innovative, it may be challenging to align them with the particular objectives of the curriculum and instructional strategies. The adoption of technological abilities and pedagogical objectives can be problematic to educators, preventing the full use of CAT unless carefully constructed and established (H. Wang, 2024).

The retention of knowledge is also one of the weaknesses of Computer-Aided Teaching implementation. Although positive changes in the immediate academic performance are observed in many studies, the long-term retention of the acquired knowledge during computer-aided learning is not well studied. This implies that CAT can occasionally reinforce temporary success as opposed to long-term knowledge. Thus, the need to ensure that learning outcomes do not only focus on short-term evaluation and, instead, help build long-term knowledge is a crucial direction of the further research (Al-Awaysheh et al., 2024).

Computer-Aided Teaching simulation-based methods provide a good practice and skill acquisition opportunities, but also possess some limitations in the professional training applications. In other areas like medical imaging, simulations are able to recreate real-world conditions to a reasonable degree, but cannot completely replace practical clinical practice. Consequently, learners might not be fully exposed to the intricacy and diversity of real life scenarios. It brings out the point that although simulations are viable as auxiliary tools, they need to be combined with practical training to guarantee the development of a set of comprehensive skills (Mdletshe et al., 2020).

4. CONCLUSION

This literature review is systematic and gives an in-depth examination of Computer- Aided Teaching, showing its increasing role in contemporary education. The results show that CAT has been developing a lot during the last decade, and more and more research is dedicated to various technologies like computer-assisted instruction systems, ICT-based platforms, simulation tools, virtual and augmented reality, artificial intelligence, and multimedia learning environments. All these technologies have been involved in the creation of interactive, flexible and learner-centered educational systems.

The review also indicates that CAT has a significant positive effect on learning outcomes, engagement and academic performance of students. Working as an individualized, self-paced, and interactive learning tool, CAT not only increases knowledge retention, but also assists in the development of both skills and overall academic success. Specifically, simulation, multimedia tools, and intelligent systems integration is an essential factor that enables a deeper comprehension and active learning.

Nonetheless, the application of CAT has a number of obstacles, regardless of its benefits. The technological infrastructure, access to software, teacher competency, student preparedness and the design of pedagogy remain issues that limit its efficiency in some situations. There is also a concern about retaining knowledge in the long term and restrictions of simulation-based learning, which underscores the importance of balanced and properly designed instruction solutions.

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Author Contributions

PD: writing of the original draft, visualisation, conceptualisation, and figure preparation.
KC: provided guidance, editing, validation, supervision and corrections throughout the manuscript preparation
BK, AG and CF: editing, validation, supervision and corrections
KE: conceptualization, supervision, critical review and editing of the manuscript, and final approval of the manuscript.

Declarations

Conflict of interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

Data availability

The authors declare that the data supporting the findings of this study are available within the article

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