EXPLORING THE RELATIONSHIP BETWEEN ARTIFICIAL INTELLIGENCE, AUTONOMOUS LEARNING, AND SKILLS REQUIRED FOR SUCCESS IN THE 21ST CENTURY

Claudia Lengua-Cantero 1
Manuel Caro-Piñeres2
Jairo Montero Pérez3

ABSTRACT

Objective: The topic of this study focuses on how autonomous learning enhances 21st century competencies through the use of artificial intelligence and educational technologies. The objective is to explore the relationship between autonomous learning, artificial intelligence and 21st century competencies.

Theoretical Framework: The main concepts and theories underpinning the research were: artificial intelligence in education, autonomous learning and 21st century skills.

Method: The methodology adopted for this research was a systematic mapping of 991 scientific articles published in the last ten years in three databases

Results and Discussion: The results obtained revealed that artificial intelligence is still in its infancy in the use of data and machine learning systems, until its impact on society as a whole is better understood. Likewise, critical thinking, collaborative work and problem solving are the competencies that show a strong relationship with both autonomous learning and artificial intelligence.

Research implications: the main fields of study were: self-regulated learning, 21st century competencies and their relationship with artificial intelligence. The impact could be seen in the educational, economic, environmental and social sectors.

Keywords: 21st Century Skills, Autonomous Learning, Artificial Intelligence, Learning, Educational Technologies.
Exploring the Relationship Between Artificial Intelligence, Autonomous Learning, and Skills Required for Success in the 21st Century

more comprehended. In the same form, critical thinking, collaborative work, and problem-solving are competencies that show a strong relationship with autonomous learning and artificial intelligence.

Implicações da pesquisa: os principais campos de estudo foram: aprendizagem autorregulada, competências do século 21 e sua relação com a inteligência artificial. O impacto pode ser visto nos setores educacional, econômico, ambiental e social.


EXPLORAR LA RELACIÓN ENTRE LA INTELIGENCIA ARTIFICIAL, EL APRENDIZAJE AUTÓNOMO Y LAS HABILIDADES NECESARIAS PARA EL ÉXITO EN EL SIGLO XXI

RESUMEN

Objetivo: El tema de este estudio se centra en cómo el aprendizaje autónomo mejora las competencias del siglo XXI a través del uso de la inteligencia artificial y las tecnologías educativas. El objetivo es explorar la relación entre el aprendizaje autónomo, la inteligencia artificial y las competencias del siglo XXI.

Marco teórico: Los principales conceptos y teorías que sustentaron la investigación fueron: inteligencia artificial en la educación, aprendizaje autónomo y habilidades del siglo XXI.

Método: La metodología adoptada para esta investigación fue un mapeo sistemático de 991 artículos científicos publicados en los últimos diez años en tres bases de datos.

Resultados y Discusión: Los resultados obtenidos revelaron que la inteligencia artificial aún está en sus inicios en el uso de datos y sistemas de aprendizaje automático, hasta que se entienda mejor su impacto en la sociedad en su conjunto. Asimismo, el pensamiento crítico, el trabajo colaborativo y la resolución de problemas son las competencias que muestran una fuerte relación tanto con el aprendizaje autónomo como con la inteligencia artificial.

Implicaciones de la investigación: los principales campos de estudio fueron: el aprendizaje autorregulado, las competencias del siglo XXI y su relación con la inteligencia artificial. El impacto se puede ver en los sectores educativo, económico, ambiental y social.

Palabras clave: Habilidades del Siglo XXI, Aprendizaje Autónomo, Inteligencia Artificial, Aprendizaje, Tecnologías Educativas.

RGSA adota a Licença de Atribuição CC BY do Creative Commons (https://creativecommons.org/licenses/by/4.0/).

1 INTRODUCTION

The strengthening of 21st century skills through the use of artificial intelligence (AI) and autonomous learning constitutes a new strategy for the generation, optimization and use of knowledge, aimed at transforming and enhancing educational processes through the use of emerging educational technologies. However, in educational environments there are various structural problems, specific to each educational system and its actors, which become limitations to its application and effectiveness. Among the main causes are: a) resistance to change, which is related to the concern of the different representatives of the system to abandon...
traditional methods that are considered safe and effective, b) the lack of curricular updating, as they focus in traditional educational models and have not adapted their curricula to address 21st century skills, c) inadequate teacher training to teach and evaluate 21st century skills effectively and little support for them, translated into scarce resources and little time, necessary to acquire updated pedagogical skills and competencies, d) the excessive focus on memorization and standardized exams, and e) the digital divide and unequal access to technology for student populations, especially in rural or low-income areas.

The use of AI in educational centers represents a great challenge for education and scientific research as a pedagogical strategy, in that it constitutes a phenomenon that is radically changing society, as one of the main drivers of the fourth industrial revolution (4IR). Furthermore, taking into account the related problems in the educational sector and the evaluation of 21st century skills, in dimensions such as creativity, problem solving and critical thinking, this requires more flexible and authentic approaches, which are not always applied properly. In addition to this, the closure of educational centers and the confinement of the entire population due to SARS-CoV-2 (COVID19), for months, created an extraordinary situation, with effects on the assisted and in-person learning of students by the teacher, when using virtual education methodologies, mediated by technological limitations and deficient self-regulated learning strategies.

In teaching and learning processes, emerging educational technologies, in this case, artificial intelligence (AI), began to be used in the educational field as tools to assist teachers in the classroom. In this regard, education has evolved significantly in the last century, largely due to the use of technologies in the classroom. In addition to this, branches of research are emerging where autonomous learning, the development of 21st-century skills, and the use of educational technologies intersect in the teaching processes within educational institutions.

1.1 AUTONOMOUS LEARNING

It is also known as self-regulated learning and is understood through cognitive, metacognitive, behavioral, motivational, emotional, and affective aspects. Consequently, this concept has become one of the central pillars in research related to education. From the perspective of educational psychology within social-cognitive theory, students' learning is considered to be an active process in which they actively participate and seek academic
Exploring the Relationship Between Artificial Intelligence, Autonomous Learning, and Skills Required for Success in The 21st Century

achievement through three stages: self-observation, self-judgment, self-reaction, going beyond mere behavioral and contextual thinking (Panadero 2017).

In this sense, Zimmerman's social-cognitive theory develops three models of self-regulated learning: the first known as triadic analysis, which represents the interaction between the environment, behavior and the person, therefore, the students' abilities to carry out processes. Self-regulated learning processes include everything from personal aspects (cognition) to the influence of environmental events and behavior (Bandura 1986).

The second is the so-called cyclic phases, which considers self-regulated learning as an individual process and the interrelation of metacognitive and motivational processes. This considers three phases in the self-regulation process, such as: a) forecasting, which stipulates that students analyze tasks and plan objectives taking into account their motivations, b) the execution of their plan using monitoring and self-control, to be cognitively engaged and motivated and c) self-reflection, in which they evaluate the task and the plan carried out, generating feedback on success or failure and thus making adjustments in future performances (Zimmerman 2000). Finally, the third is the so-called Multi-Level, which consists of four phases for self-regulation to be achieved, such as: observation, emulation, self-control and self-regulation (Zimmerman 2000).

Likewise, in the analysis of the relationship between motivation and self-regulated learning, the existence of four phases was established: planning, monitoring, control and reflection. In that sense, cognition was incorporated with learning judgments and feelings, highlighting that the individual is the only one who can control his or her behavior by virtue of the learning context (Pintrich, 2000). In addition to the above, there is a work focused on explaining the role of goals in the self-regulated learning process for the achievement of tasks, where goals are bases for knowledge and behavior (Boekaerts & Rozendaal 2006). Along the same lines, the purpose of this type of learning is to generate an expansion of knowledge and skills, which involves personal goals in the development of tasks. Additionally, limits can be established to achieve their development, but leaving aside well-being and personal goals, and finally, commitments are protected, so attention is maintained towards goals and tasks (Boekaerts 2011).

On the other hand, from the metacognitive view, self-regulated students are active and maintain their learning through monitoring and metacognitive strategies (Winne et al. 2011). This model consists of four phases, which include: definition of tasks, setting goals and a plan, execution of study tactics and finally, this adapts metacognitively, when the student decides to make long-term changes in their motivation, beliefs and learning strategies (Efklides 2011).
Likewise, another model that includes a metacognitive background is the one developed by (Hadwin et al. 2017), in which, unlike the previous one, motivation and affect occupy a central role, and consists of two levels: the first called macrolevel, which includes the personal characteristics of the student, and a second level called microlevel, in which the interaction between the type of task and the characteristics of the student occurs (Efklides 2011).

Another vision of self-regulated learning, from the context of collaborative learning, establishes that self-regulation can occur collaboratively by sharing learning between individuals, this is based not on individual processes, but on a social and joint process (Hadwin et al. 2017), addressing crucial self-regulation in collaborative environments, which implies that individual cognitive, metacognitive, motivational, emotional and behavioral actions involve a process of interaction and collaboration, between students, to achieve shared goals (Hadwin et al. 2017). Finally, some recent studies describe self-regulated or autonomous learning as the capacity in which individuals achieve established goals, through planning, motivation and cognition (Theobald & Bellhäuser 2022). Likewise, a relationship has been established between school performance and this type of learning, with which students express feeling mostly satisfied and are less likely to abandon their studies (Liborius et al. 2019), because this type of learning is implemented appropriately, generates greater emotional, social and cognitive maturity in students, so by introducing it into the learning processes with strategies such as problem solving and critical thinking, it will be opportune to make changes and introduce innovative forms of teaching and learning that lead to better educational outcomes (Milheiro Silva et al. 2021).

1.2 ARTIFICIAL INTELLIGENCE IN EDUCATION

AI has a varied application, since thanks to the fifth generation of computers developed in Japan, a development career has been promoted in different areas, where education is not left out (Pérez, 1989). Likewise, the progress in the use of expert systems is evident, which aim to correctly reproduce the behavior of a human expert in a specific area (Liu et al. 2022). In this sense, expert systems have a large amount of information and reasoning processes, which can generate advantages in teaching-learning processes, and are conducive to their use because they do not depend on time or space (Liu et al. 2022). The application of AI is possible in a wide variety of fields and areas, being applicable in any area of human endeavor and its application in education involves educational research, in relation to consultation in databases and computerized libraries, as well as, allows specialized statistical processes in education, the
Exploring the Relationship Between Artificial Intelligence, Autonomous Learning, and Skills Required for Success in The 21st Century

simulation of processes, such as pilot experiments, and the manipulation of variables that in reality are complex in their modeling (Ponce 1994). Additionally, it helps in the training and advice of intellectual capital, voice recognition and its support in transcription, in addition to its application in teaching, which allows the training of trainers, the study of the interaction between the teacher and the student and support in the development of cognitive skills of the latter (Ponce 1994).

The use of AI in education is beneficial for teaching-learning processes, especially, pedagogical applications in big data can help in achieving students' competencies in the academic field (Garcia et al. 2020). For its part (Moreno Padilla 2019), mentions that AI allows the reduction of difficulties in access to learning, which thanks to it accelerates the development of global objectives that are around education, which allows generating an improvement in the learning outcomes (Moreno Padilla 2019). The use of AI in education, through the integration of systems, allowed the use of robots as teachers' colleagues. Also, it has allowed the improvement of teachers' efficiency, which has led to an improvement in the quality of the teaching provided (Chen et al. 2020). Thus, the incorporation of AI in education involves the use of adaptive chatbots to resolve doubts for students, the use of platforms for collaborative work, and the implementation of adaptive teaching systems, which are the best known and with greater experience, which consist of intelligent tutoring systems, providing personalized advice for learning, and are based on student profiles. Their great advantage is that they have costs that are considered lower than traditional means (Jara & Ochoa 2020).

1.2.1 Intelligent Tutor Systems

An intelligent tutor system (ITS) is a software system that uses artificial intelligence (AI) techniques to represent knowledge and interactions with students to teach them (Hillsdale & Erlbaum NJ 1998). Likewise, STIs support the idea of being able to impart knowledge, which seeks to emulate or imitate the behavior of a human tutor (Cataldi & Lage 2009). ITSs are a fundamental part of AI in education. One of the predecessors is computer-assisted instruction (CAI, Computer-Assisted Instruction) and the first ITSs were mainly outlined in the search for adaptive teaching. The objective of an ITS is to enable the computer to get involved in the teaching process using AI techniques (Huapaya 2009).

The ITSs are systems based on three types of complex knowledge, according to its goals and operation: a) domain knowledge, which is built based on topics from a specific area of knowledge, b) strategy knowledge and teaching methods, which is responsible for the
particular guidance method, and c) knowledge about the student, where learning styles are established (Huapaya 2009).

Now, the applicability of ITSs is very broad, since their use can help in the learning of a second language and the rehabilitation of aphasia, which consists of a strategy for efficiency in the learning process. To make this possible, some ITS provide visual, auditory or tactile information through its avatar (Macedonia et al., 2018). The main advantages of an ITS system are to imitate the behavioral patterns of a human tutor, this allows them to adapt to each need present in the students, in addition, the flexibility to display and deploy personalized content represents its greatest advantage (Cisneros Reyes et al., n.d.).

The ITS can be used for teaching physics, pedagogical systems for distance education, learning mathematics, algorithms in engineering courses, reading comprehension, teaching and learning algebra, culminating in a system of modules to learn to apply the principle of work and energy to solve dynamics problems. Therefore, it can be stated that STIs are innovative tools for the teaching-learning process, and generate an important impact in the educational context, to detect shortcomings and needs of individuals in a personalized way, which allows the design of an appropriate methodology for each student (Durango Hernández & Pascuas Rengifo 2015).

1.3 EDUCATIONAL TECHNOLOGIES

Educational technologies have become an integrative, living and polysemous concept in the context of pedagogy, due to the intervention of various sciences and disciplines, acquiring multiple meanings (Cabero 2009). The concept has evolved since military training in the United States, where it was necessary to implement tools with instructional programs to train soldiers and officers. From this need, it was defined as changes in learning in which graphic media and technological (Koschmann 2012). In this sense, educational technologies are considered as a systematic way of obtaining an optimal educational process using technology combined with teaching and learning techniques (UNESCO 1984).

On the other hand, some authors propose four paradigms around educational technologies, namely: a) computer-assisted instruction (CAI), focused on the instructional vision; b) intelligent tutoring systems (ITSs), related to processes cognitive AI; c) learning environments and their importance for conceptual understanding and problem solving, and d) computer-supported collaborative learning (CSCL), under which computers are used for the acquisition of knowledge and its experience with collaborative groups (Luján Ferrer & Salas Madriz 2011). In recent years, it is considered the discipline that studies learning processes
linked to media and/or digital platforms, within an instructional context (Serrano et al., 2016), thus, this type of tools contribute to the self-regulated learning of students (Cabero Almenara 2015).

1.4 LEARNING ENVIRONMENT

Learning environments are made up of physical spaces, however, they occur through interactions between human beings, which is why the physical space is only an instrument, given that the interaction with this space is where the learning processes really develop skills, to the extent that innovative processes are included and energized in the scenarios (Duarte 2003). Also, they must have certain characteristics, such as: the quality of resources, the flexibility to adjust to different contexts and adapt to technological changes, promote autonomous learning and interaction between students; In order for them to be responsible for their learning process individually and in groups as warranted, finally, they must be appropriate tools for the use of time and space (Castro Florez 2019).

1.5 21ST CENTURY SKILLS

1.5.1 Creativity

Creativity is a thinking skill considered within the competencies of the 21st century as a fundamental factor for improving the conditions of education. It is related to elements such as the environment, personality, and the development of higher cognitive processes. It has been studied by a variety of authors, including (González-Moreno & Molero-Jurado 2022), (Álamos & Montes 2022) y (Troncoso A. et al. 2022), among others, whose definitions point to a direct relationship with problem-solving, which allows for the generation of unconventional solutions. Likewise, the connection between learning and creativity enables the dynamic and comprehensive recognition of the talents and abilities that human beings possess (Muñoz Silva et al. 2021). The aforementioned components are immersed in all the daily processes that take place (Cárdenas Martínez 2019).

Likewise, creativity is a capacity present in anyone that arises spontaneously to solve problems or create knowledge. It emphasizes its influence in the educational context and identifies the variables related to it. According to the study conducted by this author, intelligence and academic performance are the most studied variables in relation to creativity.
at all academic levels (González-Moreno & Molero-Jurado 2022). Therefore, to achieve the effectiveness of true creative ability, several integrated actors are necessary within a synergistic objective that involves (Troncoso A. et al. 2022). Furthermore, a technical concept, a praxis that engages a community and its educational establishment, also suggests that it is essential to create optimal conditions for creativity to emerge. Additionally, (Troncoso A. et al. 2022) consider the challenge of systematizing creative stimulation in education from three dimensions: the curriculum, the student, and the teacher, through the implementation of strategies to address the challenges of the present.

1.5.2 Problem Solving

Problem solving is a scientific activity closely linked to education (Piñeiro et al. 2015). It is also the most essential part of mathematical learning, where students develop skills and abilities, including observation, data organization, analysis, hypothesis formulation, experimentation, application of procedures, verification, and providing explanations for the strategies used to solve problems (Zomeño et al. 2019). Furthermore, there is a need to explore alternatives different from traditional ones according to information processing models, emphasizing the benefits of contextualized learning and its relationship with the environment entorno (Piñeiro et al. 2015).

Finally, in problem solving, new perspectives are required to guide the methods and forms of teaching and learning, surpassing the trend of mere abstraction. It seeks to apply knowledge to real-world contexts and also requires new dispositions that guide students, grounded in theoretical explanations and reconceptualizations. These dispositions should provide the opportunity to explore a theory and facilitate a clearer understanding of the problem context, rather than reducing it to the formulation of abstract statements (Piñeiro et al., 2015).

1.5.3 Digital Literacy

Digital literacy in the educational context is a skill that encompasses the necessary components to communicate, access, use information, and solve problems through electronic tools (George Reyes & Avello-Martínez 2021). Agrees that the main objective of studying digital literacy is to analyze how virtual information is used in specific situations to achieve explicit educational purposes (George Reyes & Avello-Martínez 2021). Since this type of literacy is a social practice with different connotations, it depends on the environment in which
the individual operates. (Del-Moral Pérez et al. 2022), (Lisenbee & Ford, 2018) and (O’Byrne et al., 2018) believe that the use of digital applications for education is rapidly increasing, and there are applications that encourage students’ oral production (Del-Moral Pérez et al. 2022).

Other definitions are based on sequences of images that stimulate intellectual activity through a structure that organizes discourse coherently and logically. In this sense, it promotes learning through observation and exploration, thus contributing to autonomous learning. It enables students to activate their own strategies to achieve established goals (Del-Moral Pérez et al. 2022) and (Panadero & Alonso-Tapia 2014)

1.5.4 Effective Communication

Effective communication considers the action of transferring information in a message with two instances, a receiver and a sender through a medium or channel, which affects the transmission of the message (González 2021), (Panadero and Alonso-Tapia 2014). In this sense, it is one of the fundamental elements in the teaching-learning processes, because it allows the correct functioning of determinants such as voice, verbal and non-verbal language, listening and motivation. For communication to be effective, several requirements must exist: a) precision, that the language used is clear and accessible, reliable, b) that there is consistency to allow efficiency in the process and c) the information must be filtered, processed and frequently fed back (González 2021).

1.5.5 Collaborative Work

Collaborative work in the educational context is an invitation for students to jointly construct, through their combined efforts, talents, and individual competencies, the achievement of established objectives or goals (Maldonado, 2007). On the other hand, (Guitert & Siménez 2000) refer to collaborative work as a knowledge-building process in which each individual benefits from the interaction with group members. They also emphasize the importance of team members assimilating and taking ownership of the set goals and supporting each other to ensure that everyone participates and learns during the process. Collaborative work is characterized by individual responsibility of members regarding their performance within the group, which implies collaboration skills such as leadership and conflict resolution (Sanz et al. 2008). It’s also important to highlight that in collaborative work and cooperative work, the latter divides the tasks to be performed by each team member, and the primary
responsibility for knowledge construction lies with the teacher (Chaljub 2014), while in collaborative work, goals are shared throughout the process, and students self-manage knowledge.

1.5.6 Critical Thinking

Critical thinking is a set of questions and assessments aimed at making judgments or positions regarding a situation or idea. It is valued as a tool or skill that should be encouraged through education and applied in life (Morales Zúñiga 2014, p. 3). Similarly, it is considered a form of reasoning that connects thoughts and ideas substantiated by the same cognitive activity, which involves examining one's own ideas (Bejarano et al. 2014). In other words, it involves the development of metacognitive processes and also entails various cognitive processes such as making inferences, comparisons, refutations, among others. It also requires the application of logic and analysis. Therefore, it involves working on some cognitive skills considered essential for critical thinking, including interpretation, analysis, evaluation, inference, explanation, and self-regulation (Facione, n.d.).

This research was centered on the development of a systematic literature review, which allowed for exploring the existence of a relationship or lack thereof between the search categories "artificial intelligence (AI)" and "autonomous learning," in relation to "21st-century skills," across eight dimensions described in detail in the methodology. This study was carried out by obtaining information from specialized databases using Boolean and reserved operator search equations. It also involved the selection of scholarly articles based on criteria related to quality, empirical evidence of findings, and the publication year. In addition, a systematic literature mapping was conducted, enabling an analysis of information pertaining to the three study categories.

2 MATERIALS AND METHODS

The research was developed under a qualitative approach with a descriptive scope. Regarding the methodology of systematic review of scientific articles, systematic mapping was used (Petersen et al., 2008), as shown in Figure 1.
2.1 DEFINITION OF THE RESEARCH QUESTION

Q1: How have 21st century skills been enhanced through autonomous learning? Q2: What are the 21st century skills enhanced through Artificial Intelligence? and Q3: What 21st century competencies have been developed through the use of educational technologies?

2.2 EXECUTION OF THE SEARCH

Selection criteria: research articles, book chapters, research results, in Spanish and English in the SCOPUS, IEEE Xplore and Scielo databases.

Search categories: Autonomous Learning, Artificial Intelligence, Educational Technologies and Learning Environment

2.3 SELECTION OF RELEVANT ARTICLES

Subcategories for search: Collaborative work, Critical Thinking, Algorithmic thinking, Flexibility, Creativity, Problem solving, Digital literacy and Effective communication.

Exclusion criteria: studies that did not report empirical findings or literature that was only available in the form of abstracts or presentations and a temporal restriction of 12 years of publication from 2010-2022.
2.4 SEARCH FOR KEY CONCEPTS

Keywords: "Autonomous learning" and "Artificial Intelligence", "Autonomous learning" and "Artificial Intelligence", "Learning environment" and "Artificial Intelligence"

2.5 SYSTEMATIC MAPPING AND DATA EXTRACTION

An AC biplot type visualization figure was used to show the results of the different relationships between the analysis categories and subcategories.

3 RESULTS

3.1 SYSTEMATIC SEARCH IN DATABASES AND SELECTION OF ARTICLES

When reviewing the search results in the SCOPUS, IEEE Xplore and Scielo databases, under the criteria described in the equations with the Boolean and reserved operators, listed in Table 1, 143 articles were obtained from IEEE Xplore, 481 articles from SCOPUS and 373 articles recovered from Scielo, for a total of 991 articles found.

Table 1
Search results in the databases

<table>
<thead>
<tr>
<th>Database</th>
<th>Search equation</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEEE Xplore</td>
<td>&quot;Autonomous learning&quot; and &quot;Artificial Intelligence&quot;</td>
<td>25 articles</td>
</tr>
<tr>
<td></td>
<td>&quot;Autonomous learning&quot; and &quot;Artificial Intelligence&quot;</td>
<td>30 articles</td>
</tr>
<tr>
<td></td>
<td>&quot;Learning environment&quot; and &quot;Artificial Intelligence&quot;</td>
<td>88 articles</td>
</tr>
<tr>
<td></td>
<td>TITLE-ABS-KEY ( &quot;Autonomous learning&quot; AND &quot;Artificial Intelligence&quot; ) AND PUBYEAR &gt; 2010 AND ( EXCLUDE ( DOCTYPE , &quot;ch&quot; ) )</td>
<td>189 articles</td>
</tr>
<tr>
<td></td>
<td>TITLE-ABS-KEY ( &quot;Autonomous learning&quot; AND &quot;Artificial Intelligence&quot; ) AND PUBYEAR &gt; 2010 AND ( EXCLUDE ( DOCTYPE , &quot;ch&quot; ) OR EXCLUDE ( DOCTYPE , &quot;bk&quot; ) ) AND ( EXCLUDE ( SUBAREA , &quot;MEDI&quot; ) OR EXCLUDE ( SUBJAREA , &quot;BUSI&quot; ) )</td>
<td>182 articles</td>
</tr>
<tr>
<td>SCOPUS</td>
<td>TITLE-ABS-KEY ( &quot;Learning environment&quot; AND &quot;Artificial Intelligence&quot; ) AND PUBYEAR &gt; 2010 AND ( EXCLUDE ( DOCTYPE , &quot;ch&quot; ) ) AND ( EXCLUDE ( DOCTYPE , &quot;bk&quot; ) ) AND ( EXCLUDE ( SUBJAREA , &quot;MEDI&quot; ) OR EXCLUDE ( SUBJAREA , &quot;BUSI&quot; ) )</td>
<td>110 articles</td>
</tr>
<tr>
<td></td>
<td>(“Inteligencia artificial”) AND (“Aprendizaje Autónomo”)</td>
<td>1 articles</td>
</tr>
<tr>
<td></td>
<td>Tecnologías Educativas</td>
<td>369 articles</td>
</tr>
<tr>
<td></td>
<td>(Ambiente de Aprendizaje) AND (Inteligencia Artificial)</td>
<td>3 articles</td>
</tr>
</tbody>
</table>
Figure 2 shows the distribution of the 991 articles recovered from the different databases used during the review, with SCOPUS being predominant, as the one that yielded more refined results in terms of the categories and subcategories of analysis, although later these Articles were subjected to scientometric screening to select those publications that met all the established criteria.

Figure 2

*Distribution of articles according to the specialized database*

![Pie chart showing distribution of articles](image)

While, in Figure 3, the 90 articles that were selected are presented, distributed from 2010 to 2022. When ordering them from highest to lowest frequency, in 2021 a total of 24 articles are shown that fit the study, followed by those published in 2022, which totaled 20, then those found in 2020, with a total of 14 and those from 2018, which totaled 9 reviewed articles.

Figure 3

*Number of articles reviewed by period of years*

![Bar chart showing number of articles per year](image)
3.2 MAPPING AND DATA EXTRACTION PROCESS

In accordance with the methodology selected for the systematic review and in order to answer the research questions, a classification of the 991 articles found after executing the search was carried out, taking as selection criterion one or several relationships that could be find in the articles, among the 21st century competencies described in (Hadwin et al. 2017) and (Theobald & Bellhäuser, 2022), and the dimensions: Autonomous learning, artificial intelligence, educational technologies and learning environment. The previous exercise resulted in the review of 90 articles, as described in Table 2.

Table 2
Number of relationships found in the articles between the dimensions Autonomous learning, artificial intelligence, educational technology and learning environment, compared to the 21st century competencies collaborative work (CW), critical thinking (CT), algorithmic thinking (AT), creativity (CRE), problem solving (SP), digital literacy (DL), effective communication (EC) and unrelated (NR).

<table>
<thead>
<tr>
<th>DIMENSION</th>
<th>CW</th>
<th>CT</th>
<th>AT</th>
<th>FL</th>
<th>CRE</th>
<th>SP</th>
<th>DL</th>
<th>EC</th>
<th>NR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autonomous learning</td>
<td>8</td>
<td>15</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Artificial Intelligence</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>Educational Technologies</td>
<td>2</td>
<td>9</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Learning environment</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Totals</td>
<td>13</td>
<td>27</td>
<td>4</td>
<td>0</td>
<td>3</td>
<td>10</td>
<td>7</td>
<td>1</td>
<td>25</td>
</tr>
</tbody>
</table>

In relation to the selected articles, a total of 90 were analyzed, the results are described in Table 2 and the coincidences are observed between the analysis categories: collaborative work, critical thinking, algorithmic thinking, creativity, problem solving, digital literacy, and effective communication, with the critical thinking competency being the one where there is the greatest coincidence, it is also observed that there are 25 articles that have no relationship with the dimensions studied, likewise, collaborative work and problem solving, respectively, are the second and third competencies that is more related to the dimensions studied. Also, it can be observed that artificial intelligence is the competence that has the least relationship with the analysis categories with only three matches, it is observed that the critical thinking competence compared to the autonomous learning dimension was where the most articles were found with 15 relations.
Figure 4

Analysis of the systematic review of the articles reviewed between 21st century competencies against AI, AA, ET and LE.

Figure 4 shows how the relationships of the dimensions or subcategories such as creativity, algorithmic thinking, problem solving and critical thinking take positive values in relation to educational technology and autonomous learning, since they are positively associated in quadrant I and IV of the graph, while artificial intelligence and the unrelated category are found in quadrant III with a negative relationship; finally, a close relationship is evident between the critical thinking competence and the autonomous learning dimension.

3.3 RESEARCH QUESTIONS

Q1: How have 21st century skills been enhanced through autonomous learning?

Figure 5 shows the relationships of the dimensions considered in the 21st century competencies, with autonomous learning, in which critical thinking is the competency that has the most prevalence within the reviewed articles, followed by collaborative work and problem solving. In the same way, it is observed that algorithmic thinking, digital skills and creativity have some relationship with the analysis categories. In this sense, little evidence was found about the relationship that exists between flexibility and this category of analysis, since it was not addressed in the reviewed articles, while there are four articles that have no relationship
between the autonomous learning category and the competencies of the 21st century.

**Figure 5**

*Relationship between autonomous learning and 21st century skills*

On the other hand, it is also valid to consider that critical thinking supports autonomous learning, by providing students with the necessary skills to process and analyze information effectively. By questioning and evaluating information, individuals can identify their own knowledge gaps and actively seek the information necessary to fill them.

In summary, autonomous learning and critical thinking reinforce each other, although the former, which is a fundamental part of the present study, clearly leverages the dimension of critical thinking through self-regulation.

On the other hand, autonomous learning by empowering students to take control of their own learning, prepares them to face the challenges of the 21st century, and also contributes to collaborative spaces, motivating students to interact and work together, virtually or in person. This gives them the opportunity to communicate, share ideas, solve problems and develop interpersonal skills. Finally, students must learn to identify problems, ask relevant questions, and develop creative solutions.

Q2: What are the 21st century skills enhanced by Artificial Intelligence?
Within this analysis, within the framework of the 21st century skills that have been enhanced with the use of artificial intelligence, three dimensions appear, but in a weak way, as illustrated in figure 6, which shows collaborative work, problem solving and literacy, present in the articles reviewed. This can be explained because AI itself is a technical discipline, which can translate its interaction into the educational context through tools that facilitate the automation of routine and repetitive tasks, thus improving efficiency within these areas of knowledge. A small relationship between problem solving and this is striking. However, it is clear that it is a field that has not been explored and may lead to future research and experimental development work, which allows for a better understanding of this category in the face of 21st century skills.

Q3: What 21st century skills have been enhanced through the use of educational technologies?
For this item, as seen in Figure 7, it was found that critical thinking, problem solving and digital literacy are the 21st century skills most frequently in the research reviewed, the above in relation to the use of technologies educational. For their part, collaborative work, algorithmic thinking and creativity are also related to this category, but in a weak way. Contrary to the above, dimensions such as flexibility and effective communication do not show solid evidence in their relationship in terms of the category of analysis. It is important to highlight that there are also a large number of articles reviewed in relation to the use of Educational Technologies that are not related to any of the 21st century competencies studied. Educational technologies provide students with access to information, encourage collaboration, enable personalized learning, promote critical thinking and problem solving, and stimulate creativity and expression.

4 DISCUSSION AND CONCLUSIONS

A variety of authors have written about autonomous learning and competence development, most of them are related to strategies for higher education (Solórzano-Mendoza 2017), (González Cástulo et al. 2018) and (Reyes 2017), in that sense, the findings establish that 21st century competence Most studied in relation to autonomous learning is critical thinking, followed by collaborative work and problem solving; Likewise, algorithmic thinking, digital skills and creativity also have some relationship with this category of analysis. Thus, creativity and collaborative work are related. In this order of ideas, any higher education institution that has creative human capital will be able to innovate in the teaching-learning processes and implement collaborative work methodologies, with the aim of achieving superior performance in its students [(Bernal et al. 2019), (Ruiz Rey et al. 2018) and (Revelo Sánchez et al. 2018).

For its part, this research shows a relationship between three of the 21st century skills and AI, collaborative work, problem solving and literacy, thus, AI can become a tool for the development of skills and the personalization of activities, mediated by the use of digital content (Ocaña-Fernández et al. 2019), in turn, AI is still in arrears on the use of data and machine learning systems, the above, until the impact is better understood throughout society (Tuomi 2022).

Critical thinking, problem solving and digital literacy are the 21st century skills with the greatest impact in the research reviewed, the above in relation to the use of educational technologies. For its part, collaborative work, algorithmic thinking and creativity are also
related to this category. On the other hand, with flexibility and effective communication, no findings were found regarding the analysis category. It is important to highlight that there are also a large number of articles reviewed in relation to the use of Educational Technologies that are not related to any of the 21st century competencies studied.

Finally, AI from an educational context is considered as an emerging technology that can facilitate the work of teachers, in this sense, its development, implementation and impact, for this field, is being studied, hence, the most recent research in relation to the development of 21st century skills and learners, is only in its initial stage.

REFERENCES


Exploring the Relationship Between Artificial Intelligence, Autonomous Learning, and Skills Required for Success in the 21st Century


Exploring the Relationship Between Artificial Intelligence, Autonomous Learning, and Skills Required for Success in the 21st Century


Exploring the Relationship Between Artificial Intelligence, Autonomous Learning, and Skills Required for Success in the 21st Century


