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INTELLIGENT AGENTS FOR VIRTUAL TEACHING AND LEARNING ENVIRONMENTS: A SYSTEMATIC REVIEW

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ABSTRACT

The application of intelligent agents in virtual teaching and learning environments began in the 1990s, when researchers began to explore the possibility of incorporating artificial intelligence technologies in educational software. In this context, this work aims to characterize the current knowledge about the use of intelligent agents in virtual teaching and learning environments. The methodology considered the formulation of guiding questions, selection of studies, evaluation, extraction, and analysis of data that pointed out how intelligent agents can be used in stages of the educational process. As results, it is noteworthy that the object of study has grown as an area of research in recent years. However, it is important to emphasize that the application of artificial intelligence techniques in education poses challenges, such as the need to integrate them with existing pedagogical practices, besides the concern with ethical and data privacy issues.

Keywords: intelligent agents, virtual environments, teaching, learning, artificial intelligence.

RESUMO

AGENTES INTELIGENTES PARA AMBIENTES VIRTUAIS DE ENSINO E APRENDIZAGEM: UMA REVISÃO SISTEMÁTICA

A aplicação de agentes inteligentes em ambientes virtuais de ensino e aprendizagem iniciou-se na década de 1990, quando pesquisadores começaram a explorar a possibilidade de incorporar tecnologias de inteligência artificial em softwares educacionais. Neste contexto, este trabalho tem o objetivo de caracterizar o conhecimento atual sobre a utilização de agentes inteligentes em ambientes virtuais de ensino e aprendizagem. A metodologia considerou a formulação de questões norteadoras, seleção de estudos, avaliação, extração e análise de dados que apontaram como os agentes inteligentes podem ser utilizados em etapas do processo educacional. Como resultados, destaca-se que o objeto de estudo tem crescido como área de pesquisa nos últimos anos. Entretanto, é importante ressaltar que a aplicação de técnicas de inteligência artificial na educação, impõe desafios, tais como, a necessidade de integrá-las com as práticas pedagógicas existentes, além da preocupação com questões éticas e de privacidade de dados.

PALAVRAS-CHAVE: intelligent agents, virtual environments, teaching, learning, artificial intelligence.

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1. INTRODUCTION

The history of virtual teaching and learning environments is marked by a constant evolution, driven by technological advances and the need to promote a more accessible and innovative education. Since the 1960s, with the emergence of the first interactive computer systems, the possibility of using technology for educational purposes was already being glimpsed. In the 1980s, with the advent of personal computers and the internet, the first virtual learning environments emerged, such as PLATO (Programmed Logic for Automatic Teaching Operations) and CSILE (Computer-Supported Intentional Learning Environment).

In the 1980s, with the advent of personal computers and the internet, the first virtual learning environments emerged, such as PLATO (Programmed Logic for Automatic Teaching Operations) and CSILE (Computer-Supported Intentional Learning Environment). With the improvement of the internet and the popularization of personal computers in the 1990s, virtual teaching and learning environments became more sophisticated and accessible, and the first Learning Management Systems (LMS) emerged, such as WebCT, Moodle, Canvas LMS and Blackboard, which offered features like content management, communication and online assessment.

In the early 21st century, these environments began to incorporate more and more technological resources, such as video classes, educational games, simulations, virtual reality, and artificial intelligence. Moreover, with the advent of social networks, new forms of interaction between the agents of educational communities have emerged, such as Facebook groups, instagram, slack, discord, and forums on content-sharing platforms.

Recently, with the COVID-19 pandemic and the increased demand for distance education, educational institutions around the world have accelerated the digitization process and adopted new technologies to ensure the continuity of teaching. New distance learning platforms have emerged, such as Zoom, Google Classroom, and Microsoft Teams, which allow synchronous classes, content sharing, and real-time interaction between students and teachers. In this context, virtual teaching and learning environments have undergone relevant innovation by starting to

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incorporate artificial intelligence techniques, such as intelligent agents, which allow for the personalization of the teaching and learning process.

Segundo Santos et al. (2021), os agentes inteligentes se caracterizam como programas capazes de aprender e tomar decisões, por meio de algoritmos de Inteligência Artificial, interagindo com os usuários e fornecendo orientações, respostas a perguntas, feedback e adaptando o conteúdo conforme as necessidades e preferências do usuário. As aplicações de agentes inteligentes em ambientes virtuais de ensino e aprendizagem incluem tutores inteligentes, personagens virtuais, assistentes virtuais e feedback em tempo real durante a realização de atividades. As a result, technology companies and educational institutions are discussing and boosting investments in research and development of intelligent agents for virtual learning environments, seeking solutions that improve efficiency in the teaching and learning process, providing a more personalized experience for the users involved.

However, there are still research challenges to be addressed until organizations can fully benefit from the potential of the technology. To our knowledge, there is no previous work that reviews research on incorporating intelligent agents into virtual teaching and learning environments.

However, the lack of studies that investigate the incorporation of intelligent agents in virtual teaching and learning environments can be characterized as a challenge. It opens a knowledge gap that can stimulate new research in the area, providing a relevant evidence base that can guide new studies and open ways for organizations to maximize the innovative potential of the technology. Given the above, this study aims to characterize the current knowledge about the use of intelligent agents in virtual teaching and learning environments.

Given the above, this work aims to characterize the current knowledge on the use of intelligent agents in virtual teaching and learning environments. To achieve this, it is structured into four sections: in addition to this introduction, Section 2 describes the methods used, Section 3 presents the results and discussions, and Section 4 provides the final considerations.

2. METHODOLOGY

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The construction of this systematic literature review was based on Kitchenham's (2004) methodology, with the intention of increasing the relevance of the materials selected for the research. The following describes the steps taken:

2.1 Planning

In order to present an overview of the research that has been conducted to boost teaching and learning relationships through the application of intelligent agents in virtual teaching and learning environments, the following guiding questions were developed:

Q1 - What are the scientific databases with the highest rate of publications, considering the research categories?

Q2 - What is the stratum of the scientific productions, considering the correlated papers identified following the inclusion and exclusion criteria?

Q3 - Are there institutions whose work excels in research related to the applicability of intelligent agents in virtual learning environments?

Q4 - What are the most researched knowledge areas in the context of intelligent agents in virtual teaching and learning environments?

Q5 - What are the goals of using intelligent agents in virtual teaching and learning environments?

Q6 - What are the main techniques and technologies being used to implement intelligent agents in virtual teaching and learning environments?

Q7 - What are the main results found in the studies, considering the object of analysis?

To contribute to the results of this study, we defined the search languages, the scientific knowledge bases, descriptors, as well as the exclusion and inclusion criteria for correlated works, considering the period between 2009 and 2023 due to the relevance and growth of research that discusses innovation in teaching and learning relationships from the incorporation of technologies.

2.2 Data collection and analysis

To subsidize the choice of articles for the search for answers to the guiding questions, the following steps were taken:

a) *Database identification by selecting related papers published between 2010 and 2022 in the following scientific databases:*

Table 1 - Databases

Id	Databases
01	EEE Xplore Digital Library
02	Scientific Research
03	ScienceDirect
04	SpringerLink
06	Scielo
07	Portal of CAPES Periodicals:
08	Digital Library of the Brazilian Computer Society
09	USP's Digital Library of Theses and Dissertations
10	Google Scholar

b) *Identification of articles in scientific databases using descriptors, including Boolean operators, as follows:*

Table 2 - Descriptors

Id	**Databases**
01	Intelligent Agents
02	Virtual teaching and learning environments
03	Intelligent agents and virtual teaching and learning environments
04	Intelligent agents or virtual teaching and learning environments
05	Intelligent agents
06	Virtual environments
07	Learning management system
08	Education
09	Artificial Intelligence
10	Artificial neural network

c) *Inclusion criteria took into consideration convergence with the object of study, seeking to identify and analyze documents by selecting qualified related works such as:*

- A1, A2, A3 and A4: scientific articles published in scientific journals, especially because they have a wider audience, indexed in renowned databases;
- B1, B2, B3 and B4: scientific articles published in recognized scientific journals, relevant and convergent results with the object of study;
- C: papers from scientific events, such as congresses and conferences with relevant and convergent results with the object of study.

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2.3 Text mining

To contribute to the data analysis, the text mining technique was used (VIVIAN et al., 2022), which allowed the extraction of important information, such as keywords, topics, concepts, and relationships between terms, through the Orange software, an open source data analysis and text mining tool that can be accessed at https://orangedatamining.com/. The data analysis process was carried out considering the following steps:

a) Importing the files: the files were imported in plain text format or in PDF file format;

b) Pre-processing: The pre-processing stage involved the removal of stopwords in Portuguese and English. Stopwords are words that appear frequently in the texts, but do not contain information relevant to the analysis;

c) Application of analysis tools: at this stage, analysis tools were applied, such as word frequency, keyword extraction, and topic analysis, which allowed a deeper understanding of the content of the texts;

d) Results visualization: the visualization of the results was carried out using graphs and tables that facilitated the identification of patterns and trends;

e) Interpretation of results: the interpretation of results was performed by means of correlation analysis and clustering. Correlation analysis allowed us to identify the relationships between words and topics, while clustering grouped the texts based on their thematic similarity.

2.4 Summary of the results

To ensure the relevance of the materials selected for the research considering the steps described, an initial sample of 67 abstracts of related works was read and verified. After applying the inclusion and exclusion criteria, the number of articles was reduced to 15, which constitute the final set of papers completely analyzed to contribute to the answers to the research questions. To illustrate, the following diagram describes the steps in the process:

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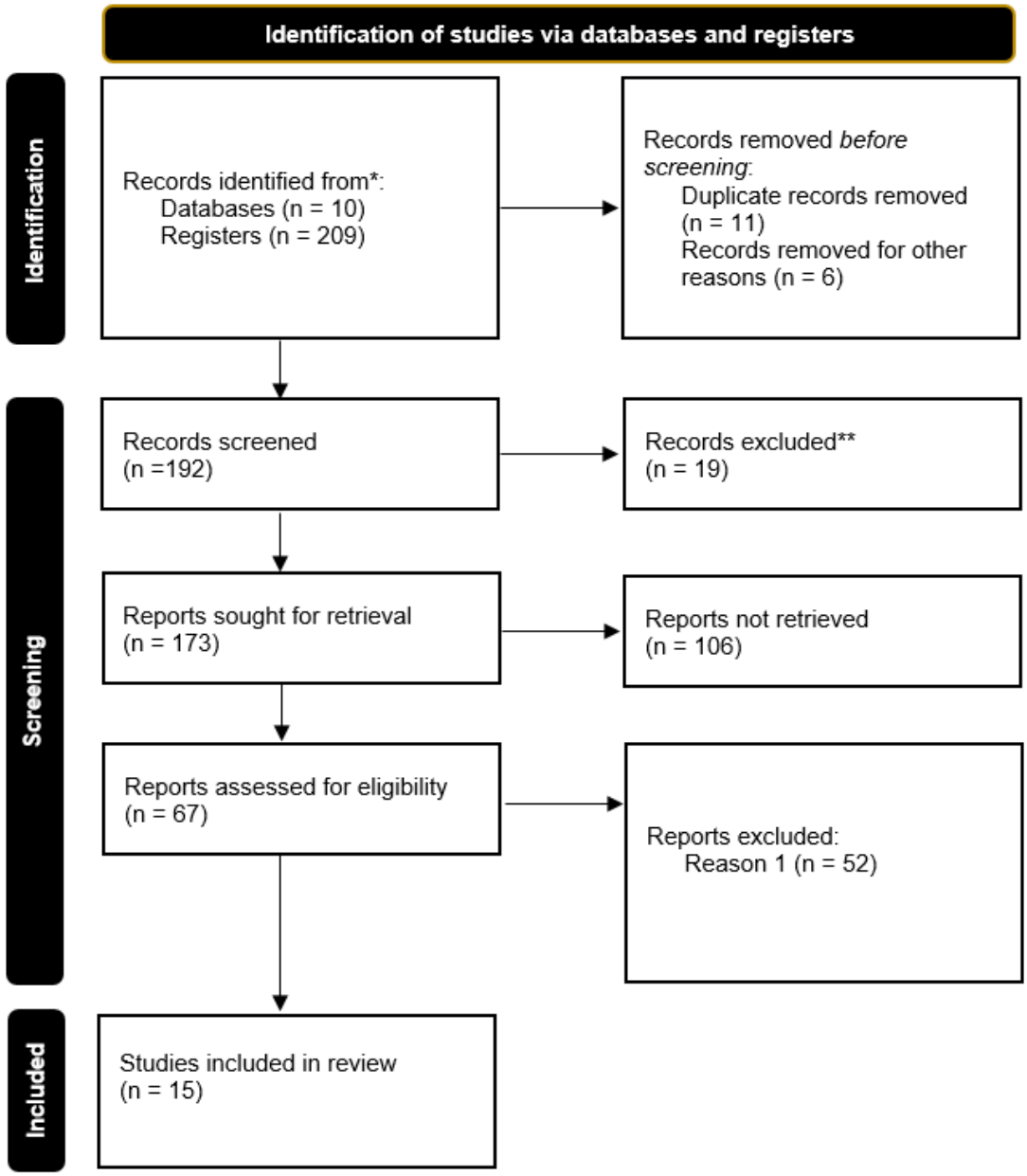

Figure 1 - Systematic review flow diagram, adapted from PRISMA (PAGE et al., 2021)

To identify similar studies used as a basis for this systematic review, the technique of term frequency analysis was applied, considering Pearson's correlation coefficient. This technique allowed the identification of terms with a high frequency of occurrence in studies related to the object of investigation, enabling the selection of the most relevant materials for critical analysis. From the selected studies, the discussions and analyses necessary for the construction of this study were conducted.

3. RESULTS AND DISCUSSION

The analysis of the 15 papers allowed us to obtain data related to the questions investigated in this systematic review. Furthermore, text mining procedures were employed in the resulting corpus, aggregating a total of 29,276 words. Below is the complete list with all the terms, quantity, and language:

Table 4 - Recurrent terms

N.	TERMS	QTY	LANGUAGE
1	Inteligência Artificial	3023	Português
2	Agentes Inteligentes	2388	Português
3	Artificial Intelligence	2.286	Inglês
4	Ambientes Virtuais De Ensino E Aprendizagem	2215	Português
5	Intelligent Agents	1.558	Inglês
6	Aprendizagem Adaptativa	1.555	Português
7	Learning Management System	1.466	Inglês
8	Tecnologias Educacionais	1.223	Português
9	Virtual Learning Environments	1.189	Inglês
10	Metodologias Ativas	1.120	Português
11	Artificial Neural Network	1.119	Inglês
12	Educação A Distância	1118	Português
13	Aprendizagem Colaborativa	1.021	Português
14	Design Instrucional	1.002	Inglês
15	E-Learning	1.002	Inglês
16	Gamificação	889	Inglês
17	Personalized Learning	871	Inglês
18	Plataformas Educacionais	789	Português
19	Machine Learning Algorithms	779	Inglês
20	Intelligent Tutoring Systems	745	Inglês
21	Mineração	690	Português
22	Educational Data Mining	676	Inglês
23	Gamification	552	Inglês
Total Vocabulary		29276	

Table 4 illustrates the dataset, which presents a list of the 23 most frequent terms related to the object of study, considering terms in Portuguese and English. The five most common terms are:

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1. Artificial Intelligence;
2. Intelligent Agents;
3. Virtual teaching and learning environments;
4. Adaptive Learning;
5. Educational Technologies.

The total number of terms in Portuguese is 19, corresponding to 63.33% of the total, while the total number of terms in English is 11, corresponding to 36.67% of the total. Below is an illustration considering the data obtained.

Figure 2 - Word cloud

The results achieved through text mining allowed the vision about the corpus under analysis to be broadened, contributing to broaden the grounds to provide data to expand the discussions provoked from the guiding questions as described below:

Q1 - What are the scientific databases with the highest rate of publications considering the research categories?

Table 5 - Databases

Id	Databases	Quantity
01	IEEE Xplore Digital Library	01
02	Scientific Research	01
03	ScienceDirect	01
04	SpringerLink	03

06	Scielo	01
07	Portal of CAPES Periodicals:	02
08	Digital Library of the Brazilian Computer Society	01
09	USP's Digital Library of Theses and Dissertations	02
10	Google Scholar	03

Consulting the varied and relevant databases provided access to a variety of works, including periodicals, theses, dissertations, and books, in related areas of knowledge, allowing an understanding of the scope of the object of study.

Q2 - What is the stratum of the scientific productions, considering the correlated papers identified following the inclusion and exclusion criteria?

The preparation of this systematic review considers the evaluation of the quality of scientific productions related to the research categories. To perform this evaluation, the stratum of related papers can be used as an indicator of quality and impact of publications in the study area, as described below:

Table 6 - Stratum of related works

Id	Periodicals	Qualis
01	Computers & education	A1 for education, computer science and interdisciplinary
02	Brazilian Journal of Computer Science in Education	A4 for interdisciplinary/computer science
03	Magazine educates more	B3 for education/interdisciplinary
04	Smart learning environments	B1 for teaching and computer science
05	Essay - evaluation and public policies in education	A1 for education and interdisciplinary
06	Brazilian Journal of Computer Science in Education	A4 for computer science, education, and interdisciplinary
07	IEEE Access	A3 for education, computer science, and interdisciplinary
08	Digital Themed Education	A1 for education and interdisciplinary
09	Education and Information Technologies	A1 for education, computer science and interdisciplinary
10	Scientific Journal in Distance Education	A2 for education and interdisciplinary
11	Creative Education	C for education, computer science and interdisciplinary

This analysis of the strata of scientific productions is important to assess the quality and relevance of the selected works, as well as to identify the main trends and gaps in the field of study.

Q3 - Are there institutions whose work excels in research related to the applicability of intelligent agents in virtual learning environments?

Table 7 - Educational Institutions

Id	Educational Institutions
01	Senai Cimatec University Center
02	University of the State of Bahia (UNEB)
03	Federal Institute of Bahia (IFBA)
04	Federal Institute of Education, Science and Technology Goiano (IF Goiano)
05	Federal Institute of Santa Catarina (IFSC)
06	Federal University of Health Sciences of Porto Alegre
07	Federal University of Uberlândia (UFU)
08	Federal University of Santa Catarina (UFSC)
09	Federal University of Rio Grande do Sul (UFRGS)
10	University of Vale do Rio dos Sinos
11	University of São Paulo (USP)
12	Federal Institute of Alagoas (IFAL)
13	Department of Statistics, University of Gujrat - Pakistan
14	International Black Sea University - Georgia
15	Universiti Teknologi Malaysia (UTM).
16	University, Saudi Arabia
17	University of Leeds, U.K. - United Kingdom
18	University of the South Pacifc Suva - Fiji

The geographical distribution of the papers considering their origin and generating evidence on both diversity and concentration of research. Of the 15 papers, 10 (67%) were produced by American universities, indicating a strong presence and influence of these institutions in the study area in question. Brazilian universities also had a significant representation, with the production of 4 papers (27%). The University of Sydney, Australia, has one paper (6%) published in the area in question.

Q4 - What are the most researched knowledge areas in the context of intelligent agents in virtual teaching and learning environments?

Table 8 - Knowledge area

Knowledge area	Large Area	Number of publications	%
Artificial Intelligence (AI):	Computer Science	22	32,8%
Education	Humanities	18	26,8%
Cognitive Psychology	Humanities	03	4,4%
Software Engineering	Computer Science	14	20,9%
Pedagogy	Humanities	06	9%
Mathematics	Exact and Earth Sciences	04	6%
Total		67	

In the context of intelligent agents in virtual teaching and learning environments, the most researched areas are Computer Sciences and Human Sciences. Considering the area of knowledge, Artificial Intelligence (AI) leads with 22 publications (32.8%), followed by Education with 18 publications (26.8%). Software Engineering also had a significant representation, with 14 publications (20.9%). Cognitive Psychology and Pedagogy had 3 (4.4%) and 6 (9%) publications, respectively. The data indicate that research in this context involves a combination of knowledge in information technology and human sciences, such as education and psychology.

Q5 - What are the goals of using intelligent agents in virtual teaching and learning environments?

The use of intelligent agents in virtual teaching and learning environments aims to enhance the educational experience for teachers and students. These goals include personalizing learning by allowing the system to adapt the content, pace, and level of difficulty to individual needs. Intelligent agents can also be designed to help students improve academic performance by providing personalized feedback and guidance throughout the learning process. In addition, they can facilitate social interaction in virtual learning environments by creating opportunities for collaboration, discussion, and feedback among students. Another advantage is the reduction of students' cognitive load by providing support for tasks such as information organization, concept review, and problem solving. Finally, intelligent agents can also be used to increase student motivation by providing positive feedback, encouragement, and rewards for engagement and learning progress.

Q6 - What are the main techniques and technologies being used to implement intelligent agents in virtual teaching and learning environments?

In order for agents to perform their functions efficiently and effectively, it is relevant to consider the use of technologies that allow their implementation. In this sense, some approaches have been used to enhance virtual teaching and learning environments that can promote innovation in teaching and learning relationships and provide a personalized and adaptive learning experience. Among them are recommendation systems, which suggest learning content based on the user's preferences and browsing history, adaptive learning models, which customize the learning process according to the individual needs of students, and pedagogical agents, which interact with students and provide personalized feedback and guidance throughout the learning process. In addition, learning support agents help students with specific tasks, and virtual and augmented reality technologies are used to create immersive virtual environments and increase student motivation and engagement. Finally, educational data analytics uses data analytics to provide insights into student performance and behavior, allowing educators to tailor the learning experience to individual needs.

Q7 - What are the main results found in the studies considering the object of analysis?

Considering the analysis of fifteen related papers, it was possible to observe that the use of intelligent agents in virtual teaching and learning environments have proven effective in improving performance in both teaching practice and student learning. A summary of the results follows:

Table 8 - Results

Id	Related work	Goal	Main results
01	Akyuz(2020)	Analyze the impact of intelligent tutoring systems on personalized learning.	The results suggest that using these systems can improve student motivation and performance, as well as promote autonomous learning and self-efficacy.
02	Asif. et al. (2017)	Build an educational data mining analysis to identify factors that influence college students' performance.	The results indicated that students' level of participation in academic activities and their average grade in prerequisite subjects are significant

			factors in predicting academic performance.
03	Costa and Fernandes (2021)	Propose an automated planning model based on genetic algorithms and Bloom's Taxonomy for sequencing pedagogical actions in the classroom.	The results indicated that the proposed model is able to generate sequences of activities that promote student learning and engagement.
04	Freitas et al. (2021)	Propose an intelligent agent-based architecture to integrate virtual learning environments.	The results indicated that the use of intelligent agents can improve student interaction with the virtual learning environment and promote personalization of learning.
05	Yağcı(2022)	Analyze academic performance using machine learning algorithms. The information included demographics, test scores, and class attendance, and was analyzed to make the predictions.	It has been evidenced that machine learning algorithms can be used to predict students' academic performance with high accuracy.
06	Palomino(2022)	Present a gamification approach for virtual learning environments that focuses on narrative and user experience.	The research highlights the importance of game design in creating engaging and effective learning experiences.
07	Parreira et al. (2021)	To analyze teachers' perceptions and evaluations of the use of artificial intelligence technologies in education.	Challenges have been identified, such as the need for training to use these technologies and concerns about the privacy of student data.
08	Reis et al. (2018)	Build a systematic review on intelligent tutoring systems that detect students' emotions.	The research highlights the importance of considering students' emotions during learning to improve engagement and effectiveness.
09	S. Alserhan et al. (2023)	Propose a virtual environment based on learning management systems.	The platform includes features such as adaptive feedback and data analytics to support personalized learning.
10	Silva and Cruz (2017)	To present a case study on the use of data mining by applying artificial neural networks to predict student profiles.	The results signalized the identification of each student's profile, thus reducing the time spent by the institution to detect possible teaching deficiencies, allowing the

			adoption of proactive actions to stimulate the students, aiming to overcome the high dropout and failure rates.
11	Santos et al. (2021)	Discuss the technological prospects for integrating Artificial Intelligence and virtualization into teaching and learning environments.	The results point to challenges and possibilities related to personalizing teaching, adapting content, and automated assessment, among other issues.
12	Sharma and Harkishan (2022)	Develop an intelligent tutoring system for teaching computer programming in the Pacific region, with the goal of providing personalized feedback to students and improving teaching effectiveness.	The results showed that the system was well received by the students and had a positive impact on academic performance.
13	Vivian et. Al. (2022)	Build a systematic literature review on educational data mining and sentiment analysis in virtual learning environments.	The authors identify trends, gaps, and challenges, highlighting the importance of considering the ethical and privacy aspects of data.
14	Zawacki-Richter et. Al. (2019)	To build a systematic literature review on the use of Artificial Intelligence in higher education, with emphasis on teaching and learning applications.	The authors emphasize the need to involve educators in the process of developing these technologies to ensure that they meet the real needs of students and teachers.
15	Zem(2017)	Propose a quality assessment approach for semantic web-based educational systems.	The author presents a model for evaluating usability, accessibility, content quality, and other aspects relevant to the success of these systems.

Another result that unfolds from this study points out that most of the articles (86.6%) were published between 2017 and 2023, totaling 13 papers. The year 2022 had the highest number of publications (4 articles), representing 26.7% of the total publications analyzed. Of the selected articles, 07 were published in English and 08 in Portuguese. The studies analyzed include the use of intelligent tutoring systems, adaptive educational games, virtual learning environments with intelligent agents, mobile learning systems, and even the use of machine learning to predict

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cognitive load in simulators. All presented relevant results, demonstrating the potential of intelligent technologies to boost teaching and learning relationships.

4. FINAL CONSIDERATIONS

This paper presented a systematic review of the literature investigating the application of intelligent agents in virtual teaching and learning environments. The review highlights that this approach has been a growing area of research in recent years, with a significant number of studies exploring its benefits and challenges. After selecting 15 related papers following the fundamentals of Kitchenham's methodology and applying inclusion and exclusion criteria, it was possible to understand the breadth of the object of study in more depth, identifying the main techniques and technologies, as well as the objectives achieved.

It was observed that education, psychology, and computing are the most researched areas of knowledge in the context of intelligent agents in virtual teaching and learning environments. In addition, a relevant number of objectives achieved were identified, including personalizing learning, improving academic performance, facilitating social interaction, reducing cognitive load, and increasing student motivation.

It was also possible to identify relevant applications of intelligent agents in virtual teaching and learning environments, such as recommendation systems, adaptive learning models, pedagogical agents, learning support agents, virtual and augmented reality. These approaches have the potential to contribute to the evolution of teaching and learning relationships by providing a more personalized, adaptive, innovative, and interactive environment.

While the review highlights the opportunities offered by the use of intelligent agents in virtual teaching and learning environments, it also points to the challenges faced in applying these technologies, such as the difficulty in integrating them with existing pedagogical practices, the need for training and capacity building of teachers and students, and concerns about ethical and data privacy issues.

Finally, the systematic review pointed to future research trends and perspectives in the area, highlighting the need for further studies and critical evaluation of the approaches used. The use of intelligent agents in virtual teaching and learning environments offers a number of relevant opportunities to enhance education and promote more effective and meaningful learning, but challenges need to be addressed before this approach can be widely used.

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