Pedagogy Wheel for Artificial Intelligence: adaptation of Carrington's Wheel

Rueda de la Pedagogía para la Inteligencia Artificial: adaptación de la Rueda de Carrington

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ABSTRACT

The effective integration of Artificial Intelligence (AI) in education is necessary to harness its benefits in the teaching and learning process. This article proposes the adaptation of Carrington's Pedagogy Wheel into an AI Pedagogy Wheel, aiming to provide a pedagogical framework for integrating AI in education. The research methodology employed is based on a systematic review and mapping, coupled with a bibliometric study of term co-occurrence analysis, to identify relevant thematic clusters that scientifically support the need for the adaptation of the Wheel. The new wheel addresses the four obtained clusters (Integration of AI to enhance education, Use of educational technologies in the teaching and learning process, Pedagogical design and innovation, and Sustainable and Ethical Education) and presents concentric rings that explain how to gradually incorporate AI across different cognitive levels (Bloom's Taxonomy) and technological integration (SAMR Model), both adapted for AI. The wheel includes examples of tools and applications to illustrate the implementation. Furthermore, a Reflective-Metacognitive level is included that addresses ethics and responsibility in the use of AI. In conclusion, the wheel adapted to AI is a viable option to enhance the effectiveness and efficiency of education, provided that educators engage in the planning and execution of the teaching and learning process to ensure its success. It is worth mentioning the importance of keeping the wheel updated due to the constant emergence of new applications.

Keywords: artificial intelligence; disruptive technologies; Carrington's Wheel; Bloom's taxonomy; SAMR model.

RESUMEN

La integración efectiva de la Inteligencia Artificial (IA) en la educación es necesaria para aprovechar sus beneficios en el proceso de enseñanza-aprendizaje. Este artículo propone la adaptación de la Rueda de la Pedagogía de Carrington a una Rueda de la Pedagogía para la IA, con el fin de ofrecer un marco pedagógico para integrar la IA en la educación. La metodología de investigación utilizada se basa en una revisión y mapeo sistemático junto a un estudio bibliométrico del análisis de co-ocurrencia de términos para identificar los clusters temáticos relevantes que respalden científicamente la necesidad de la adaptación de la Rueda. La nueva rueda atiende a los cuatro clusters obtenidos (Integración de la IA para mejorar la educación, Uso de tecnologías educativa en el proceso de enseñanza y aprendizaje, Diseño e innovación pedagógica y Educación Sostenible y Ética) y presenta anillos concéntricos que explican cómo incorporar gradualmente la IA en diferentes niveles cognitivos (Taxonomía de Bloom) e integración tecnológica (Modelo SAMR) ambos adaptados a la IA, con ejemplos de herramientas y aplicaciones. Además, se incluye un nivel Reflexivo-Metacognitivo que aborda la ética y responsabilidad en el uso de la IA. En conclusión, la rueda adaptada a la IA es una opción viable para mejorar la eficacia y eficiencia de la educación, con la condición de que los docentes participen en la planificación y ejecución del proceso de enseñanza y aprendizaje para garantizar su éxito. Cabe mencionar la importancia de mantener la rueda actualizada debido a la aparición constante de nuevas aplicaciones.

Palabras clave: inteligencia artificial; tecnologías disruptivas; Rueda de Carrington; taxonomía de Bloom; modelo SAMR.

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INTRODUCTION

In recent years, technology has transformed the way in which modern-day teaching and learning takes place. Nevertheless, education has evolved to incorporate an emerging disruptive technology: Artificial Intelligence (hereinafter 'AI'), understood as 'a field of study that combines the applications of machine learning, algorithm productions, and natural language processing' (Akgun & Greenhow, 2022, p.1). It is, therefore, crucial to adapt to these changes in the field of education and consider how we can effectively integrate AI in education. A clear example of AI inclusion is that which is sparked by ChatGPT (Cooper, 2023; Duha, 2023); recent studies suggest that the proper use of such a tool could boost teaching and learning (Baidoo-Anu & Owusu, 2023; Skavronskaya et al., 2023).

In line with Huang et al. (2021), AI technology has the potential to improve students' cognitive ability and learning, as well as the efficiency of the teaching and learning process. It is therefore essential to effectively consider AI integration in education in order to leverage its transforming power with regard to improving the quality of education and student development.

At present, AI integration in education is regarded as a highly relevant tool for improving the learning process, given its ability to personalise teaching and learning, provide automated feedback and offer more objective, accurate assessments (Castaneda, 2023). According to Chen et al. (2020), AI could revolutionise the education sector by providing new opportunities for personalised learning, student assessment and educational research.

It is fundamental to highlight that, although AI offers many opportunities for education, it is not a blanket solution for all educational issues. Therefore, it is essential for it to be used consciously and reflectively in line with the educational context in question, in order to make the most of its potential benefits. Accordingly, it is necessary to reflect critically and thoroughly in order to ensure the effective and responsible use of AI in education. In this regard, teachers play a fundamental role in the integration of AI in education. Celik (2023) suggests that teachers should have specific knowledge of AI-related technology and pedagogy in order for it to be effectively integrated in education. They should also have an understanding of ethics to assess AI-based decisions and ensure they use it responsibly and fairly.

This idea has already been developed by Carrington (2016) through his Pedagogy Wheel (Padagogy Wheel) for technology integration, a tool he designed to help teachers integrate technology in their pedagogical practice, with a focus on pedagogy as opposed to technological applications. The reason this wheel works as a tool for improving the design and assessment of student-centred learning is because all the sections of the wheel are interconnected, thus indicating that learning is not a linear process, but rather a process in constant evolution (Carrington, 2015).

In this regard, Allan Carrington's Pedagogy Wheel features several concentric rings: 1) a central ring featuring the six cognitive levels of Bloom's Taxonomy, 2) a subsequent ring with the four levels of technology integration according to the SAMR Model and 3) outer rings containing examples of technology tools and apps that may be used for each cognitive and technology integration level.

Based on these ideas, the Pedagogy Wheel proposed by Carrington (2017) combines the two theoretical frameworks mentioned above (Bloom's Taxonomy and SAMR Model) in a visual representation (see Figure 1) that allows for the selection of

appropriate technology tools and strategies for each level of cognitive skill and technology integration.

Figure 1
Pedagogy Wheel v5

Source: Carrington (2016). https://designingoutcomes.com/english-speaking-world-v5-0/
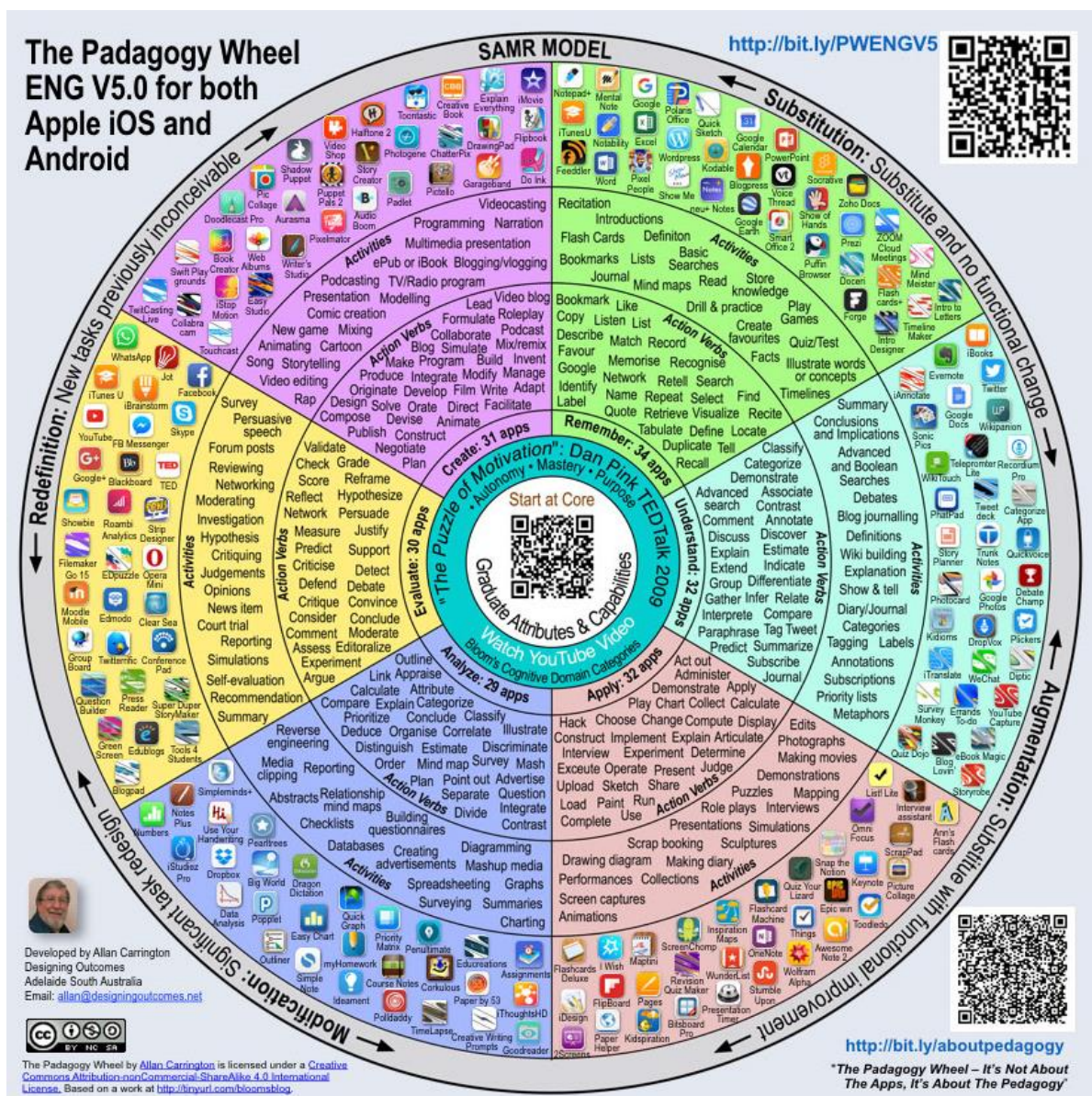
Allan Carrington's Pedagogy Wheel has proven to be an effective tool for improving the quality of teaching (Zhang et al., 2018) and learning (Matta et al., 2016) in the context of technology. However, the wheel does not consider AI as a technology that can be integrated in teaching and learning.

Therefore, in light of the changes being triggered by AI in the field of education, this study proposes an adaptation of Allan Carrington's Pedagogy Wheel (2017) in the form of a new AI Pedagogy Wheel that allows for the effective AI integration in education at all stages. This proposal is based on the premise that AI has the potential

to substantially transform and improve education, so long as it is used in a responsible and conscious manner (Wiley, 2023). For this reason, the creation of an AI Pedagogy Wheel, as adapted from Allan Carrington's original model, is crucial in order to harness the benefits of this emerging technology in the teaching and learning process, as it facilitates the selection of appropriate technological AI tools and strategies for each level of cognitive skill and AI technology integration. The aim is to create a more personalised, interactive and effective educational environment in line with the needs and expectations of students in today's digital and technological era.

METHODOLOGY

To ensure scientific rigour in the article and justify the need for the adapted AI Pedagogy Wheel, a research method based on a systematic mapping review was followed in order to answer the following mapping questions (MQ), together with a bibliometric study involving co-occurrence analysis of terms in order to answer the following research questions (RQ) shown in Figure 2.

Figure 2
Mapping Questions (MQ) and Research Questions (RQ)
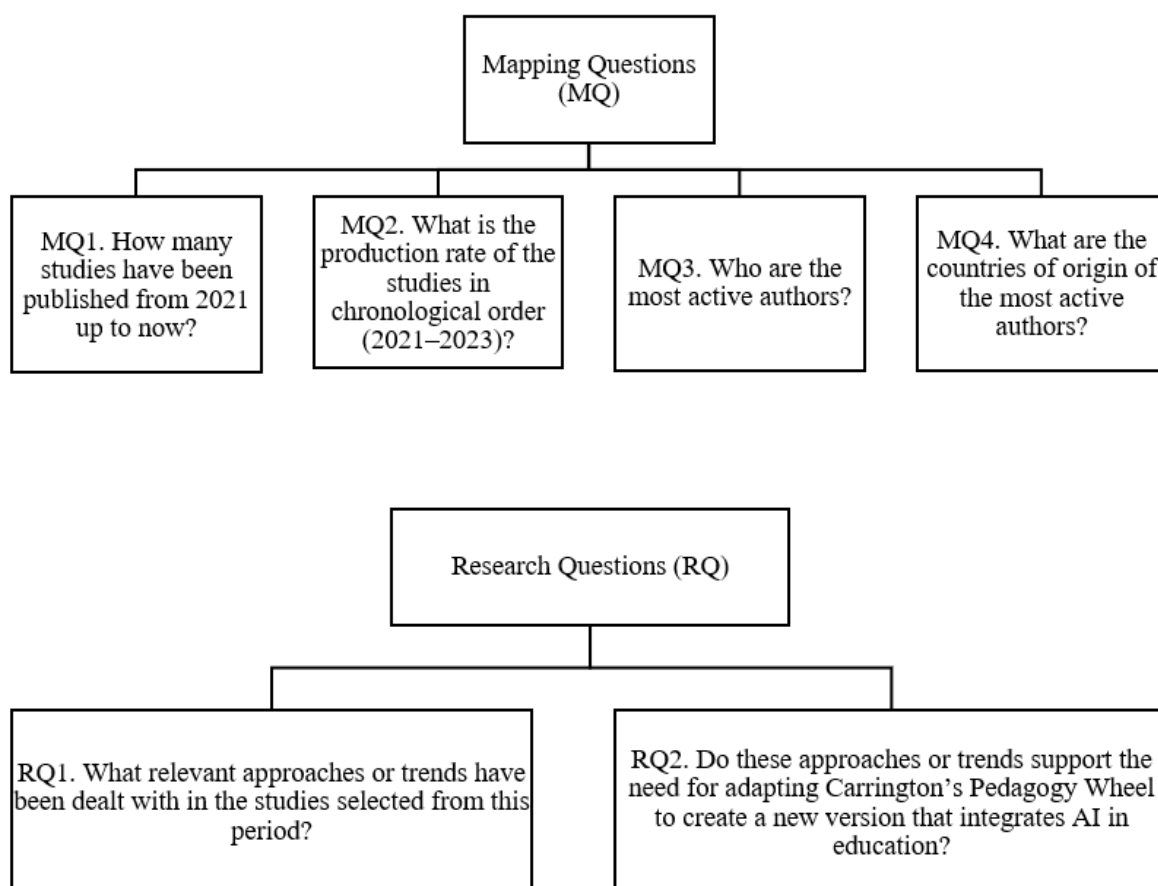
Source: own elaboration.

A systematic review of the literature was carried out in line with the guidelines set out in the PRISMA Statement. An exhaustive search of academic databases (Web of Science/WoS and Scopus) was conducted using the following search phrase: 'artificial intelligence' AND 'education' AND 'integration' AND 'learning', taking into account the title, summary, author keywords and KeyWords Plus. The studies were collected selected according to the eligibility criteria shown in Table 1:

Table 1
Eligibility criteria for studies

Reasons	Search	Inclusion criteria	Excluded works	
			WoS	**Scopus**
1	Date of publication		98	420
2	Language	English and Spanish	4	12
3	Type of document	Research articles	48	240
4	Type of publication	Full-text articles published in peer-reviewed journals	39	55
5	Subject Area	Educational Research/ Social Sciences	73	91

Source: own elaboration.

Out of the 280 articles found on WoS, 262 were excluded following the application of the relevant filters, leaving 18 articles to be analysed. Meanwhile, of the 861 articles found on Scopus, 818 were excluded according to the established criteria, resulting in the analysis of 43 studies. Of the 61 articles (18 studies from WoS and 43 from Scopus), 17 duplicates were eliminated, leaving a total of 44 articles to be analysed that provide us with a current view of the state of research published in this area in recent years (2021–2023).

For the bibliometric study based on co-occurrence analysis of keywords, the programme VOSviewer was used. The analysis was simplified by taking into account only those keywords with a frequency of occurrence of at least 2. Thus, a square matrix of N x N elements representing the co-occurrence between pairs of keywords was formed and a bibliometric network of the relationships between the keywords through nodes and links was created in graph form. This allowed for the visualisation and analysis of the connections between keywords.

RESULTS

Results of the systematic mapping review

The mapping questions (MQ) set out in this study are answered below. With regard to the first question MQ1. 'How many studies have been published from 2021 up to now?', Table 2 shows a summary of the 44 references analysed in this review, together with an identifier used for referencing throughout the analyses.

Table 2
References of the systematic review

N.º	References of the systematic review
[1]	A'mar, F., & Eleyan, D. (2022). Effect of principal s technology leadership on teacher's technology integration. *International Journal of Instruction*, *15*(1), 781–798. https://doi.org/10.29333/iji.2022.15145a
[2]	Abd-alrazaq, A., AlSaad, R., Alhuwail, D., Ahmed, A., Healy, P. M., Latifi, S., Aziz, S., Damseh, R., Alrazak, S. A., & Sheikh, J. (2023). Large Language Models in Medical Education: Opportunities, Challenges, and Future Directions. *JMIR Medical Education*, *9*. https://doi.org/10.2196/48291
[3]	Aksoy, N., & Ozturk, N. (2021). Integration of a virtual pharmacy simulation program "MyDispense" in clinical pharmacy education. *Pharmacy Education*, *21*(1), 604-611. https://doi.org/10.46542/pe.2021.211.604611
[4]	Andersen, R., Mørch, A. I., & Litherland, K. T. (2022). Collaborative learning with block-based programming: investigating human-centered artificial intelligence in education. *Behaviour and Information Technology*, *41*(9), 1830-1847. https://doi.org/10.1080/0144929X.2022.2083981
[5]	Arteaga, J. V, Gravini-Donado, M. L., & Riva, L. D. Z. (2021). Digital Technologies for Heritage Teaching: Trend Analysis in New Realities. I*nternational Journal of Emerging Technologies in Learning*, *16*(21), 132-148. https://doi.org/10.3991/ijet.v16i21.25149
[6]	Celik, I., Dindar, M., Muukkonen, H., & Järvelä, S. (2022). The Promises and Challenges of Artificial Intelligence for Teachers: a Systematic Review of Research. *TechTrends*, *66*(4), 616-630. https://doi.org/10.1007/s11528-022-00715-y
[7]	Chan, C. K. Y. (2023). A comprehensive AI policy education framework for university teaching and learning. *International Journal of Educational Technology in Higher Education, 20*(1). https://doi.org/10.1186/s41239-023-00408-3
[8]	Chivu, R.-G., Popa, I.-C., Orzan, M.-C., Marinescu, C., Florescu, M. S., & Orzan, A.-O. (2022). The Role of Blockchain Technologies in the Sustainable Development of Students' Learning Process. *Sustainability (Switzerland)*, *14*(3). https://doi.org/10.3390/su14031406
[9]	Choi, S., Choi, J., Peters, O. A., & Peters, C. I. (2023). Design of an interactive system for access cavity assessment: A novel feedback tool for preclinical endodontics. *European Journal of Dental Education*. https://doi.org/10.1111/eje.12895
[10]	Ding, Z., Jiang, S., Xu, X., & Han, Y. (2022). An Internet of Things based scalable framework for disaster data management. *Journal of Safety Science and Resilience*, *3*(2), 136-152. https://doi.org/10.1016/j.jnlssr.2021.10.005
[11]	El Hadraoui, H., Zegrari, M., Hammouch, F.-E., Guennouni, N., Laayati, O., & Chebak, A. (2022). Design of a Customizable Test Bench of an Electric Vehicle Powertrain for Learning Purposes Using Model-Based System Engineering. *Sustainability (Switzerland), 14*(17). https://doi.org/10.3390/su141710923
[12]	Essel, H. B., Vlachopoulos, D., Tachie-Menson, A., Johnson, E. E., & Baah, P. K. (2022). The impact of a virtual teaching assistant (chatbot) on students' learning in Ghanaian higher education. *International Journal of Educational Technology in Higher Education, 19*(1). https://doi.org/10.1186/s41239-022-00362-6
[13]	Fergus, S., Botha, M., & Ostovar, M. (2023). Evaluating Academic Answers Generated Using ChatGPT. *Journal of Chemical Education*, *100*(4), 1672-1675. https://doi.org/10.1021/acs.jchemed.3c00087
[14]	Hsu, T.-C., Abelson, H., Lao, N., & Chen, S.-C. (2021). Is it possible for young students to learn the Ai-STEAM application with experiential learning? *Sustainability (Switzerland), 13*(19). https://doi.org/10.3390/su131911114
[15]	Järvelä, S., Nguyen, A., & Hadwin, A. (2023). Human and artificial intelligence collaboration for socially shared regulation in learning. *British Journal of Educational Technology*. https://doi.org/10.1111/bjet.13325

N.º	References of the systematic review
[16]	Jia, F., Sun, D., Ma, Q., & Looi, C.-K. (2022). Developing an AI-Based Learning System for L2 Learners' Authentic and Ubiquitous Learning in English Language. *Sustainability (Switzerland)*, *14*(23). https://doi.org/10.3390/su142315527
[17]	Kaldaras, L., Yoshida, N. R., & Haudek, K. C. (2022). Rubric development for AI-enabled scoring of three-dimensional constructed-response assessment aligned to NGSS learning progression. *Frontiers in Education*, *7*. https://doi.org/10.3389/feduc.2022.983055
[18]	Kamruzzaman, M. M., Alanazi, S., Alruwaili, M., Alshammari, N., Elaiwat, S., Abu-Zanona, M., Innab, N., Mohammad Elzaghmouri, B., & Ahmed Alanazi, B. (2023). AI- and IoT-Assisted Sustainable Education Systems during Pandemics, such as COVID-19, for Smart Cities. *Sustainability (Switzerland)*, *15*(10). https://doi.org/10.3390/su15108354
[19]	Kim, K., & Kwon, K. (2023). Exploring the AI competencies of elementary school teachers in South Korea. *Computers and Education: Artificial Intelligence*, *4*. https://doi.org/10.1016/j.caeai.2023.100137
[20]	Kim, N. J., & Kim, M. K. (2022). Teacher's Perceptions of Using an Artificial Intelligence-Based Educational Tool for Scientific Writing. *Frontiers in Education*, *7*. https://doi.org/10.3389/feduc.2022.755914
[21]	Kohnke, L., Moorhouse, B. L., & Zou, D. (2023). Exploring generative artificial intelligence preparedness among university language instructors: A case study. *Computers and Education: Artificial Intelligence*, *5*. https://doi.org/10.1016/j.caeai.2023.100156
[22]	Lentz, A., Siy, J. O., & Carraccio, C. (2021). AI-ssessment: Towards Assessment As a Sociotechnical System for Learning. *Academic Medicine*, *96*(7), S87-S88. https://doi.org/10.1097/ACM.0000000000004104
[23]	Liu, D. S., Sawyer, J., Luna, A., Aoun, J., Wang, J., Boachie, L., Halabi, S., & Joe, B. (2022). Perceptions of US Medical Students on Artificial Intelligence in Medicine: Mixed Methods Survey Study. *JMIR Medical Education*, *8*(4). https://doi.org/10.2196/38325
[24]	Marquez, R., Barrios, N., Vera, R. E., Mendez, M. E., Tolosa, L., Zambrano, F., & Li, Y. (2023). A perspective on the synergistic potential of artificial intelligence and product-based learning strategies in biobased materials education. *Education for Chemical Engineers*, *44*, 164–180. https://doi.org/10.1016/j.ece.2023.05.005
[25]	Moldt, J.-A., Festl-Wietek, T., Madany Mamlouk, A., Nieselt, K., Fuhl, W., & Herrmann-Werner, A. (2023). Chatbots for future docs: exploring medical students' attitudes and knowledge towards artificial intelligence and medical chatbots. *Medical Education Online*, *28*(1). https://doi.org/10.1080/10872981.2023.2182659
[26]	Nikonova, E., Yakhyaeva, K., Pivkina, N., & Schetinina, A. (2023). Using Artificial Intelligence Tools in Teaching a Foreign Language in Higher Technical Institutions. *European Journal of Contemporary Education*, *12*(2), 578-589. https://doi.org/10.13187/ejced.2023.2.578
[27]	Ouyang, F., Wu, M., Zheng, L., Zhang, L., & Jiao, P. (2023). Integration of artificial intelligence performance prediction and learning analytics to improve student learning in online engineering course. *International Journal of Educational Technology in Higher Education*, *20*(1). https://doi.org/10.1186/s41239-022-00372-4
[28]	Prahani, B. K., Alfin, J., Fuad, A. Z., Saphira, H. V, Hariyono, E., & Suprapto, N. (2022). Learning Management System (LMS) Research During 1991–2021: How Technology Affects Education. *International Journal of Emerging Technologies in Learning*, *17*(17), 28–49. https://doi.org/10.3991/ijet.v17i17.30763
[29]	Prahani, B. K., Rizki, I. A., Jatmiko, B., Suprapto, N., & Amelia, T. (2022). Artificial Intelligence in Education Research During the Last Ten Years: A Review and Bibliometric Study. *International Journal of Emerging Technologies in Learning*, *17*(8), 169-188. https://doi.org/10.3991/ijet.v17i08.29833
[30]	Pu, S., Ahmad, N. A., Khambari, M. N. M., & Yap, N. K. (2021). Identification and analysis of core topics in educational artificial intelligence research: A bibliometric analysis. *Cypriot Journal of Educational Sciences*, *16*(3), 995-1009. https://doi.org/10.18844/CJES.V16I3.5782

N.º	References of the systematic review
[31]	Qushem, U. B., Christopoulos, A., Oyelere, S. S., Ogata, H., & Laakso, M.-J. (2021). Multimodal technologies in precision education: Providing new opportunities or adding more challenges? *Education Sciences*, *11*(7). https://doi.org/10.3390/educsci11070338
[32]	Rott, K. J., Lao, L., Petridou, E., & Schmidt-Hertha, B. (2022). Needs and requirements for an additional AI qualification during dual vocational training: Results from studies of apprentices and teachers. *Computers and Education: Artificial Intelligence*, *3*. https://doi.org/10.1016/j.caeai.2022.100102
[33]	Sanchez-Pena, M., Vieira, C., & Magana, A. J. (2023). Data science knowledge integration: Affordances of a computational cognitive apprenticeship on student conceptual understanding. *Computer Applications in Engineering Education*, *31*(2), 239-259. https://doi.org/10.1002/cae.22580
[34]	Shenkoya, T., & Kim, E. (2023). Sustainability in Higher Education: Digital Transformation of the Fourth Industrial Revolution and Its Impact on Open Knowledge. *Sustainability (Switzerland)*, *15*(3). https://doi.org/10.3390/su15032473
[35]	Shi, D., Zhou, J., Wang, D., & Wu, X. (2022). Research Status, Hotspots, and Evolutionary Trends of Intelligent Education from the Perspective of Knowledge Graph. *Sustainability (Switzerland)*, *14*(17). https://doi.org/10.3390/su141710934
[36]	Shi, Z., Wu, Z., Zhang, Z., Chen, Y., & Liu, X. (2022). Learning Path Planning Algorithm Based on Career Goals and Artificial Intelligence. *International Journal of Emerging Technologies in Learning*, *17*(10), 256-272. https://doi.org/10.3991/ijet.v17i10.28455
[37]	Sunday, K., Oyelere, S. S., Agbo, F. J., Aliyu, M. B., Balogun, O. S., & Bouali, N. (2022). Usability Evaluation of Imikode Virtual Reality Game to Facilitate Learning of Object-Oriented Programming. *Technology, Knowledge and Learning*. https://doi.org/10.1007/s10758-022-09634-6
[38]	Vidanaralage, A. J., Dharmaratne, A. T., & Haque, S. (2022). AI-based multidisciplinary framework to assess the impact of gamified video-based learning through schema and emotion analysis. *Computers and Education: Artificial Intelligence*, *3*. https://doi.org/10.1016/j.caeai.2022.100109
[39]	Villegas-Ch, W., Sánchez-Viteri, S., & Román-Cañizares, M. (2021). Academic activities recommendation system for sustainable education in the age of COVID-19. *Informatics*, *8*(2). https://doi.org/10.3390/informatics8020029
[40]	Wang, X. (2022). Influences of Learning Emotion on Learning Outcome in Online Teaching Mode. *International Journal of Emerging Technologies in Learning*, *17*(8), 126-139. https://doi.org/10.3991/ijet.v17i08.30459
[41]	Wardat, Y., Tashtoush, M. A., AlAli, R., & Jarrah, A. M. (2023). ChatGPT: A revolutionary tool for teaching and learning mathematics. *Eurasia Journal of Mathematics, Science and Technology Education*, *19*(7). https://doi.org/10.29333/ejmste/13272
[42]	Yong, L. C., Aziz, N. M., & Mohd-Rahim, F. A. (2022). Adapting to a new normal during covid-19: Leveraging the smart building system with bim integration for lifecycle sustainability. *Planning Malaysia*, *20*(4), 209-222. https://doi.org/10.21837/pm.v20i24.1198
[43]	Zhai, C., & Wibowo, S. (2023). A systematic review on artificial intelligence dialogue systems for enhancing English as foreign language students' interactional competence in the university. *Computers and Education: Artificial Intelligence*, *4*. https://doi.org/10.1016/j.caeai.2023.100134
[44]	Zhang, Y. Z. (2022). Influence of Teacher-Student Interaction on Course Learning Effect in Distance Education. *International Journal of Emerging Technologies in Learning*, *17*(10), 215–226. https://doi.org/10.3991/ijet.v17i10.30913

Source: own elaboration.

Next, an answer is provided for question MQ2. 'What is the production rate of the studies in chronological order (2021–2023)?'; the results are shown in Figure 3. Out of the three years under analysis, the greatest proportion of articles (48%) corresponds to the year 2022. It is important to bear in mind that the year 2023 has not yet concluded at the time of writing, yet it already represents 36% of the total number of

articles. This suggests a clear trend of increased interest in the field, evidenced by the significant increase in publications since 2021.

Figure 3
Production rate of the studies in chronological order
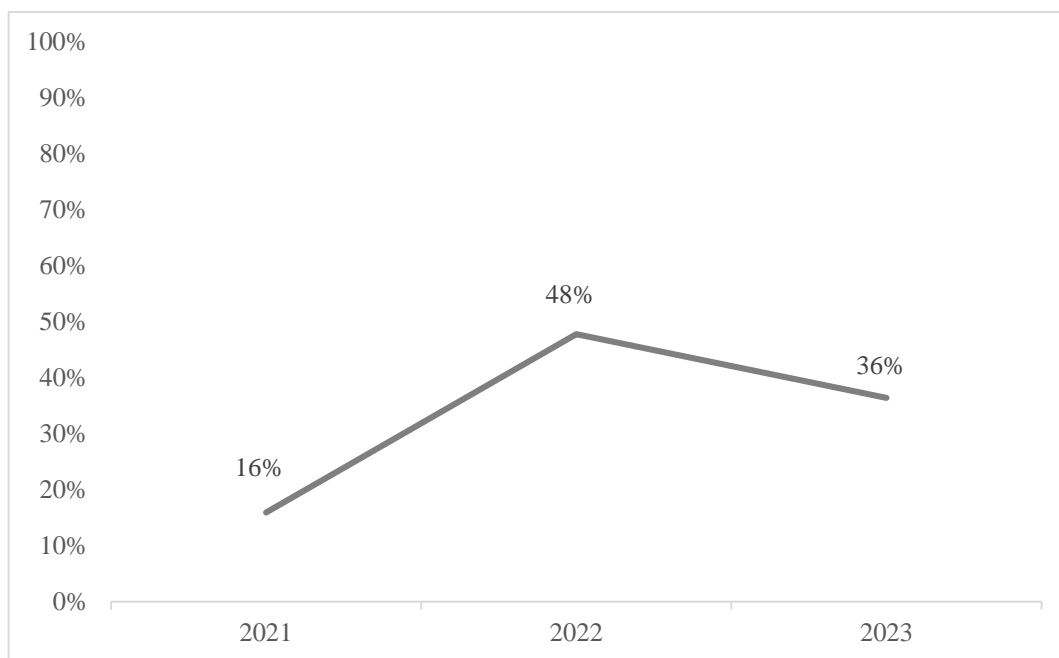
Source: own elaboration.

With regard to questions MQ3. 'Who are the most active authors?' and MQ4. 'What are the countries of origin of the most active authors?', the results are shown in Figure 4.

Within the group of 173 authors of the 44 works selected for the systematic literature review (see Table 2), 4 authors stand out as they have each contributed 2 publications, thus establishing themselves as the most active contributors. The countries of origin of these authors are Indonesia, Finland and Sweden.

Figure 4
Authors and countries of origin of the most active authors
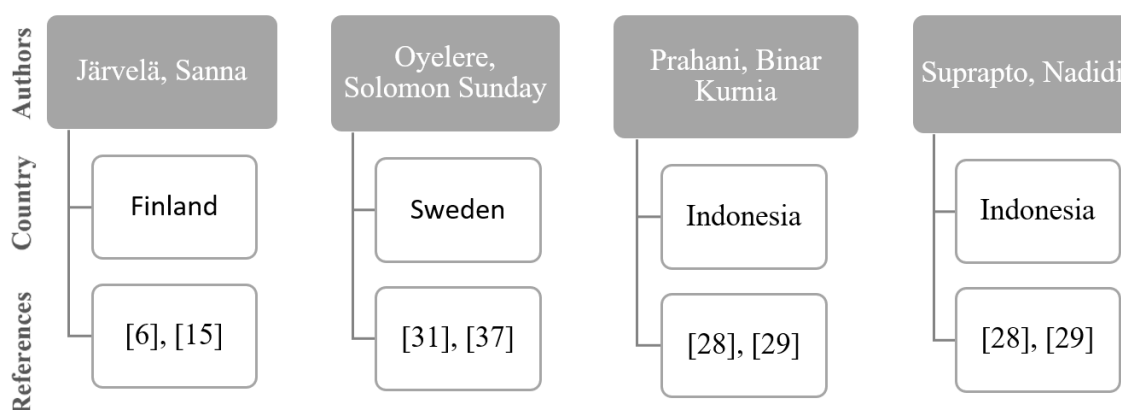
Source: own elaboration.

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Results of the keyword co-occurrence analysis

The main objective of keyword co-occurrence analysis is to identify the relevant research topics related to AI and education. To achieve this, co-occurrence analysis was carried out for the keywords extracted from the 43 articles under analysis. A frequency of occurrence threshold of a minimum of 2 times was set in order to select the most significant keywords. From the 332 initial keywords, a total of 36 keywords met this criterion and will be analysed in detail.

To ensure consistency and coherence in the topic groups, a minimum number of 5 keywords was set to form a cluster. Based on these settings, the resulting co-occurrence network is shown in Figure 5. This Figure shows how many times the keywords appear together in the texts analysed and how they are grouped into four clusters corresponding to the colours red, green, blue and yellow. These clusters were formed based on the similarity between keywords, allowing us to identify the research topics related to AI and education addressed in the articles under analysis.

Figure 5
Map of co-occurrence of terms
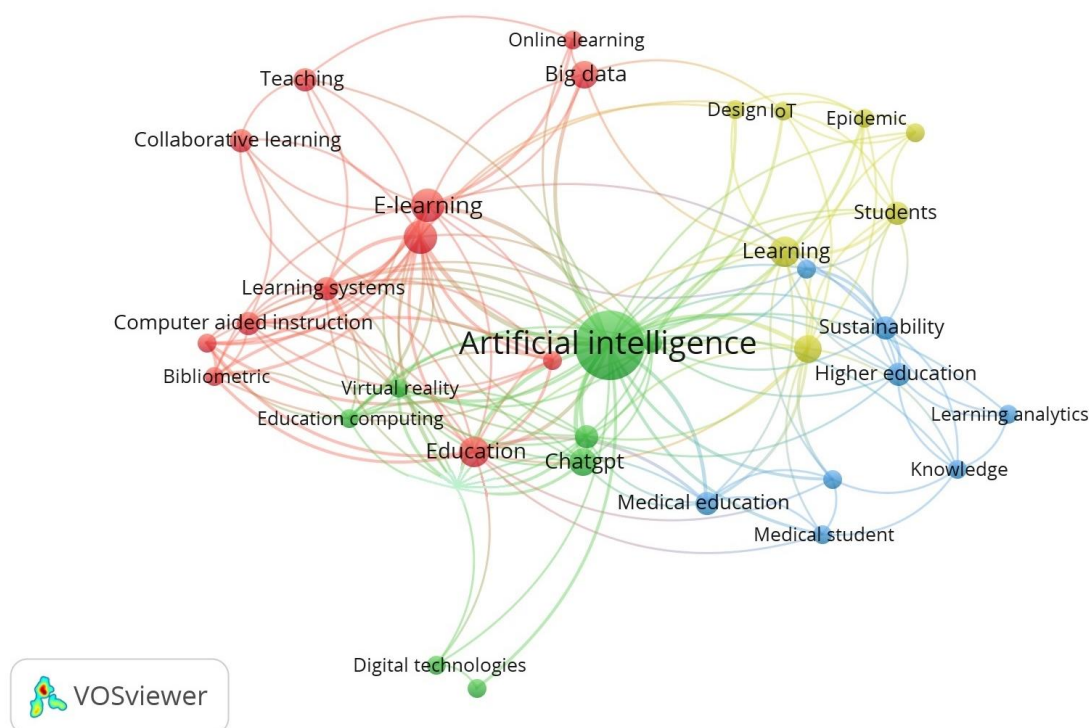
Source: own elaboration.

The research questions (RQ) set out in this study are answered below. Specifically, question RQ1. 'What relevant approaches or trends have been dealt with in the studies selected from this period?' is answered in Table 3, which shows a summary of the network, the topic categories created based on the keywords and the references related to each topic category (some articles may fall under more than one cluster, but they have been grouped according to the specific area dealt with in the article).

Table 3
Groups of keywords based on co-occurrence

Cluster	Topic categories	Cluster description	Keywords (frequency of occurrence)	References of the systematic review
Cluster 1 (green)	AI integration to improve education	Represents the integration of artificial intelligence in education with the aim of improving the educational experience.	Artificial intelligence (25), Chatgpt (4), Generative AI (3), Digital technologies (2), Education computing (2), Foreign language learning (2), Sustainable development (2), Virtual reality (2).	[2], [4], [6], [7], [12], [13], [15], [16], [19], [20], [21], [23], [25], [26], [27], [29], [30], [32], [35], [36], [41], [43]
Cluster 2 (red)	Use of educational technologies in the teaching and learning process	Represents aspects related to the use of digital technologies in the teaching and learning process.	E-learning (6), Engineering education (6), Education (5), Big data (4), Collaborative learning (3), Computer aided instruction (3), Learning systems (3), Teaching (3), Bibliometric (2), Bibliometrics analysis (2), Online learning (2), Scopus database (2).	[3], [5], [9], [22], [28], [31], [37], [38], [40], [44]
Cluster 3 (yellow)	Pedagogical design and innovation	Approach centred on learning and curriculum design in order to explore how disruptive technologies can impact and improve education in different contexts.	Learning (5), Students (5), Curriculum (4), Design (2), Epidemic (2), Internet (2), IoT (2).	[1], [11], [14], [17], [24], [33]
Cluster 4 (blue)	Sustainable and ethical education	Approach based on improving education, taking into account ethics and sustainability in the education and training of professionals.	Higher education (3), Medical education (3), Sustainability (3), Humans (2), Knowledge (2), Learning analytics (2), Medical student (2), Sustainable education (2).	[8], [10], [18], [34], [39], [42]

Source: own elaboration.

Adapting Carrington's Pedagogy Wheel to an AI Pedagogy Wheel is justified based on the topic clusters identified in the analysis. These clusters highlight the importance of technology, knowledge integration and innovation in the field of education.

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Taking into account the topic clusters identified in the analysis, we may now answer the following question: RQ2. Do these approaches or trends support the need for adapting Carrington's Pedagogy Wheel to create a new version that integrates AI in education?

The first cluster focuses on AI integration and therefore provides opportunities for exploring how this innovative technology can optimise education and improve students' learning at various levels in different contexts. Therefore, this cluster is key for the adapted wheel, since it offers a theoretical basis for AI integration in the context of pedagogy. The second cluster focuses on the integration of digital technologies in education with the aim of improving and enriching the teaching and learning process. This group of keywords covers different areas, with the use of technologies in the educational context as their common denominator. Adapting the wheel to an AI version would involve integrating pedagogical approaches based on emerging technologies, fostering efficiency, personalised learning, responsible use of technological resources and a solid digital infrastructure to implement AI in the teaching and learning process. The third cluster, 'pedagogical design and innovation', highlights the value of adapting educational approaches and curriculums to new technologies and emerging trends. The adapted wheel would integrate AI and emerging technologies in pedagogical design and innovation, with the aim of developing more efficient and up-to-date educational approaches in line with the latest trends in technology to improve teaching and learning experiences. Finally, the cluster 'sustainable and ethical education' places emphasis on sustainability and ethics in education. In this regard, the wheel adapted to include AI would underline the importance of taking into account questions of ethics and sustainability in education by means of reflective, metacognitive approaches that allow for critical reflection on the use of AI in education.

In summary, the adapted AI Pedagogy Wheel is justified because these topic clusters show how AI can influence and transform different aspects of education, from teaching and learning to curriculum design. The outcome of the analysis underlines the importance of integrating educational technology in the teaching and learning process, harnessing the potential of AI to improve education, promoting the ethical and sustainable use of AI and fostering pedagogical design and innovation. This will enable the development of a more up-to-date and relevant perspective of pedagogy in the age of AI and digital technologies.

Allan Carrington's Pedagogy Wheel adapted to the Artificial Intelligence Pedagogy Wheel

As mentioned above, Allan Carrington's Pedagogy Wheel does not consider AI as a technology that can be integrated in teaching and learning. For this reason, the creation of an AI Pedagogy Wheel, as adapted from Allan Carrington's original model, is necessary because it allows for the effective integration of AI in the teaching and learning process by providing a solid, well-structured pedagogical framework. This would provide a response to the clusters obtained previously, which reflect the relevance and necessity of integrating AI into the teaching and learning process.

In the case of the AI Pedagogy Wheel, like the original, it is composed of several concentric rings showing how AI can be gradually integrated into teaching and learning at different cognitive and technology integration levels.

The central ring shows Bloom's Taxonomy (Bloom & Krathwohl, 1956), a hierarchical structure of six cognitive levels used to design and classify learning objectives. In ascending order of complexity, the levels are: remember, understand, apply, analyze, evaluate and create.

The AI Pedagogy Wheel proposed by the authors in this paper adapts the cognitive skill levels of Bloom's Taxonomy to AI, thus providing a structured and clear approach that allows teachers and learners to work towards more advanced and in-depth learning goals. Along these lines, Lameras and Arnab (2021) propose a taxonomy of AI applications in education linked to teaching and learning practice. This taxonomy is divided into four categories: (1) support for teaching and learning, (2) evaluation and feedback, (3) personalised learning and (4) classroom management. However, although there is no AI-specific Bloom's Taxonomy, the authors have chosen to adapt Bloom's Taxonomy and to create an AI Pedagogy Wheel with the same theoretical underpinning as Carrington's Pedagogy Wheel, in order to make the adaptation as accurate as possible.

Table 4 shows some examples of how to use Bloom's Taxonomy as a guide for both the teaching process and the learning process through activities that effectively integrate AI.

Table 4
Bloom's Taxonomy for Artificial Intelligence

		Description	Description applied to AI	Examples with AI
Cognitive skill levels	**Remember**	At this level, the student should be able to remember information they have learned previously. This includes the ability to recognise and retrieve information such as details, terms, events and concepts.	At this level, AI can help students to remember information more efficiently through the use of memory and information retrieval systems.	*Teaching process*: AI can be used to create question and answer systems that allow students to revise concepts and remember important information. *Learning process*: Students use AI tools to make automatic text summaries or create mind maps that help them to remember key information.
	Understand	At this level, the student should be able to understand information. This implies the ability to interpret the meaning of information, make inferences and explain ideas in their own words.	At this level, AI can help students to understand more complex concepts by providing examples and analogies that are easy to understand.	*Teaching process*: AI can be used to create interactive simulations or visual material to help students understand difficult concepts. *Learning process*: Students use AI tools to translate texts to other languages or obtain definitions of unfamiliar words.
	Apply	At this level, the student should be able to apply the information they have learned previously to new or different situations. This includes the ability to use acquired knowledge to solve problems, complete tasks and make decisions.	At this level, AI can help students to apply what they have learned to real-world situations through the use of virtual simulations and scenarios.	*Teaching process*: AI can be used to create personalised recommendation systems that suggest specific activities or exercises for students to apply what they have learned. *Learning process*: Students use AI tools to create multimedia presentations or to design creative projects in which they apply the concepts they have learned.

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Jiménez-García, E., Orenes Martínez, N., & López-Fraile, L. A. (2024). Pedagogy Wheel for Artificial Intelligence: adaptation of Carrington's Wheel. [Rueda de la Pedagogía para la Inteligencia Artificial: adaptación de la Rueda de Carrington]. *RIED-Revista Iberoamericana de Educación a Distancia, 27*(1), 87-113. https://doi.org/10.5944/ried.27.1.37622

Analyze	At this level, the student should be able to break down information into smaller parts and study the relationships between these parts. This implies the ability to identify patterns, detect errors and evaluate rationale.	At this level, AI can help students to analyse complex information more efficiently by identifying patterns and relationships in large datasets.	*Teaching process*: AI can be used to analyse student data and provide detailed information on their progress, strengths and weaknesses. *Learning process*: Students use AI to analyse large datasets or to identify patterns in complex information.
Evaluate	At this level, the student should be able to make critical judgements and evaluations about information. This implies the ability to compare and contrast, judge and evaluate the quality of information.	At this level, AI can help students to evaluate their own learning and progress through the use of evaluation and feedback systems.	*Teaching process*: AI can be used to create automatic evaluation systems that provide instant feedback to students and teachers about student performance. *Learning process*: Students use AI tools for self-evaluation and to receive feedback on their own performance.
Create	At this level, the student should be able to use the information obtained to create something new. This implies the ability to generate new ideas, come up with creative solutions to problems and create unique products.	At this level, AI can help students to create original content through the use of content generation tools.	*Teaching process*: AI can be used to create immersive, personalised learning environments that enable students to create original content and express their creativity. *Learning process*: Students use AI to create multimedia content or to come up with innovative solutions to complex problems.

Source: own elaboration.

The following ring represents the SAMR Model proposed by Puentedura (2014). This model is a reference framework for technology integration in teaching and learning, i.e. it focuses on how technology is used in teaching and learning, from simple substitutions to redefinition of the way in which the educational process is carried out. In ascending order of complexity, the levels are: Substitution, Augmentation, Modification and Redefinition.

This model provides a guide for the effective integration of technology in the classroom and for improving the quality of learning according to these four levels of technology integration in teaching and learning (Garcia-Utrera et al., 2014), which emerged as a relevant topic in the four clusters obtained from the keyword co-occurrence analysis.

In terms of AI, Lameras and Arnab (2021) use this model as a framework for understanding how AI can be used at different levels to improve education. However, this study goes beyond by exploring this approach further, with Table 5 showing a detailed description of the five levels of integration, as well as some examples of how the SAMR Model can be used as a guide for AI integration in the teaching and learning process.

Table 5
SAMR Model for Artificial Intelligence

Levels of integration		**Description**	**Description applied to AI**	**Examples with AI**
	Substitution	At this level, technology is used as a direct substitute for traditional tools without causing any changes to the teaching and learning process. In other words, technology is used simply to carry out the same task that was previously carried out manually or without the use of digital tools.	At this level, AI is used as a direct substitute for traditional tools without causing any significant changes to the teaching and learning process.	*Teaching process:* AI can be used in the form of a chatbot to answer students' frequently asked questions about the course content. *Learning process:* Students use voice-to-text translation tools to take notes during classes, reducing the need to take notes and allowing for better concentration in class.
	Augmentation	At this level, technology begins to improve traditional tools and processes by means of providing additional features that are not found in non-digital tools. This allows students to carry out tasks more efficiently and effectively.	At this level, AI is used to augment and improve existing activity in the teaching and learning process.	*Teaching process:* AI can be used on online teaching platforms with personalised recommendation systems that suggest additional learning resources based on the needs of each student. *Learning process:* Students use an AI application to improve their written grammar by means of automatic revision of their essays.
	Modification	At this level, AI is used to significantly change the teaching and learning process. This implies the restructuring of learning activities to make them more effective through the use of technology.	At this level, AI is used to create new possibilities and transform activity in the teaching and learning process.	*Teaching process:* AI can be used in data analysis and machine learning systems to identify learning patterns and adapt teaching to the individual needs of each student. *Learning process:* Students interact with AI-based chatbots to improve their pronunciation and conversation skills in a foreign language.
	Redefinition	At this level, technology greatly transforms the way in which the teaching and learning process is carried out. Technology allows students to create, collaborate and share ideas in ways that were not previously possible.	At this level, AI is used to significantly modify existing activity in the teaching and learning process.	*Teaching process:* AI can be used in machine learning systems to personalise the syllabus for each student and adapt it according to their progress and individual needs. *Learning process:* Students use an adaptive learning platform that automatically adjusts the difficulty level of content according to each student's performance.

Source: own elaboration.

The outer rings of the AI Pedagogy Wheel contain examples of AI tools and apps that can be used for each cognitive and AI technology integration level. These suggested AI tools and applications available for each cognitive level are just a sample and are by no means an exhaustive list, given the growing number of applications that are currently emerging.

Finally, the proposed AI Pedagogy Wheel includes an additional ring featuring a new aspect: the Reflective-Metacognitive level (covered by the fourth cluster: sustainable and ethical education). The inclusion of the Reflective-Metacognitive level in the wheel is important because it allows students and teachers to reflect critically on the use of AI and how it affects their learning and teaching. With regard to the teaching process, teachers at this level can assess how they are integrating technology in their teaching, reflect on the impact this is having on students and make changes where necessary. This implies a reflective and metacognitive approach towards technology, specifically AI, that is more critical and analytical, rather than simply using it as a tool.

With regard to the learning process, students can also reflect critically on how they use it and the impact it is having on their learning. They can assess how they are using AI to learn, identify what is effective and what is not, and make changes to their learning approach where necessary. Here, reflection refers to the process through which students can critically assess and analyse their own learning, while metacognition refers to students' ability to monitor their own learning and understand the learning strategies they use. Both skills are essential for successful lifelong learning, and are particularly important in the context of AI-focused education.

Along these lines, there are several studies that justify the need for reflection and metacognition in the use of AI in education. Luckin (2018) believes that AI can be a valuable tool for improving education, but it is important to reflect on how it is used and what impact it has on students and learning overall. Therefore, she highlights the importance of reflecting on how AI can be used effectively in education, and how it can work alongside human intelligence to improve learning.

Furthermore, Selwyn (2019) underlines how important it is for teachers to carefully consider how AI is integrated in the classroom and how they can use it to improve students' learning. They must also reflect on the potential consequences of AI for teaching and the relationship between humans and machines in the classroom. Siemens and Baker (2012) analyse how AI and data mining can be used in education and the importance of reflecting on the ethical and pedagogical implications of its use. In this regard, reflection on the use of AI for educational data analysis and the collaboration between the actors involved may contribute towards the more effective and responsible use of technology in education.

With respect to metacognition, according to Cerchiaro et al. (2021), this refers to the "knowledge that a person has about their own cognitive processes and products, as well as the monitoring and regulation of these processes in terms of the achievement of an objective or goal" (p. 3). Another perspective is that offered by Porayska-Pomsta (2016), who identifies the use of AI as a methodology for supporting educational praxis and teacher metacognition, as it provides personalised, adaptive, real-time feedback to students, while helping teachers to reflect on their pedagogical practice and make informed decisions.

Nevertheless, the proposed inclusion of this Reflective-Metacognitive level refers more to the ethical and responsible use of AI, where educators can discuss these issues with students and foster the responsible and ethical use of AI. In this way, AI allows teachers to design and implement pedagogical strategies that foster reflection and metacognition in their students as key skills for their future learning.

Therefore, including this Reflective-Metacognitive level in the wheel allows for the identification of areas for improvement and opportunities for improving AI integration in the educational process, ensuring the effective and responsible use of technology.

Figure 6 shows the AI Pedagogy Wheel together with Bloom's Taxonomy and the SAMR Model, plus the Reflective-Metacognitive ring featuring a selection of appropriate AI tools and technological strategies for each cognitive skill and AI technology integration level.

Figure 6
AI Pedagogy Wheel
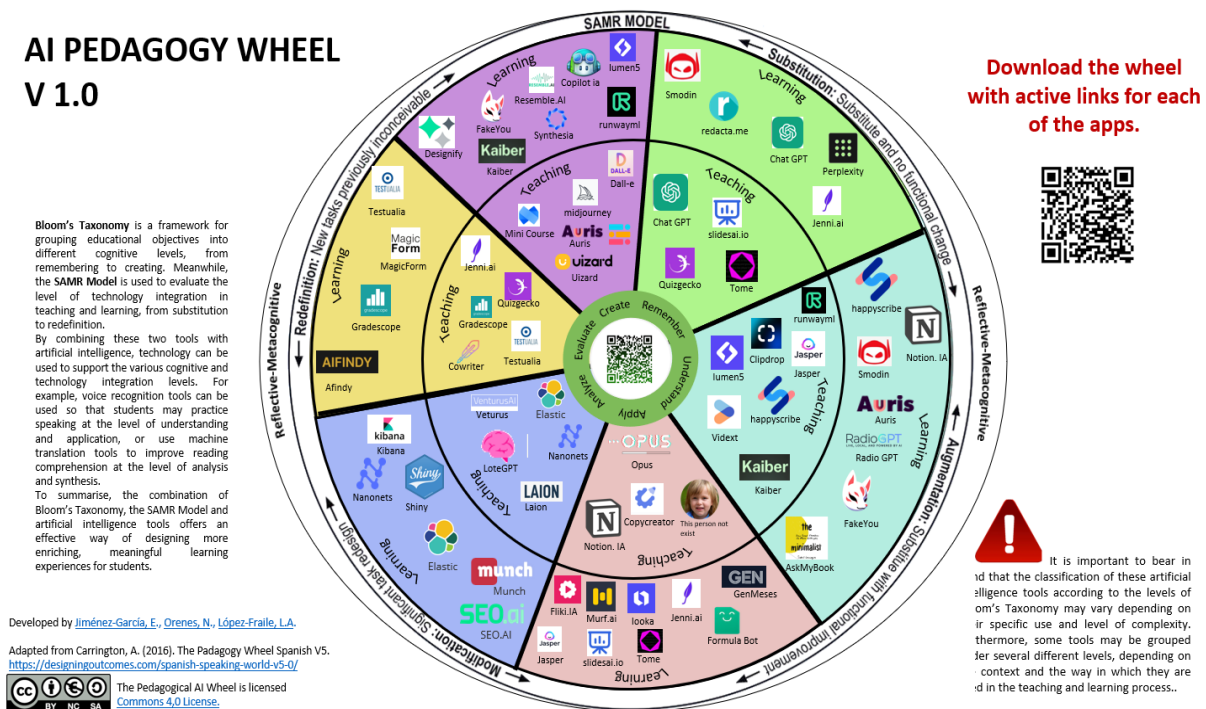
Source: own elaboration. Adapted from Carrington (2016).
(Link to download the wheel with active links for each of the apps)

It must be noted that these are just some examples of AI tools and apps that may be used for each cognitive and integration level. There are lots of other tools and apps available that may be adapted and modified according to the specific needs and objectives of the learning activity in line with students' level of skill and knowledge in terms of AI.

DISCUSSION AND CONCLUSIONS

The relationship between AI and education is a topic that has gained increasing attention in recent years, given the great potential of AI to improve the quality and efficiency of learning. The systematic review of the 43 relevant articles has demonstrated the growing trend in research about AI in education. Specifically, the fact that in 2023 a significant proportion of articles have already been published, despite the year not yet being over, indicates the possibility that research in this field will continue to grow, thus signalling the importance and relevance of the topic.

Furthermore, regarding the authors who have contributed the most (Järvelä, Sanna; Oyelere, Solomon Sunday; Prahani, Binar Kurnia and Suprapto, Nadi) and the

geographical diversity of the countries of origin of these authors (Indonesia, Finland and Sweden) demonstrates the international, globalised nature of research in this field.

Meanwhile, turning to AI integration in education, Pedro et al. (2019) explored this relationship in their study and underlined the opportunities and challenges that arise when implementing AI in the area of education to achieve sustainable development. Personalised learning is one of the key opportunities that AI has to offer, as it adapts educational content to the specific needs of each student, allows for the early detection of learning difficulties and offers personalised feedback. Bhutoria (2022) found similar results, where AI is able to take into account the learning requirements and habits of students and optimise learning trajectories.

However, it is important to underline that teachers should be considered a fundamental part of the planning and execution of personalised education with AI. The active involvement of teachers in this process is essential to ensure learning objectives are achieved and that students' needs are observed. Moreover, as already mentioned, this wheel can be a support tool for teachers, but it is important that teachers are trained to use AI appropriately, to understand its limitations and to make the most of these emerging technologies (Salas-Pilco et al., 2022).

In this sense, AI integration in education must be done carefully, and must be part of a broader, more balanced approach that combines technology with pedagogy and teaching expertise. Lameras and Arnab (2021) and Cope et al. (2021) emphasise that AI should be used as a tool for supporting and improving the teaching and learning process, rather than completely replacing teachers or fully automating the educational process. It is therefore important to understand that AI cannot replace the human relationship between teacher and student, which is fundamental to successful learning.

In line with this idea, the clusters identified in the topic analysis (1. AI integration to improve education, 2. use of educational technologies in the teaching and learning process, 3. pedagogical design and innovation and 4. sustainable and ethical education) reveal the key areas in which AI can have a meaningful impact on education. Thus, adapting the Pedagogy Wheel for AI according to these clusters provides an up-to-date, relevant framework that enables educators to effectively consider how to harness AI capabilities in curriculum planning, teaching methodology, assessment and other key areas of the teaching and learning process.

In addition, one of the contributions made is the inclusion of a new outer ring in the AI Pedagogy Wheel: the Reflective-Metacognitive level. The inclusion of such a level could be an important step towards ensuring the effective and responsible use of AI in education. This is due to the need to understand the crucial role of reflection and metacognition in the educational process. Authors such as Bostrom (2014) emphasise the importance of reflecting on the potential impacts of AI on society and the need to develop strategies to ensure that these impacts are positive. In this regard, he addresses the potential risks and benefits of AI and how its development should be handled with caution and reflection. Drigas et al. (2023) propose a meta-learning model that combines metacognition with smart technologies to improve learning outcomes. The model consists of nine layers, with the metacognition layer referring to the learner's ability to reflect on their own learning process. It is therefore essential that students learn to reflect on their own learning process and develop effective metacognitive strategies to enhance their learning, especially in situations where technology tools such as AI are used.

Therefore, the adaptation of this wheel is necessary because the authors seek to ensure the pedagogical use of AI in education. However, it is important to note that AI

has limitations and disadvantages that need to be considered. While this technology may improve efficiency and accuracy in several areas, its misuse can have negative effects on society. In education, it is important for ethical, moral and privacy issues to be addressed when it comes to handling personal data, as underlined by Renz and Vladova (2021) and Yuskovych-Zhukovska et al. (2022). It is therefore essential to establish clear policies and protective measures to avoid any discrimination or harm to students. As such, the potential benefits of AI in education can be harnessed without compromising privacy and ethics. Furthermore, it is crucial that students and teachers develop competency for the age of AI, as highlighted by UNESCO (2021). This involves understanding the ethical and social aspects of AI, such as data privacy and security, as well as the impact it may have on society (Arrieta et al., 2020).

Consequently, it is essential that AI is applied responsibly and ethically in education, as this tool has a direct impact on the development and education of students. For this reason, it is crucial to have a theoretical framework supported by pedagogy that enables teachers and students to understand the scope and limitations of AI, as well as to acquire critical skills that allow them to assess the accuracy and reliability of the results it provides.

In this regard, the proposal set out in this article stands as a valuable tool for education. It should be noted that the inclusion of the AI Pedagogy Wheel in this theoretical framework is particularly relevant, as this tool is centred around the effective integration of technology and pedagogy. As such, it seeks to ensure that teaching and learning methods are appropriate for the specific context in which AI is used.

Finally, it is worth highlighting that this AI wheel is just an initial approach towards the proper integration of this technology in the age of AI. However, it is important to consider that given the constant emergence of numerous new AI apps, this wheel should be regularly updated to ensure it remains relevant and useful.

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