

ORIGINAL

Smart Tutors: improving the quality of higher education through AI

Tutores Inteligentes: mejora de la calidad de la educación superior a partir de la IA

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Cite as: Rodríguez Cairo D, Ramírez Echavarría Y. Smart Tutors: improving the quality of higher education through AI. LatIA. 2023; 1:8.
<https://doi.org/10.62486/latia20238>

Submitted: 23-08-2023

Revised: 08-10-2023

Accepted: 14-12-2023

Published: 15-12-2023

Editor: Prof. Dr. Javier González Argote 

ABSTRACT

Intelligent Tutoring Systems (ITS) are revolutionizing higher education through artificial intelligence (AI), offering personalized and adaptive learning experiences. In this sense, the study aimed to analyze the impact of ITS on the quality of higher education based on AI. For this purpose, a bibliographic review was carried out that explored the main trends around the current topic. Among the findings, it was recognized that ITS use advanced algorithms, such as data mining and Bayesian networks, which allow educational content to be dynamically adjusted to meet the individual needs of students, improving learning effectiveness and keeping students more engaged and motivated. This integration was shown to significantly improve knowledge retention and reduce dropout rates through real-time, personalized interventions. In addition, a focus on the sustainability and scalability of these systems was evident, integrating sustainable design principles. These developments made it possible to ensure that intelligent tutors can be widely implemented in various educational institutions without losing their effectiveness, thus improving the quality of higher education in a sustainable and expansive manner.

Keywords: Smart Tutors; Artificial Intelligence; Personalization Of Learning; Sustainability; Higher Education.

RESUMEN

Los tutores inteligentes (*Intelligent Tutoring Systems*, ITS) están revolucionando la educación superior mediante la inteligencia artificial (IA), ofreciendo experiencias de aprendizaje personalizadas y adaptativas. En este sentido el estudio tuvo como objetivo analizar el impacto los ITS en la calidad de la educación superior a partir de la IA. Para ello se realizó una revisión bibliográfica que exploró las principales tendencias en torno al tema actual. Entre los hallazgos se reconoció que los ITS utilizan algoritmos avanzados, como minería de datos y redes bayesianas, que permiten ajustar dinámicamente el contenido educativo para satisfacer las necesidades individuales de los estudiantes, mejorando la eficacia del aprendizaje y manteniendo a los estudiantes más comprometidos y motivados. Esta integración demostró mejorar significativamente la retención de conocimientos y reducir las tasas de deserción escolar mediante intervenciones personalizadas en tiempo real. Además, se evidenció un enfoque hacia la sostenibilidad y escalabilidad de estos sistemas, integrando principios de diseño sostenible. Estos desarrollos permitieron asegurar que los tutores inteligentes puedan ser implementados ampliamente en diversas instituciones educativas sin perder su efectividad, mejorando así la calidad de la educación superior de manera sostenible y expansiva.

Palabras clave: Tutores Inteligentes; Inteligencia Artificial; Personalización del Aprendizaje; Sostenibilidad; Educación Superior.

INTRODUCTION

Artificial intelligence (AI) has revolutionized numerous fields of science, and higher education is no exception. Higher education today faces a number of challenges, including the growing demand from an increasingly diverse student population with different needs, interests, and learning styles. In addition, the rapid evolution of technology and changes in the labor market requires that educational programs constantly adapt to ensure that graduates acquire the skills they need to be successful.^(1,2,3,4,5,6)

In order to reduce the challenges facing higher education, intelligent learning environments emerge that are characterized by the integration of learning resources using intelligent and mobile technologies to provide personalized and inclusive learning experiences in the interrelationship of these processes.^(7,8,9,10,11)

It should be noted that the implementation of AI in education requires rigorous planning and appropriate training for both teachers and students. Academic institutions must ensure that AI is used ethically and responsibly. Under this premise, there has been an increase in guidance regarding the use and purpose of AI applications, without neglecting the search for the development of human intelligence as an essential factor in the use of this new technology.^(12,13,14,15,16)

In this scenario, Intelligent Tutoring Systems (ITS) are presented as a key innovation to improve the quality and accessibility of education. These systems use advanced AI algorithms to provide personalized educational support, adapting to the individual needs of learners while enabling real-time feedback.^(17,18,19,20)

Intelligent tutoring systems (ITS) are computer applications designed to facilitate the teaching-learning process as a collaboration between the virtual tutor and the student. Their goal is to effectively deliver and assist in learning specific concepts. The design and development of these systems are based on the principles of cognitive psychology, educational research, and computer science.⁽¹⁸⁾

Computer-assisted instruction through intelligent tutoring systems (ITS) has its origins in the 1960s, when they began to be researched and developed in academic centers and universities. However, it was only with the advent of microcomputers that these systems gained greater relevance and implementation.^(20,21)

Initially, these systems focused on providing basic tutoring and tracking student progress. With the advancement of technology and the development of more sophisticated algorithms, ITS has improved in its customization and adaptability. At their core is the implementation of data mining techniques and Bayesian networks that facilitate the analysis of these systems on large volumes of educational data, identifying patterns and dynamically adjusting the educational content to meet the specific needs of each student.^(22,23)

Furthermore, the integration of ITS in real educational environments has proven to be a crucial step. In this sense, their application in authentic classrooms and educational programs has generated accurate assessments with systematic adjustment based on direct feedback from students and educators. This ability to adapt to real contexts is a transcendental step for their acceptance and success in higher education.^(12,13)

A relevant aspect of the implementation of intelligent tutoring systems (ITS) in higher education is their ability to address problems inherent to the teaching-learning process, whose inability to be solved has led students to experience various negative emotional responses, such as frustration, demotivation, lack of personal fulfillment and even academic stress. Under this perspective, ITSs, by offering instruction tailored to the needs of each student, have the potential to mitigate these problems and achieve better results, resulting in greater academic satisfaction and well-being.^(19,24,25,26)

Additionally, the sustainability and scalability of intelligent learning assistants have been highlighted as primary areas of study. These advances seek not only to optimize the use of computational resources but also to ensure that the systems can be deployed in diverse environments without undermining their ability to improve academic outcomes.^(27,28)

In this way, intelligent tutors become a significant tool in the application of AI in higher education, integrating effectively in real educational contexts to transform the learning experience and sustainably improve educational quality. Therefore, the present study aims to analyze the impact of intelligent tutor systems on the quality of higher education based on AI.

METHOD

For the development of this literature review article, an exhaustive search of the relevant scientific literature was carried out. This is based on a qualitative approach with a descriptive scope.^(29,30)

The search strategy used included the review of electronic databases such as Scopus, Web of Science, and Google Scholar, using the following categories combined: intelligent tutor systems, higher education, artificial intelligence, sustainability, and personalization of learning. The selection criteria focused on the relevance, timeliness, and pertinence of the topic (table 1).

Table 1. Selection Criteria		
Criteria	Inclusion	Exclusion
Type of document	Scientific journal articles	Books, theses, conferences
Subject	Studies addressing the use of intelligent tutoring systems in higher education.	Studies focusing on other educational levels
Date of publication	Articles published between 2018 and 2024	Articles published before 2018
Language	Articles published in English or Spanish	Articles in another language

Initially, an exhaustive review of the titles and abstracts of the articles identified in the bibliographic search was carried out. Subsequently, a detailed reading of the articles was carried out, which made it possible to determine their relevance and quality.

In this way, relevant information was extracted from the selected articles, such as the objectives of the study, the context of the research, the methodologies employed, the main findings, and the conclusions derived. This information was organized and processed to form a comprehensive thematic analysis of the identified findings.

Finally, the findings were synthesized to provide an overview of how intelligent tutoring systems are improving the quality of higher education. Among the main trends identified were Personalization and Adaptability of Learning, Integration of Artificial Intelligence in the Real Educational Context, and Sustainability and Scalability of ITSs.

RESULTS AND DISCUSSION

Personalization and Adaptability of Learning

Intelligent tutoring systems are designed to deliver highly personalized and adaptive learning experiences by leveraging the capabilities of artificial intelligence. These systems use advanced algorithms that allow them to dynamically adjust learning content and activities based on data collected in real-time about each student's specific needs and performance.^(18, 29)

Personalization entails that each learner is assessed and taught individually. For this, an AI-based system can be used to assess the learner's level and determine the most appropriate content. There are several methods for delivering personalized content, with adaptive learning and adaptive learning being the most widespread.⁽²⁹⁾

Adaptive learning and adaptive learning methods refer to educational approaches that dynamically adapt to the individual needs and abilities of learners. Several studies agree that these approaches share the following characteristics.^(30,31,32,33,34)

Table 2. Characteristics of the approaches: Adaptive learning and adaptive learning	
Adaptive learning	Adaptive learning
Refers to educational approaches that use advanced technologies such as artificial intelligence and data analysis to dynamically adjust content, activities and teaching strategies.	It refers to the student's ability to adapt and regulate his or her own learning process.
It is based on the collection and analysis of student performance information in real time.	It implies that the learner has an active role in making decisions about his or her learning strategies, resources and pace of learning.
It allows customizing the learning experience to meet the unique needs of each learner.	It requires the learner to develop metacognitive skills such as self-monitoring and self-assessment.
Adaptive learning systems can automatically adjust the difficulty, pace and sequencing of materials.	Allows the learner to adjust their learning approaches based on their individual strengths, weaknesses and preferences.
The goal is to optimize the learning process and maximize the success of each student.	Encourages autonomy and self-regulation of learning by the learner.

A key aspect involved in the adaptability of learning guaranteed by these systems is the application of data mining techniques and Bayesian networks to identify patterns in learner behavior. Data mining consists of extracting relevant knowledge from large volumes of information stored in various sources, such as databases, data warehouses, or other data repositories.^(35,36) As a function of this, it allows intelligent tutors to analyze large volumes of educational data, such as responses to assignments, response times, and interactions in the virtual classroom, to detect trends and anticipate difficulties.^(18,23,37,38,39)

Bayesian networks, on the other hand, are used to model the probability of certain educational outcomes based on the student's previous performance and other contextual variables. This is made possible by allowing prior beliefs about conditional dependencies between variables to be encoded into the structure of their model.^(22,40) This probabilistic approach helps intelligent tutors to customize recommendations and educational resources accurately and effectively.^(18,37,41)

In addition, intelligent tutors incorporate machine learning techniques that allow them to continuously

improve their recommendations.^(42,43) As they interact with more students, these systems refine their algorithms, resulting in even more precise personalization.⁽⁴⁴⁾ For example, they can identify which teaching methods are most effective for certain student profiles and adjust the approach accordingly. This level of adaptability not only improves learning effectiveness but also keeps learners more engaged and motivated.^(13,18)

In this way, intelligent tutoring systems represent an innovative technological solution capable of significantly optimizing educational outcomes while fostering greater student engagement and motivation.

Integration of AI in the Real Educational Context

The implementation of intelligent tutor systems (ITS) in real educational contexts has experienced significant growth, with multiple opportunities to transform education. Currently, their integration into classrooms and educational programs is being observed, allowing a more accurate assessment of their effectiveness in authentic conditions beyond controlled environments or laboratories.⁽¹⁸⁾

Over the past two decades, the teaching effectiveness of these ITSs has been found to almost parallel that of real-life teachers, with the key difference being that the solutions provided by ITSs are generated in real-time from student input rather than being predefined as is the case with Computer-Aided Interaction.⁽¹⁸⁾ This integration in real contexts is critical to adjust and optimize ITS functions based on direct feedback from students and educators, ensuring that the systems are truly useful and adaptive.

Online tutoring can take place in two modalities or combination. In the synchronous modality (real-time), a tutor designated by the teacher of the subject prior to the beginning of the course establishes the possible doubts and clarifications that must be ready to be answered at a predetermined time. Both the consultations and the answers will be supervised by the teacher, who will issue observations during his classes when he considers it necessary to reinforce a topic. For this purpose, means such as chats, videoconferences, or voice calls with a real teacher hired for these functions can be used. On the other hand, asynchronously, resources and times will be established that the student can use when he/she cannot reach a class or wants clarification of a topic but cannot do it in real time. The difference is that the response will no longer be either face-to-face or, at the same time, the teacher will be connected by digital means.^(12,45,46)

Indicator	Synchronous Online Tutoring	Asynchronous Online Tutoring
Interaction	Real-time interaction between tutor and student.	Deferred interaction, without simultaneous overlapping.
Flexibility of schedules	Less flexible, requires tutor and student to agree on a schedule.	More flexible, student accesses when desired.
Feedback	Immediate and personalized feedback.	Feedback can be slower and generic.
Collaboration	Easier and more dynamic, allows group work.	More challenging, requires better organization.
Tutor Availability	Limited to agreed schedule.	Extensive, student can access when needed.
Technology Required	Videoconferencing, digital whiteboard, etc.	Forums, email, online resources.
Efficiency	Allows for more intensive and detailed interaction.	Allows for greater independence and autonomy of the learner.
Appropriate for	Topics that require detailed explanation by the tutor.	Review, practice and self-study topics.

From the previously represented table, it is possible to conclude that the synchronous modality presents greater possibilities and effectiveness in cognitive outcomes than the asynchronous modality, which is similar to previous studies.^(47,48,49) Likewise, research based on the pandemic context of COVID-19 reflects similar results where synchronous e-learning environments are associated with greater support for basic psychological needs and overall student satisfaction compared to asynchronous environments.^(50,51)

Research has shown that ITSs can dramatically improve knowledge retention and reduce dropout rates through personalized interventions based on real data. These systems use real-time data analytics to identify patterns of student behavior and performance. For example, if a student shows signs of struggling with a particular topic, the ITS can provide additional resources or change the teaching strategy to facilitate comprehension.^(1,7,52)

Along these same lines, numerous studies report findings regarding the relationship between self-regulated learning and intelligent learning environments, including ITS. The student's ability to manage his learning process develops thinking, metacognition, and, with it, the learning strategies essential for academic success. That is why it is considered a tool that supports and strengthens self-regulated learning.^(7,37,52,53,54,55)

Thus far, the implementation of intelligent tutoring systems in real educational contexts has been shown to

be highly beneficial. As reflected, ITSs not only support students by providing personalized interventions and immediate feedback but also help educators optimize their teaching strategies to achieve better educational outcomes.

Sustainability and Scalability

An emerging trend in the field of intelligent tutors is the focus on the sustainability and scalability of these systems. Current research is devoted to exploring how to sustain the effectiveness of intelligent tutors on a large scale and in the long term, which is crucial for their widespread implementation in diverse educational institutions.^(13,34,56,57)

To achieve this, sustainable design principles are integrated into the development of intelligent tutors. This includes the efficient use of computational resources with the aim of reducing operational costs and minimizing environmental impact. For example, the use of optimized algorithms that require less processing power and memory contributes significantly to the sustainability of the system.^(37,58,59)

Also, the ability to adapt to different educational contexts is another crucial aspect of the scalability of intelligent tutors. These systems must be flexible enough to function in a variety of educational settings, from large universities to small community institutions. This implies not only the ability to customize educational content according to local needs but also the ability to integrate with each institution's existing technological infrastructure.^(27,60,61)

Thus, the efficient management of technological resources, together with the ability to adapt to different learning environments, ensures that ITSs can consolidate their long-term impact and guarantee successful implementation at a high level.

CONCLUSIONS

Intelligent tutoring systems (ITS) represent a key innovation in the application of artificial intelligence to higher education. These systems have evolved from providing basic tutoring to offering increasingly personalized and adaptive learning experiences. Advanced techniques such as data mining and Bayesian networks have enabled ITSs to analyze large volumes of educational data, identify relevant patterns, and dynamically adjust content to meet individual student needs, improving knowledge retention and reducing dropout.

The integration of ITSs into real educational environments has enabled their rigorous evaluation and continuous adjustment, facilitating their acceptance and success. In addition, research has focused on ensuring the sustainability and scalability of ITS by developing standardized frameworks for their effective implementation in various institutions. With this in mind, it is possible to affirm that intelligent tutoring systems have positioned themselves as a promising solution to address the challenges of higher education.

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FINANCING

The authors did not receive funding for the development of this research.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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