Nanotechnology Perceptions
ISSN 1660-6795
www.nano-ntp.com

Current Applications of Computational Intelligence in Education: A Systematic Review

Darwin Augusto Moscoso Montoya

Universidad Nacional de San Agustín de Arequipa, darasesor@gmail.com

Computational intelligence is the ability of humans to imitate machines to perform tasks normally considered human intelligence, such as learning, reasoning, and problem solving. Computational intelligence can be used to improve problem-solving ability, understanding human behavior and developing logical reasoning taking into account computer science, among others. This data can be used to create a personalized learning plan adaptable to the individual needs of each student. Therefore, this study seeks to analyze the current applications of computational intelligence in education from the perspective of a systematic review, using globally recognized databases, such as Scopus, Web of Science and Dimensions, with specific search formulas. The time interval selected for the review was from 2013 to 2024, focused on the topic of education. Inclusion and exclusion criteria were applied to filter the results, eliminating research not related to the topic or those with restricted access, subscription, payment, repeated or retracted publications. This article concludes by stating that computational intelligence has the potential to transform education, adapting it to the specific needs of each environment. The following are detected as application trends: the development of more advanced techniques for detecting deception, the optimization of educational processes, the development of specialized educational environments, the application of immersive technologies in higher education and the development of Smart Educational Cities. This article also presents general suggestions based on work aimed at improving the use of operational intelligence in education.

Keywords: Computational intelligence, Education, Educational transformation.

1. Introduction

Computational intelligence has emerged as a dynamic and promising field of research that merges the fundamental principles of computer science and computational intelligence. This scope encompasses a variety of innovative approaches and advanced techniques designed to equip machines with the ability to learn, adapt, and perform tasks autonomously, reflecting characteristics commonly associated with human intelligence. From machine learning algorithms to neural networks and evolutionary algorithms, computational intelligence encompasses a diverse spectrum of methodologies that seek to transform the way machines interact with data and address complex problems. In this article, we will explore the most

recent developments in the field of computational intelligence, highlighting its applications, current challenges, and its potential impact on various disciplines, from business decision-making to scientific problem-solving.

Traditional models struggle to cope with complexity, noise, and the existence of a changing environment, while Computational Intelligence (CI) offers solutions to both complicated and inverse problems. The main characteristic of CI is adaptability, which encompasses the fields of machine learning and computational neuroscience. CI also comprises biologically inspired technologies, such as swarm intellect, as part of evolutionary computation and encompasses broader areas such as image processing, data collection, and natural language processing (Sadollah & Sinha, 2020).

Computational intelligence has recently been studied from various fields, highlighting medical treatment (Verma et al., 2020), health information (Manocha et al., 2021; Jena et al., 2021), diagnosis and medical treatment during the COVID-19 pandemic (Kose et al., 2022),Bioinformatics and biostatistics (Cazzaniga et al., 2020), in multidisciplinary research (Elngar et al., 2022), to improve business models (Pedrycz et al., 2021), for information retrieval (Saini et al., 2021) and in digital pedagogy (Deyasi et al., 2020).

As for the reviews carried out on computational intelligence, these are multiple and have varied study objectives. Thus, those carried out by Alnashwan et al., (2023) on speech problem detection, Narasimhan & Victor, (2023) on the prediction of the severity of diseases, to combat the pandemic (Xu et al., 2022; Tseng et al., 2020), for the hospitality industry (Guerra-Montenegro et al., 2021) and for preventive maintenance (Wong et al., 2022), stock market prediction (Teixeira Zavadzki et al., 2020) and even in agriculture (Badgujar et al., 2023). The absence of bibliographic reviews in the field of education is evident.

Educational big data analytics and computational intelligence have transformed the understanding of learning ability and computing power, catalyzing the emergence of Education 4.0. However, educators and researchers still struggle to identify appropriate methods for analyzing the various data generated in educational settings. The complexity and uncertainty inherent in heterogeneous and homogeneous data often compound these challenges (Ikegwu et al., 2023).

That is why the topic of this research on computational intelligence in education justifies its relevance through its ability to fundamentally transform the educational experience and address contemporary challenges in the educational field. The increasing integration of technology in education has generated a paradigm shift in the way we teach and learn, and computational intelligence emerges as a crucial field to optimize this process (Xhafa et al., 2010).

First, the ability of computational intelligence to personalize teaching and adapt to the individual needs of students highlights its revolutionary potential. Individualization of learning, supported by intelligent algorithms that understand and respond to specific preferences and learning styles, has the power to significantly improve educational effectiveness and student achievement (Bellas & Sousa, 2023). In addition, the application of technologies such as virtual reality, augmented reality, and data mining in the educational context, as addressed in the reviewed research, highlights the transformative role of

computational intelligence (El Alami et al., 2007). These technologies offer immersive learning experiences and enable the efficient collection and analysis of educational data, contributing to a deeper understanding of teaching and learning processes (Vasilakos et al., 2004). It should be noted that it is necessary to know if computational intelligence in education not only responds to contemporary demands, but also aims to transform education towards a more personalized, efficient and equitable approach.

The lack of systematic reviews on the proposed topic is corroborated, giving rise to the need to build an RSL that analyzes the development and trends of computational intelligence in education, considering the importance of this topic for the whole world. Therefore, it will seek to analyze the current applications of computational intelligence in education from the perspective of a systematic review.

2. Material and methods

A systematic review of scientific articles was carried out based on the generation of the question: How is computational intelligence applied in education? And the complementary questions are: How has research evolved in this area?, Which countries have produced the largest amount of research on the subject?, What research has had an impact on CI in education?, What functions does CI currently fulfill in education?, What are the requirements for an adequate implementation of CI in education? and what trends are identified and recommended for future research? The Scopus, Web of Science databases considered to be the most important worldwide for the thematic area of the study were selected (Hosseiniara, 2023), in addition to the innovative research platform and database Dimensions (Orduña-Malea & Delgado-López-Cózar, 2018), using as search formulas in the databases Search formula in Scopus (TITLE ("computational intelligence" AND education) OR TITLE ("intelligent computing" AND education) OR TITLE ("cognitive computing" AND education) OR TITLE ("computational intelligence" AND education)), repeating this same formula in Web of Science while in Dimensions it was limited to (TITLE AND ABSTRACT ("computational intelligence")) obtaining 19 results in Web of Science, in Scopus 46 results and 402 results in Dimensions, totaling 467 scientific documents. Table 1 shows the filters that were applied to these results:

Table 1. Criteria for the selection of documents

To Include	To Exclude
All research in the time interval between 2013 and 2024 was included. Thematic areas (education). Published scientific articles	All research that was not related to the topic of the research was excluded. Those investigations that have restricted access or subscription or payment. Repeated publications The publications that were retracted.

The data filtering was carried out by the researcher, author of this research, generating a database in Excel software (V. 2019 for Windows) to filter duplicate documents. The complete detail of the filtering can be seen in Figure 1, where the PRISMA diagram is outlined. Finally, 15 scientific documents that meet the inclusion and exclusion criteria set out in Table 1 were

selected.

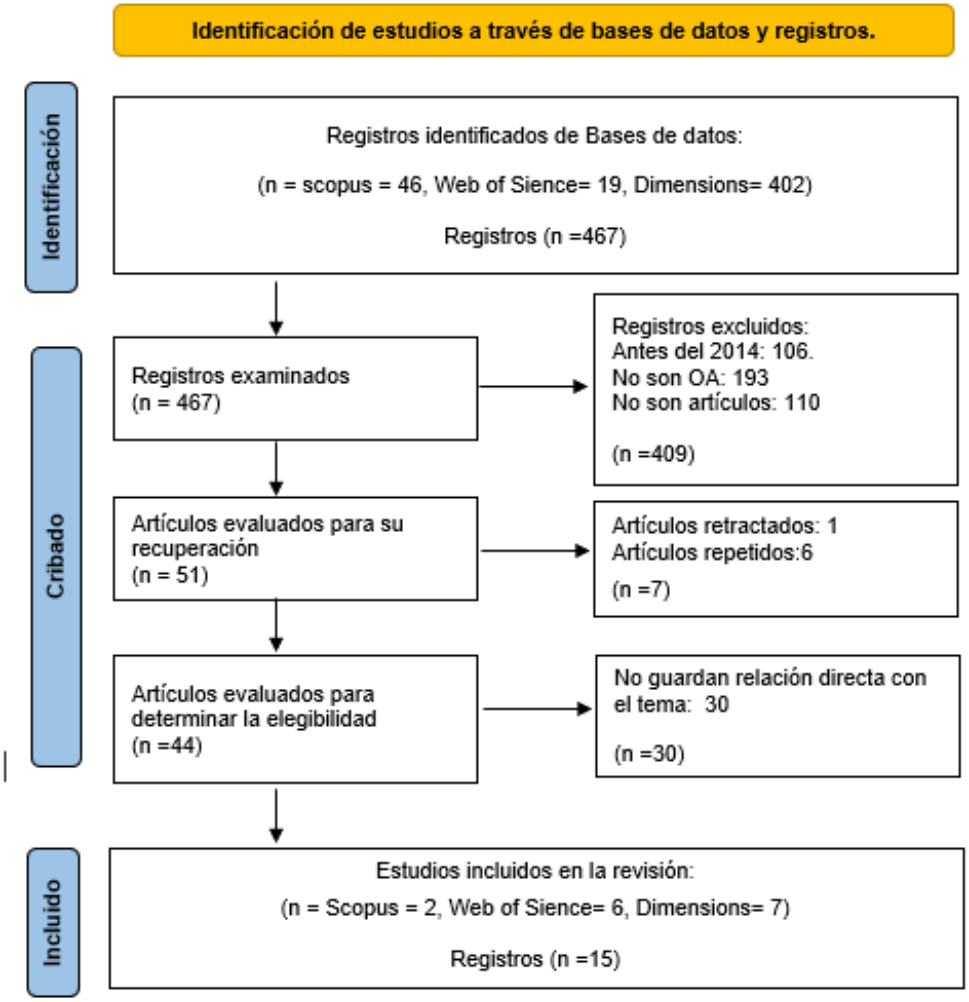

Figure 1. PRISMA Flowchart. In original language Spanish

3. Results

Figure 2 shows a higher production in 2023 (4) and 2021 with the same amount, followed by 2022 (3). While the years 2018 (2), 2017 (1) and 2020 (1) show lower production. The sustained growth that this topic maintains is clear, being of interest and novelty for scientific journals.

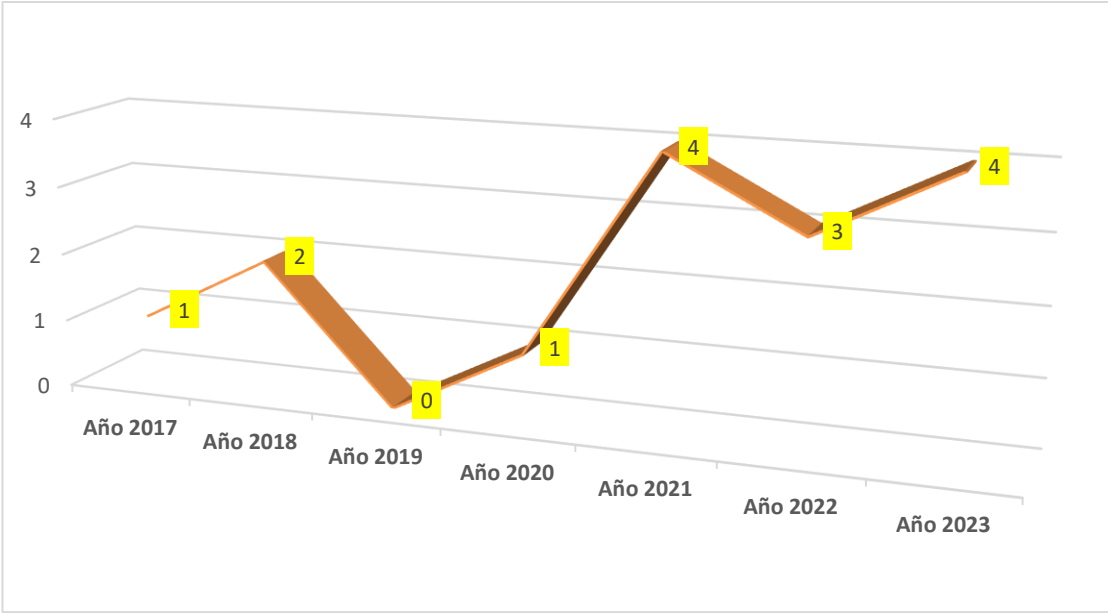

Figure 2. Annual scientific production on Computational Intelligence in Education. In original language Spanish

Table 3 presents the findings referring to scientific production by country regarding Computational Intelligence in Education, with China (7) standing out, followed by India with two scientific publications.

Table 2. Scientific production by country regarding Computational Intelligence in Education

Country	fi	%
China	7	46.67%
India	2	13.33%
Indonesia	1	6.67%
Lithuania	1	6.67%
Poland	1	6.67%
Brazil	1	6.67%
USA	1	6.67%
Australia	1	6.67%
Total	15	100.00%

Regarding table 4, it shows the impact of scientific production regarding Computational Intelligence in education, highlighting the Brazilian research entitled "Application of Computational Intelligence to Improve Education in Smart Cities" which was published on January 18, 2018 and belongs to the authors Everton Gomede, Fernando Henrique Gaffo, Gabriel Ulian Briganó, Rodolfo Miranda De Barros and Leonardo De Souza Mendes, being published by the magazine Sensors of the MDPI publishing house.

Table 4. Impact of scientific production on computational intelligence in education

Authors	Year	Country	Dating	Item Name
Gomede et al.	2018	Brazil	46	Application of computational intelligence to improve education in smart cities
Wahyono et al.	2020	Indonesia	19	Smart Online Courses Using Computational Intelligence
Zhong et al	2021	China	16	On the Gap between Domestic Robotic Applications and Computational Intelligence
Zhu et al.	2021	Australia	11	A Survey of Computational Intelligence in Educational Timetabling
Kumar et al.	2021	India	4	3D animation and virtual reality integrated cognitive computing for teaching and learning in higher education
Goštautaitė and Kurilov	2021	Lithuania	4	Comparative Analysis of Exemplar-Based Approaches for Students' Learning Style Diagnosis Purposes

In this article, the authors present a model that uses data mining and data science to develop knowledge profiles of students, ultimately helping educators make informed decisions for their students' success. The model uses computational intelligence to improve education in smart cities, and provides key findings on factors that influence student achievement. In addition, it offers insights into how educators can effectively use students' knowledge profiles to enhance their learning experience in smart cities.

Regarding the qualitative analysis, to generate the results, the articles were analyzed, selecting fragments that contained relevant ideas and then grouping those that shared similar themes or approaches, after that, the main themes or key concept were identified, encompassing these related themes. The final categories resulting from this analysis are shown below in Table 5.

Table 5. Main categories found in research on Computational Intelligence in Education

Categories	Authors
1. Personalized adaptation and efficient management of educational resources	Ma, S., Wang, G., Goštautaitė, J Kurilov, Wahyono et al., Wu.
2. Educational optimization with computational management	Liu, T., Tang, L., Yao, L., Zhu, G.
3. Personalization and security in specialized education	Lisowski, J., Shang, R., Qin, Y.
4. Technological immersion in higher education	Kumar, A., Dey, R., Rao, G.M., Vengatesan, K., Kumar, V.
5. Smart Educational Cities	Gomede, E., Gaffo, F.H., Briganó, G.U., de Barros, R.M., Mendes, L. S

These five thematic categories are explained below, explaining their disaggregated content.

The category "Personalized adaptation and efficient management of educational resources" focuses on the application of computational intelligence to personalize the educational experience and efficiently manage educational resources.

Ma, (2021) highlights in his research on the use of soft computing techniques to detect deception in online exams, by exploring novel techniques, such as the use of recurrent neural networks for the detection of facial expressions from EEG (electroencephalography) signals. This makes clear the potential of computational intelligence to address real-world problems in education. On the other hand Wang (2017) applied MATLAB visualization technology to improve students' sensory understanding. It also considers the virtual simulation of actions in

the process of studying the reform of the physical education teaching strategy based on intelligent computing.

Whereas Goštautaitė & Kurilov (2021) They developed a system of adaptive online courses based on computational intelligence, based on the cultivation of computational thinking in students by combining theory with practice and autonomous resolution of technical problems. Wahyono et al., (2020) They developed a system that uses computational intelligence to calculate content and topics in educational resources, by utilizing a framework for system design based on models such as the Dick and Carey model and Research and Development (R&D) methods.

At last Wu, (2022) It implemented a fuzzy clustering algorithm for the music educational resource management system, making use of machine learning to create personalized user models, based on online behaviors, interests, and preferences.

Therefore, these authors contribute to the understanding and application of computational intelligence to adapt and efficiently manage educational resources, addressing aspects such as the detection of deception in online exams, the development of adaptive systems and the improvement of teaching in areas such as physical education.

The category "Educational Optimization with Computational Management" refers to research that addresses the use of computational management techniques and methods to optimize educational processes. In this specific case, the authors Liu et al., (2022) They are involved in studies that explore the application of computational management technology in the educational field.

Some possible areas of focus could include the development of systems or platforms that facilitate the management of information in educational archives, the efficiency of the work of teaching staff, or the use of computational methods to improve specific processes within the educational environment. Educational optimization involves the effective use of computational tools to make education more effective.

The category "Personalization and security in specialized education" encompasses research that focuses on the personalized adaptation of educational environments and the implementation of safety measures, particularly in specialized contexts. The authors Lisowski, (2021) and Shang & Qin (2022) They are associated with studies that address these aspects in the educational field.

Research that explores the use of artificial intelligence and safety methods for the training of maritime officers stands out, ensuring the improvement of practical training and appropriate decision-making. (Lisowski, 2021). In addition, the importance of technologies such as massive data storage and processing to ensure the security and operation of medical educational platforms is addressed, as well as the construction of the Internet of Things (IoT) and intelligent computing for higher medical education (Shang & Qin, 2022). Together, these aspects seek to personalize the educational experience and ensure safety in specialized environments.

The category "Technological immersion in higher education" brings together research that focuses on how advanced technologies, such as virtual reality (VR), augmented reality (AR) and 3D animation, are applied in the field of higher education. The authors Kumar et al.,

(2021)and D. Kumar et al., (2021) are associated with studies that explore the impact of these technologies on student learning and understanding, as well as the transformative potential of artificial intelligence (AI) and immersive technologies in educational quality.

Also noteworthy are the research that proposes models to improve the learning experience through the use of virtual and augmented reality in the medical field, as well as the integration of 3D animation to optimize information retention. It is also about the future of higher education enabled by artificial intelligence and immersive technologies, highlighting its enormous potential to change teaching at this level. Overall, this category seeks to explore how technology can significantly improve education in higher education institutions.

Finally, the "Smart Educational Cities" category focuses on the application of computational intelligence, data mining and data science to improve education in urban environments. The authors Gomede et al., (2018) They are associated with research that highlights how these technologies can contribute to student success through the use of knowledge profiles. The proposed models seek to provide recommendations to improve the learning experience in smart cities, enabling educators to make informed decisions.

Here, the personalization of educational services to strengthen student motivation and learning stands out as a theme, as well as the use of massive data storage and processing technologies to guarantee the security and normal functioning of educational resources. The construction of the Internet of Things (IoT) and intelligent computing to advance higher medical education is also highlighted. Together, this category seeks to explore how computational intelligence can transform education in urban environments, improving the teaching process and making it more relevant.

Based on what has been analyzed, it is clear that computational intelligence has the potential to transform education, improving the learning process of students and the efficiency of educational processes. The areas of application of computational intelligence in education are diverse, including teaching, learning, management and assessment (D. Kumar et al., 2021). Thus, some of the specific applications of computational intelligence in education include:

Computational intelligence can personalize student learning by considering their needs and learning styles. An adaptive learning system can use data about student performance, learning preferences, and goals to provide personalized learning content and activities (Gomede et al., 2018).

In addition, it can create immersive learning experiences that allow the process of forming new knowledge to be more active and engaging. Thus, virtual reality and augmented reality can help generate experiences for students in which they face situations as if it were reality. (A. Kumar et al., 2021).

Computational intelligence can also automate administrative and educational tasks, freeing educators to focus on more important activities (Lisowski, 2021). For example, chatbots can be used to answer student questions, learning management systems (LMS) can be used to automate tasks such as enrollment and progress tracking, and recommendation systems can be used to suggest relevant educational resources for students.

Finally, computational intelligence can be used to make a comprehensive assessment of students whose results are more accurate and efficient (Goštautaitė & Kurilov, 2021). This is

evidenced by adaptive assessment systems that can provide real-time feedback to students, machine learning systems can be used to analyse large amounts of learning data to identify trends and patterns, and virtual reality systems can be used to create more immersive and engaging assessment environments.

It was also found that in order to get the most out of computational intelligence in education, it is necessary to have an adequate technological infrastructure: Computational intelligence requires a robust technological infrastructure to be able to function effectively (Shang & Qin, 2022). It is also necessary to have trained professionals: The use of computational intelligence in education requires professionals trained in pedagogy as well as knowledge of modern information and communication technologies. And policies and frameworks need to be developed: Policies and frameworks need to be developed to guide the use of computational intelligence in education (Liu et al., 2022).

It is clear then that the use of computational intelligence in education has the potential to generate a significant impact on the educational field, both at the individual and social levels.

At the individual level, computational intelligence can enhance student learning, improving their skills and reaching their full potential. For example, computational intelligence can help students with special needs access to quality education, students in rural areas benefit from high-quality instruction, and students from all backgrounds achieve their educational goals (Shang & Qin, 2022; Wahyono et al., 2020; Tang & Hare, 2023)

At the social level, computational intelligence can contribute to improving educational equity, reducing educational gaps and, above all, helping students effectively face the challenges of the 21st century. For example, computational intelligence can enable students, regardless of their background, to have access to quality education, to reduce educational gaps between students from different socioeconomic backgrounds, and to prepare the professional profile of students, who require skills such as computational thinking, problem-solving, and creativity (D. Kumar et al., 2021; Zhu et al., 2021; Wang, 2017; Zhong et al., 2021)

Therefore, computational intelligence can be used as an important tool that can enhance education by generating a change in it. However, to make the most of its potential, it is necessary to have an adequate technological infrastructure, trained professionals, and policies and frameworks to guide its use.

4. Discussion

Regarding the question of the development of research on computational intelligence in education, it is observed that the production in the aforementioned field was more significant in 2023, with a total of four contributions, and in 2021, which also registered four contributions. The year 2022 continues in importance with three contributions. In contrast, the years 2018 and 2017 present a lower production, with two and one contribution respectively, while the year 2020 shows a more modest production with a single contribution. The trend of sustained growth in this topic is evident, consolidating it as an area of interest for scientific production and novelty for specialized journals.

As for the countries that have produced the most research in the field of computational

intelligence in education, China tops the list with a total of seven scientific publications, followed by India, which has two contributions in this domain. This is because in 2016, the government launched a plan to establish itself as the center where the best and largest production in the world is produced by 2030. China established its national AI strategy for education as part of this technological vision (Jing, 2017).

The research that impacted on CI in education is reflected in a Brazilian research published in 2018, under the title "Application of computational intelligence to improve education in smart cities". This study, carried out by Everton Gomede, Fernando Henrique Gaffo, Gabriel Ulian Briganó, Rodolfo Miranda De Barros and Leonardo De Souza Mendes, is distinguished by its focus on improving education in smart urban environments. Published in the journal Sensors of the MDPI publishing house, the research reveals the implementation of technologies such as data mining and data science to elaborate student knowledge profiles. This approach provides educators with critical tools to make informed decisions and promote student success. In addition, the proposed model uses computational intelligence to offer valuable insights into the factors influencing student achievement, providing specific details on how educators can leverage these knowledge profiles to optimize the learning experience in smart urban environments.

Regarding the functions that CI currently fulfills in education, the research presented is grouped into five major thematic categories that highlight the functions of computational intelligence in various educational contexts. In the category "Personalized adaptation and efficient management of educational resources", approaches to personalize the educational experience and efficiently manage resources are explored. Ma (2021) addresses the detection of deception in online exams using soft computing techniques, while Wang (2017) contributes to the development of adaptive systems using MATLAB visualization technology.

The category "Educational Optimization with Computational Management" focuses on the use of computational management techniques and methods to optimize educational processes. Liu et al. (2022) participate in studies that apply computational management technology in the field of education, which allow the effective and quality development of education through computational tools.

In "Personalization and Security in Specialized Education," authors such as Lisowski (2021) and Shang & Qin (2022) explore personalized adaptation in specialized educational settings and the implementation of safety measures. Topics such as the training of maritime officers and security on medical educational platforms are addressed, using artificial intelligence and security methods.

The category "Technological immersion in higher education" highlights the application of advanced technologies in higher education. Kumar et al. (2021) and D. Kumar et al. (2021) propose models to improve the learning experience through virtual reality, augmented reality and 3D animation, as well as the integration of artificial intelligence, transforming educational quality at this level.

Finally, the smart educational cities category focuses on the application of computational intelligence in urban environments. Gomede et al. (2018) highlight the importance of knowledge profiles, providing recommendations to improve the learning experience in smart

cities, addressing the personalization of educational services and the security of educational resources. This research explores the potential of computational intelligence to transform education, adapting it to the specific needs of each environment.

Analysing the requirements that allow a good implementation of CI in education and to maximise its positive impact, it is imperative to have a solid technological infrastructure, properly trained professionals and well-developed frameworks and policies. This technology has the potential to revolutionize education at individual and societal levels. Thus, computational intelligence emerges as a powerful tool, but its successful implementation depends on adequate technological, professional, and regulatory preparation in the educational field.

Finally, based on the research presented, various trends and areas of interest within computational intelligence in the educational field are observed. A recommendation for further research is the development of more advanced techniques for detecting deception in virtual assessment environments. Ma's (2021) research highlights the use of soft computing and recurrent neural networks, and this approach could be refined considering the constant evolution of deception methods.

Another area of interest is the optimization of educational processes. The application of computational tools to improve the effectiveness and quality of education is suggested. The development of more sophisticated algorithms and models could be deepened to address specific problems in the management of educational information and in the efficiency of teaching processes.

The development of specialized educational environments is a critical issue that deserves continued attention. Research could focus on developing advanced security and personalized adaptation technologies, using more advanced methods of artificial intelligence and machine learning to improve hands-on training and decision-making in specialized situations. In the field of higher education, the application of immersive technologies such as virtual and augmented reality is still a pending issue to be investigated. It is recommended to continue exploring and implementing these technologies, considering new ways to integrate computational intelligence and immersive technologies to further transform the quality of education at this level.

It is clear that the development of Smart Educational Cities offers opportunities to personalize educational services and improve safety. Future research could focus on the practical implementation of these concepts, considering the interconnectedness of education systems in urban environments and the long-term impact on the quality of education.

Computational intelligence in education is therefore still a broad and evolving field. Continuing to explore the application of advanced techniques, improving safety in specialized educational settings, and the practical implementation of emerging technologies in higher education levels and urban settings are promising areas for future research.

5. Conclusions

Computational intelligence has the potential to transform education, adapting it to the specific

needs of each environment. The research presented in this document explores various application trends and areas of interest within this field, highlighting the development of more advanced techniques for detecting deception, the optimization of educational processes, the development of specialized educational environments, the application of immersive technologies in higher education and the development of Smart Educational Cities.

To harness the greatest potential of computational intelligence in education, it is recommended that future research focus on the development of advanced deception detection techniques: These techniques must be able to identify the most sophisticated methods of deception, which are constantly evolving. In addition, in the optimization of educational processes: The development of more sophisticated algorithms and models must be deepened to address specific problems in the management of educational information and in the efficiency of teaching processes. Attention should also be focused on the development of advanced security technologies and personalized adaptation, using more advanced methods of artificial intelligence and machine learning. These technologies should continue to be explored and implemented, considering new ways to integrate computational intelligence and immersive technologies to further transform educational quality at this level. Finally, attention should be focused on the practical implementation of these concepts, considering the interconnection of education systems in urban environments and the long-term impact on the quality of education.

References

1. Alnashwan, R., Alhakbani, N., Al-Nafjan, A., Almudhi, A., & Al-Nuwaiser, W. (2023). Computational Intelligence-Based Stuttering Detection: A Systematic Review. Diagnostics, 13(23). Scopus. https://doi.org/10.3390/diagnostics13233537
2. Badgujar, C., Das, S., Figueroa, D. M., & Flippo, D. (2023). Application of Computational Intelligence Methods in Agricultural Soil–Machine Interaction: A Review. Agriculture (Switzerland), 13(2). Scopus. https://doi.org/10.3390/agriculture13020357
3. Bellas, F., & Sousa, A. (2023). Publisher: Computational intelligence advances in educational robotics. Frontiers in Robotics and AI, 10. https://www.frontiersin.org/articles/10.3389/frobt.2023.1150409
4. Cazzaniga, P., Besozzi, D., Merelli, I., & Manzoni, L. (2020). Computational Intelligence Methods for Bioinformatics and Biostatistics: 16th International Meeting, CIBB 2019, Bergamo, Italy, September 4–6, 2019, Revised Selected Papers. Springer Nature.
5. Deyasi, A., Mukherjee, S., Mukherjee, A., Bhattacharjee, A. K., & Mondal, A. (2020). Computational Intelligence in Digital Pedagogy. Springer Nature.
6. El Alami, M., Casel, N., & Zampunieris, D. (2007). An Architecture for e-Learning System with Computational Intelligence. In B. Apolloni, R. J. Howlett, & L. Jain (Eds.), Knowledge-Based Intelligent Information and Engineering Systems (pp. 58-65). Springer. https://doi.org/10.1007/978-3-540-74827-4_8
7. Elngar, A. A., Chowdhury, R., Elhoseny, M., & Balas, V. E. (2022). Applications of Computational Intelligence in Multi-Disciplinary Research. Academic Press.
8. Gomede, E., Gaffo, F. H., Briganó, G. U., De Barros, R. M., & Mendes, L. D. S. (2018). Application of Computational Intelligence to Improve Education in Smart Cities. Sensors, 18(1), Article 1. https://doi.org/10.3390/s18010267
9. Goštautaitė, D., & Kurilov, J. (2021). Comparative Analysis of Exemplar-Based Approaches for Students' Learning Style Diagnosis Purposes. Applied Sciences, 11(15), 7083. https://doi.org/10.3390/app11157083

10. Guerra-Montenegro, J., Sánchez-Medina, J., Laña, I., Sánchez-Rodríguez, D., Alonso-González, I., & Del Ser, J. (2021). Computational Intelligence in the hospitality industry: A systematic literature review and a prospect of challenges. Applied Soft Computing, 102. Scopus. https://doi.org/10.1016/j.asoc.2021.107082
11. Hosseiniara, R. (2023). General comparison of scientific databases of Scopus, PubMed, and Web of Science. Novelty in Clinical Medicine, 2(3), 168-169. https://doi.org/10.22034/ncm.2023.380213.1059
12. Ikegwu, A. C., Nweke, H. F., & Anikwe, C. V. (2023). Recent trends in computational intelligence for educational big data analysis. Iran Journal of Computer Science. https://doi.org/10.1007/s42044-023-00158-5
13. Jena, O. P., Tripathy, A. R., Elngar, A. A., & Polkowski, Z. (2021). Computational Intelligence and Healthcare Informatics. John Wiley & Sons.
14. Jing, M. (2017, October 14). China turns to artificial intelligence to boost its education system. South China Morning Post. https://www.scmp.com/tech/science-research/article/2115271/china-wants-bring-artificial-intelligence-its-classrooms-boost
15. Kose, U., Watada, J., Deperlioglu, O., & Saucedo, J. A. M. (2022). Computational Intelligence for COVID-19 and Future Pandemics: Emerging Applications and Strategies. Springer Nature.
16. Kumar, A., Dey, R., Madhukar Rao, G., Pitchai, S., Vengatesan, K., & Ambeth Kumar, V. D. (2021). 3D Animation and Virtual Reality Integrated Cognitive Computing for Teaching and Learning in Higher Education. In Recent Trends in Intensive Computing (pp. 615-620). IOS Press. https://doi.org/10.3233/APC210252
17. Kumar, D., Alam, M., & Polat, K. (2021). Interactive Attendance System for Modern Education Using Computational Intelligence. Journal of the Institute of Electronics and Computer, 3(1). https://doi.org/10.33969/JIEC.2021.31006
18. Lisowski, J. (2021). Computational Intelligence in Marine Control Engineering Education. Polish Maritime Research, 28(1), 163-172. https://sciendo.com/es/article/10.2478/pomr-2021-0015
19. Liu, T., Tang, L., Yao, L., & Zhu, G. (2022). [Retracted] Teaching Archives Information Management and Quality Diagnosis Method from the Perspective of Collaborative Education Based on Intelligent Computing. Security and Communication Networks, 2022, e4194667. https://doi.org/10.1155/2022/4194667
20. Ma, S. (2021). A Study of Two-Way Short- and Long-Term Memory Network Intelligent Computing IoT Model-Assisted Home Education Attention Mechanism. Computational Intelligence and Neuroscience, 2021, e3587884. https://doi.org/10.1155/2021/3587884
21. Manocha, A. K., Jain, S., Singh, M., & Paul, S. (2021). Computational Intelligence in Healthcare. Springer Nature.
22. Narasimhan, G., & Victor, A. (2023). Analysis of computational intelligence approaches for predicting disease severity in humans: Challenges and research guidelines. Journal of Education and Health Promotion, 12(1). Scopus. https://doi.org/10.4103/jehp.jehp_298_23
23. Orduña-Malea, E., & Delgado-López-Cózar, E. (2018). Long live the competition! New dimensions for the search and evaluation of scientific information. ThinkEPI Yearbook, 12, 304-3010. https://doi.org/10.3145/thinkepi.2018.45
24. Pedrycz, W., Martínez, L., Espin-Andrade, R. A., Rivera, G., & Gómez, J. M. (2021). Computational Intelligence for Business Analytics. Springer Nature.
25. Sadollah, A., & Sinha, T. (2020). Recent Trends in Computational Intelligence. BoD – Books on Demand.
26. Saini, D., Chaudhary, G., & Gupta, V. (2021). Computational Intelligence for Information Retrieval. CRC Press.
27. Shang, R., & Qin, Y. (2022). Research on Humanistic Quality Higher Medical Education

Based on Internet of Things and Intelligent Computing. Computational Intelligence and Neuroscience, 2022, e8633190. https://doi.org/10.1155/2022/8633190

28. Tang, Y., & Hare, R. (2023). Combining Gamification and Intelligent Tutoring Systems in a Serious Game for Engineering Education. arXiv. https://doi.org/10.48550/arxiv.2305.16568
29. Teixeira Zavadzki, S., Kleina, M., Oscar Drozda, F., & Augusto Mendes Marques, M. (2020). Computational Intelligence Techniques Used for Stock Market Prediction: A Systematic Review. IEEE Latin America Transactions, 18(4), 744-755. Scopus. https://doi.org/10.1109/TLA.2020.9082218
30. Tseng, V. S., Jia-Ching Ying, J., Wong, S. T. C., Cook, D. J., & Liu, J. (2020). Computational Intelligence Techniques for Combating COVID-19: A Survey. IEEE Computational Intelligence Magazine, 15(4), 10-22. Scopus. https://doi.org/10.1109/MCI.2020.3019873
31. Vasilakos, A. (Thanos), Devedzic, V., Kinshuk, & Pedrycz, W. (2004). Special Issue: Computational Intelligence in Web-Based Education. Journal of Interactive Learning Research, 15(4), 297-298. https://www.proquest.com/docview/211275809/citation/9D8C4441D5B343B1PQ/1
32. Verma, J. K., Paul, S., & Johri, P. (2020). Computational Intelligence and Its Applications in Healthcare. Academic Press.
33. Wahyono, I. D., Saryono, D., Asfani, K., Ashar, M., & Sunarti, S. (2020). Smart Online Courses Using Computational Intelligence. International Journal of Interactive Mobile Technologies (iJIM), 14(12), 29-40. https://doi.org/10.3991/ijim.v14i12.15601
34. Wang, S. (2017). The Teaching Reform of College Students' Entrepreneurship Education Combined. Journal of Information Technology Review, 8(2).
35. Wong, S. Y., Ye, X., Guo, F., & Goh, H. H. (2022). Computational intelligence for preventive maintenance of power transformers. Applied Soft Computing, 114. Scopus. https://doi.org/10.1016/j.asoc.2021.108129
36. Wu, M. (2022). A Music Teaching Resource Management Model Based on Fuzzy Clustering Algorithm. Mobile Information Systems, 2022, 1-11. https://doi.org/10.1155/2022/3469869
37. Xhafa, F., Caballé, S., Abraham, A., Daradoumis, T., & Juan, A. (2010). Computational Intelligence for Technology Enhanced Learning (Vol. 273). https://doi.org/10.1007/978-3-642-11224-9
38. Xu, Z., Su, C., Xiao, Y., & Wang, F. (2022). Artificial intelligence for COVID-19: Battling the pandemic with computational intelligence. Intelligent Medicine, 2(1), 13-29. Scopus. https://doi.org/10.1016/j.imed.2021.09.001
39. Zhong, J., Ling, C., Cangelosi, A., Lotfi, A., & Liu, X. (2021). On the Gap between Domestic Robotic Applications and Computational Intelligence. Electronics, 10(7), 793. https://doi.org/10.3390/electronics10070793
40. Zhu, K., Li, L. D., & Li, M. (2021). A Survey of Computational Intelligence in Educational Timetabling. International Journal of Machine Learning and Computing, 11(1), 40-47. https://doi.org/10.18178/ijmlc.2021.11.1.1012