



The Impact of Artificial Intelligence on Education for Sustainable Development: "A Systematic Review"

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Abstract. In recent years, we have witnessed an era characterized by rapid development, during which concepts of education and sustainable development have become central in global discussions. The focus is on empowering individuals and societies towards sustainability by striking a balance between economic progress, environmental awareness, and social justice, as sustainable development seeks to enhance the quality of life for current and future generations.

In this context, the role of artificial intelligence (AI) emerges as one of the most significant innovations in our current era, as it represents a technological revolution that plays a vital role in shaping the future.

Through a comprehensive systematic review by reviewing and analyzing literature related to reviews in the recent period (from 2020 to 2024), following stages such as document collection, eligibility screening, quality assessment, and data coding, the aim was to understand the impact of technology in the era of artificial intelligence on the fields of education and sustainable development globally.

This study provided a distinct contribution to understanding how technology, particularly artificial intelligence, affects the quality of education and achieves sustainable development goals. This systematic review is expected to have a significant impact on guiding research to keep up with the era's transformations and respond to the current societal requirements, as well as to achieve effective improvements in educational systems.

Keywords: Education, Sustainable Development, Artificial Intelligence, Methodological Review.

1 Introduction

In recent decades, technology has undergone a radical transformation of the world around us. Experts believe that the upcoming digital shift, affecting our lives, interactions, businesses, trade, and learning, will occur through the use of Artificial Intelligence (A.I) in the near future [1].

Considering that Artificial Intelligence possesses revolutionary capabilities, computers have been able to learn and make predictions or decisions without the need for explicit programming [2]. Artificial Intelligence represents the ability of computers to replicate human activities and perform tasks that require human-like thinking. It can be beneficial to human resources if used correctly and in accordance with the cultural context. However, users must understand their role as learners when using Artificial Intelligence and it should be employed in accordance with ethical and scientific principles to avoid potential risks in the future. Recently, the use of Artificial Intelligence has been evident in various scientific fields such as information systems, health, education, and industry, playing a vital role and contributing in multiple ways to the prosperity and advancement of nations [3].

Artificial Intelligence (AI) represents a significant outcome of the industrial revolution due to its diverse applications in various fields such as industry, economy, technology, and education. This innovation demonstrates limitless potential, paving the way for further industrial revolutions and causing a fundamental shift in human life. A S. Boubha et al [4] found that the use of AI applications in various fields plays a vital role that cannot be denied in our current world. It emphasizes the need for preparation to enter the fourth industrial revolution through investing in human capital and adopting smart technology. Although the field of artificial intelligence remains broad, many of its theories are still under development and research.

AI technology is rapidly evolving and plays a crucial role in various fields, including the education system. It enhances the efficiency and effectiveness of the education system through various means, such as adaptive learning, predictive analysis, smart educational systems, natural language processing, and educational games. The continuous development of artificial intelligence is expected to have significant potential for improving various aspects of human life. Researchers have embraced this idea to enhance the role of AI in achieving efficiency and effectiveness in education [4].

The importance of using artificial intelligence techniques in education lies in their focus on social and human aspects, promoting interpersonal interaction, and improving the quality of education. For example, I.O. Kotlyarova et al [6] proposed an organizational framework for using AI techniques in education, specifying the known and utilized aspects of these technologies in enhancing the educational process. The scientific and educational justifications for using AI techniques in education are emphasized. Considering that artificial intelligence refers to a computer system's ability to perform human tasks such as thinking and learning, tasks that traditionally require human intelligence, this technology enables a degree of flexibility and customization that was previously impossible in education. It revolutionizes universities and research centers, significantly contributing to facilitating the teacher's task. A significant transformation in education is expected as a result of using AI technologies [5].

Applications of Artificial Intelligence (AI) in education have captured the attention of academic researchers, focusing on studying learning processes in various contexts, whether in traditional educational environments or workplaces. The convergence of artificial intelligence and learning sciences, such as education, psychology, neuroscience, linguistics, sociology, and anthropology, aims to facilitate the development of effective and flexible learning environments and comprehensive tools. Over time, various research areas using artificial intelligence have emerged to address new challenges in education, each with its own vision and methodologies [6].

Unfortunately, artificial intelligence faces several key challenges evident in the accumulation and description of experiences in the field of education. However, information related to these challenges remains inadequately organized and has not sufficiently addressed its human and ethical aspects [7].

On the other hand, the concept of sustainable development, which is a priority for the international community, requires a focus on its seventeen goals [8] and three dimensions, whether environmental, economic, or social [9]. Artificial intelligence (AI) constitutes a vital tool for achieving sustainable development goals by offering diverse applications in various sustainability sectors. AI techniques can be used, for example, to develop sustainable solutions in areas such as energy efficiency, agriculture, water management, waste management, and transportation. The role of artificial intelligence is not limited to that; it also encompasses areas of monitoring and prevention of environmental pollution. However, addressing the potential risks of AI technologies in the field of sustainability is crucial. Therefore, ethical and legal regulations must be strengthened, in addition to increasing user awareness, to ensure the use of AI technologies following sustainability principles [10].

This is clearly affirmed through a focus on the fourth goal outlined in the United Nations Sustainable Development Agenda, which strives to 'ensure inclusive and equitable quality education and promote lifelong learning opportunities for all' [11]. This fourth goal highlights the importance of education as a key driver for achieving sustainable development goals. Within this framework, the educational discourse should undergo a fundamental shift, emphasizing social and environmental justice and making them integral priorities in education. A redefinition of the prevailing educational discourse is necessary, incorporating an approach that places social and environmental orientations at the center of educational attention and consideration [12].

The development of artificial intelligence in the sustainability field can be enhanced by introducing a new definition of sustainable AI. This definition focuses on making AI products integrate seamlessly with preserving environmental resources, economic models, and social values throughout all stages, from training and configuration to execution. Sustainable artificial intelligence is not limited to its applications; it also addresses the entire technological social system. To achieve a balance between innovation in AI and fair, sustainable resource distribution, as well as justice between generations and the relationship between the environment, society, and the economy. [13].

Highlighting the uses of AI applications for developing a sustainable environment in various sectors, such as biodiversity, energy, water, transportation, air, and agriculture, is also possible. Artificial intelligence is a powerful tool for reducing the impacts of climate change and improving environmental sustainability.

The importance of using smart technologies in addressing environmental issues lies in improving the management of environmental resources, enhancing biodiversity, increasing energy and water use efficiency, developing smart transportation systems, combating air pollution, improving agricultural processes, and achieving sustainable progress in various aspects of human-environment interaction. It is crucial to develop environmentally friendly AI technologies to ensure the sustainability of these efforts and their non-negative impact on the environment. Despite existing limitations that need to be overcome, such as the need to develop policies and regulations that promote sustainability, positive interaction with the community, and ensuring the protection and security of data privacy [14].

It can be argued that artificial intelligence technologies can be a key factor in achieving the Sustainable Development Goals for 2030. With its capabilities in visualization, decision-making, and prediction, artificial intelligence can support efforts in areas such as healthcare, biodiversity monitoring, and environmental conservation. However, potential challenges must be considered, such as the shortage of clean energy required to power artificial intelligence applications, and the risks of excessive exploitation of natural resources due to increased access to ecosystem information [15].

2 Problem Statement

This study aims to provide a comprehensive insight into the interactions between the field of education and the applications of artificial intelligence (AI) technologies in the context of sustainability, shedding light on the complex connections between them. Thus, achieving the integration of artificial intelligence with the concept of sustainability is possible by realizing sustainable development goals across various sectors, making education play a fundamental role as a link between these two aspects.

The role of this research paper is to address the following problem statement:

How can the integration of artificial intelligence into education contribute to achieving the Sustainable Development Goals?

3 Methodology

To ensure a thorough and comprehensive understanding of the main question of this study, we adopted a mixed-methods methodology that relies on a consistent combination of qualitative and quantitative data. [16].

This systematic framework of research using a mixed approach presents a methodological pluralism that combines numerical and textual data relating to the subject studied [17]. The process of identifying and analyzing documents related to recent literature reviews addressing the impact of technology and artificial intelligence on the fields of education and sustainable development globally was carried out following a systematic literature review method based on the following steps:

- Step 1: *Document collection.*
- Step 2: *Eligibility Assessment.*
- Step 3: *Quality Evaluation.*
- Step 4: *Data Coding.*

3.1 Document collection:

A time frame for the search has been set, spanning the last five years (from 2020 to 2024), without geographical constraints, focusing on studies related to the topic. The search was conducted by a research team consisting of two university professors, an educational framework for secondary education, and a physics and chemistry teacher for high school education. The scope of the search was narrowed down to include all previous reviews containing the following synonyms: "*Sustainable development – Technology – Artificial intelligence – Education*".

The joint search was conducted across various databases to collect all documents related to the topic. However, the most prominent databases, based on document quality, are as follows: "*Science Direct, Scopus, HAL.Science, ...*".

During the initial search process, English was adopted due to the abundance of results based on this language. A total of 234 documents were extracted as of February 27, 2024, after which the systematic review process commenced directly.

3.2 Eligibility Assessment and Quality Evaluation:

The documents were examined using the Decision Tree, a technique used to illustrate the decision-making process during research or study. The tree branches out in multiple directions to display different options and sub-details for each choice [18].

By using the Decision Tree, researchers and scientists can organize their thoughts and research details systematically, making it easier for readers to understand the steps taken in the study. This tool is also an effective means for making strategic decisions and prioritizing in the context of scientific research [19]. (Figure 1).

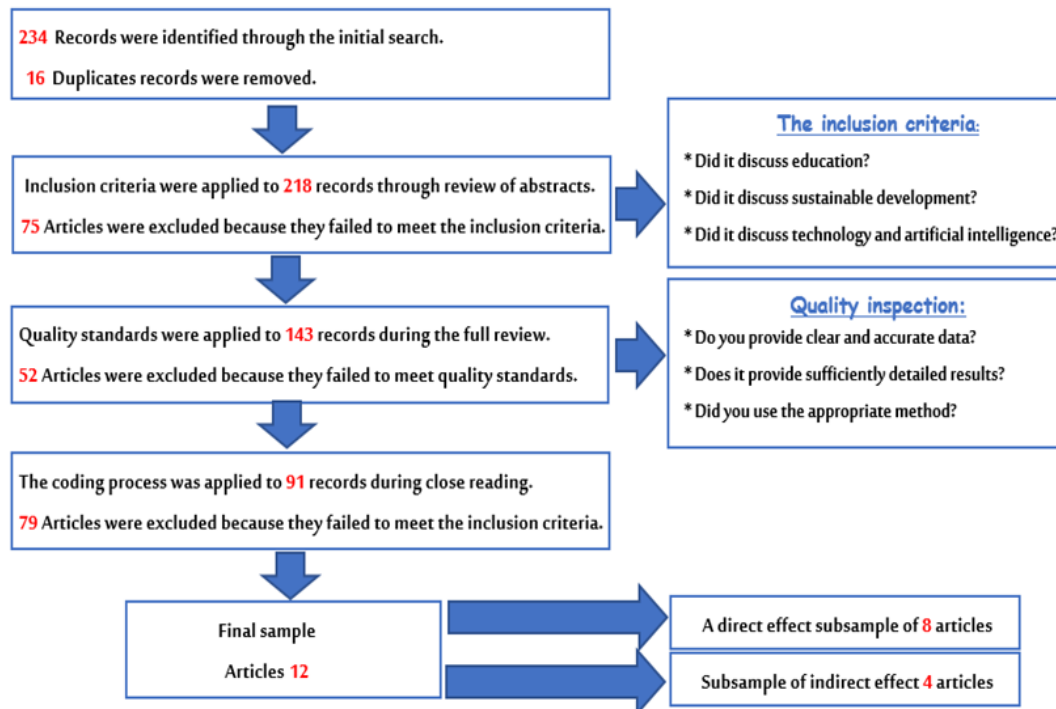


Fig. 1. Decision Tree for the Research Process Using Decision Tree

The research team read all 234 documents, using the decision tree, important studies aligning with the study's criteria were retained.

After conducting a quality assessment for all studies, the research team decided to exclude the studies that did not meet quality standards, as they did not provide clear and accurate results or directly relevant data on the topic.

3.3 Data Coding:

The data were coded and categorized in an Excel table to facilitate the classification of publications based on several criteria. After a thorough review process, it was found that only 8 documents met the decision tree criteria.

4 Results and Discussion

The obtained documents were classified according to (*Title, year, countries, Study Period, sample, Purpose of the study, Results and recommendations*) in the following specific tables:

Table 1. Review N°1: The Role of Artificial Intelligence

N°	01
Title	The Role of Artificial Intelligence of Things in Achieving Sustainable Development Goals: State of the Art [20]
Year	2024
Countries	Greece; Norway; Finland; Colombia
Study Period	The study was conducted on all documents from 1989 to 2022
Sample	The analysis covered 9,182 documents
Purpose of the study	Through bibliometric analysis, this study aims to provide an overview of the role of Artificial Intelligence (AI), Internet of Things (IoT), and Artificial Intelligence of Things (AIoT) in achieving sustainable development. • This study contributed to bridging the gap in the literature regarding the use of artificial intelligence and the Internet of Things in the context of sustainable development. • The study highlighted the role of artificial intelligence as a key driver in achieving sustainable development goals.
Results	• A gradual transition from traditional systems to technology-supported smart systems was observed. • Despite artificial intelligence still being in its early stages, it is considered an essential component for achieving sustainable development goals. • Artificial intelligence shows immense potential for transforming various sectors and achieving a sustainable future. • Future studies should focus on specific goals or areas of sustainable development.
Recommendations	• More experimental studies involving the application of artificial intelligence in real-world scenarios should be conducted.

Table 2. Review N°2: How can artificial intelligence impact sustainability

N°	02
Title	How can artificial intelligence impact sustainability? A systematic literature review [21]
Year	2022
Countries	India; Germany
Study Period	The study was conducted on all documents from 1991 to 2022
Sample	The review relied on 287 articles out of 8341
Purpose of the study	Through the systematic literature review, this study aims to identify the impact of artificial intelligence on sustainability for addressing issues across various fields. • Many researchers have worked on using artificial intelligence and machine learning to achieve sustainable development goals. • Effective mechanisms have been developed using artificial intelligence to meet the needs of the current generation without compromising the capabilities of future generations.
Results	• The review provided graphs and tables that will provide ideas and inspiration for future researchers on how to engage in the field of artificial intelligence in sustainable development. • Integrating sustainable management practices with the use of artificial intelligence requires high computational efficiency and sufficient time.

Recommendations	• Based on the information provided in the study, this study enabled researchers to identify gaps in current research on the use of artificial intelligence in sustainable development. • There is a need to search for suitable mechanisms to manage issues related to our environment, economy, and society to move forward towards sustainability. • Deep consideration should be given to the opportunities and challenges associated with the field of artificial intelligence in sustainable development.
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Table 3. Review N°3: Sustainability and the Digital Transition

N°	03
Title	Sustainability and the Digital Transition: A Literature Review [22]
Year	2022
Countries	Portugal
Study Period	The study was conducted on all documents from 2009 to 2021
Sample	The analysis covered 282,887 documents
Purpose of the study	Through a systematic review of bibliometric literature, this study aims to understand recent developments in sustainability and digital transformation, such as artificial intelligence and the Internet of Things, in order to bridge the knowledge gap and highlight potential contributions.
Results	• Despite the effectiveness of digital transformation in promoting sustainability, there is limited attention to this aspect. • Digital transformation processes have shown significant potential to develop sustainable solutions that address many social, environmental, and economic issues. • In the environmental dimension, digital transformation is used to improve sustainability in urban development, waste management, and pollution control. • In the economic dimension, digital transformation contributes to enhancing a circular economy, digital sharing, and sustainable design for manufacturing and infrastructure. • In the social dimension, there is a need for multidimensional policy strategies to address the digital divide and promote social equality. • Digital technology perspectives for development should be targeted through education, healthcare, etc.
Recommendations	• Alternative and innovative methods should be explored, including innovation through experimentation, additional strategies, and sustainable dynamic benefits that can be achieved.

Table 4. Review N°4: Exploring the Role of Artificial Intelligence in Sustainable Decision Making

N°	04
Title	Exploring the Role of Artificial Intelligence in Sustainable Decision Making: A Systematic Literature Review [23]
Year	2023
Countries	Morocco
Study Period	The study was conducted on all documents from 2018 to 2023
Sample	The review relied on 101 articles out of 109

Purpose of the study	This study aims, through a systematic review of literature using academic databases such as Scopus and Web of Science, to understand the applications of artificial intelligence and explore how it can contribute to making sustainable decisions within organizations. • Artificial Intelligence (AI) has become a significant area of interest in making sustainable decisions within organizations.
Results	• Artificial intelligence can be used to improve the efficiency of decision-making processes, reduce errors and biases, and generate sustainable and innovative solutions. • More research in this field is advised to better understand the issues, constraints, and opportunities associated with using artificial intelligence in sustainable decision-making.
Recommendations	• Artificial intelligence should be embraced and implemented in organizations, along with addressing implicit practices and challenges associated with its use.

Table 5. Review N°5: A Bibliometric Review of Education for Sustainable Development

N°	05
Title	A Bibliometric Review of Education for Sustainable Development, 1992–2022 [24]
Year	2023
Countries	China
Study Period	The study was conducted on all documents from 1992 to 2022
Sample	The review relied on 2279 articles out of 4541
Purpose of the study	This study aims, through a bibliometric review, to understand the foundations of research in education for sustainable development and the innovation of educational technology. • The study provided a reference for researchers in the field of education and artificial intelligence for sustainable development. • The main research areas of education for sustainable development were divided into the following five categories: Foundations of research in education for sustainable development, environmental education, higher education for sustainable development, sustainable development literacy, and innovation in educational technology.
Results	• This study provides a retrospective view of research in education for sustainable development in a reliable, transparent, and objective manner. • The importance of using technology to facilitate the transfer of information more quickly and widely was emphasized. • Encouraging the establishment and formation of international, regional, and national networks with a diverse range of partners, including universities and civil society, is crucial. • Guiding principles should be provided to governments to guide them in adopting a comprehensive, multidisciplinary approach to implementing education for sustainable development and integrating it into their national education policies and systems.
Recommendations	• There is an urgent need for a comprehensive review of the field of education for sustainable development and its relationship with technology. • Leveraging the benefits of technology to achieve sustainable development goals is essential.

Table 6. Review N°6: Educator Competences in Sustainability Education

N°	06
Title	Educator Competences in Sustainability Education - A Systematic Review of Frameworks [25]
Year	2020
Countries	Spain; Germany
Study Period	The study was conducted on all documents from 2013 to 2019
Sample	The review relied on 14 articles out of 627
Purpose of the study	This study aims, through a systematic review of scientific literature, to guide the professional development of teachers in the field of sustainability by analyzing and evaluating the necessary competencies for them.
Results	• The theoretical foundations for addressing scientific literature on sustainability concepts and competencies are not sufficiently developed. • Few researchers critically address sustainability, acknowledging its contradictions even as they engage in this broad approach to sustainability. • It was found that European frameworks dominate the field, with some influence from American perspectives. • The article identifies gaps in addressing teacher competencies. • Emphasis should be placed on the role of teachers in sustainability education and the necessity to enhance their effectiveness.
Recommendations	• More research is needed to address specific challenges and provide practical and effective tools for teachers. • Professional development for teachers should be guided, and necessary competencies should be identified through the analysis of sustainability frameworks and models.

Table 7. Review N°7: A Scientific Perspective on Using Artificial Intelligence

N°	07
Title	A Scientific Perspective on Using Artificial Intelligence in Sustainable Urban Development [26]
Year	2023
Countries	Romania
Study Period	The study was conducted on all documents from 2012 to 2022
Sample	The analysis covered 20 documents
Purpose of the study	This study aims, through a systematic literature review, to verify the dimensions considered when integrating artificial intelligence into sustainable urban development.
Results	• Through analyzing the results of studies, it became evident that artificial intelligence has significant potential for developing integrated and sustainable applications. • Economic and environmental success can be achieved through the utilization of artificial intelligence techniques. • An increase in published research on the topic has been observed since 2018. • The peak of studies addressing this topic was recorded in 2020. • Artificial intelligence progress plays a pivotal role in securing the future of upcoming generations.

Recommendations	• This study has provided an opportunity for further investigations in the field of artificial intelligence, paving the way for deeper studies and research. • Artificial intelligence technology can simplify individuals' lives by integrating it into sustainable development. • Further research in this field is essential to obtain more accurate data regarding individual developments. • Partnerships should be formed among various stakeholders, such as local citizens, civil society, industry, and government. • Transparency and accountability should be ensured in the implementation and dissemination of artificial intelligence applications.
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Table 8. Review N°8: Machine Learning Technologies for Sustainability

N°	08
Title	Machine Learning Technologies for Sustainability in Smart Cities in the Post COVID Era [27]
Year	2020
Countries	Spain
Study Period	The study was conducted on all documents from 2015 to 2019
Sample	The review relied on 65 articles out of 261
Purpose of the study	This study aims, through a systematic literature review, to understand the relationship between the concepts of smart cities and artificial intelligence techniques and their potential applicability. • The potential solution to addressing environmental and health issues in smart cities lies in the use of artificial intelligence techniques.
Results	• This work lays a fundamental groundwork and introduction for future research related to this topic. • Areas and dimensions of sustainability were analyzed, and the sustainable development goals related to this topic were discussed. • This work is part of a broader action plan aimed at promoting sustainable development goals and designing and developing products tailored to smart cities to enhance sustainability. • It is imperative to advance the functioning of smart city networks to enhance data exchange in the event of disease outbreaks or disasters.
Recommendations	• Improving planning and management is necessary to make cities more inclusive, secure, resilient, and sustainable due to unprecedented urban growth in recent years.

Based on the main conclusions drawn from the analyzed reviews, it has been found that the impact of technology on education for sustainable development in the era of artificial intelligence represents a vital and evolving field deserving intensive study and careful analysis at present. There has been a noticeable increase in published documents on this subject in recent years on a global level, aiming to effectively contribute to addressing the gap in the literature regarding the use of technology, especially artificial intelligence and the Internet of Things, in the context of sustainable development. Additionally, a gradual transition from traditional systems to technology-supported smart systems has been observed, reflecting advancements in resource management and utilization towards more efficient and sustainable methods [20].

Although Artificial Intelligence (AI) shows immense potential for achieving a sustainable future, it is still in its early stages, indicating the need for more attention and efforts to further develop this field to meet the needs of the current generation without compromising the capabilities of future generations [21]. Digital transformation is considered one of the most significant factors contributing to sustainability across various social, economic, and environmental aspects. However, there is limited focus on the education sector, and studies indicate the need for clear and multi-dimensional educational strategies to address the current digital divide, which has shown recent increases in indicators of sustainability [22]. While AI has become a major area of interest with its various applications for sustainability within organizations such as schools and universities, it is necessary to emphasize some potential benefits of AI use, such as improving decision-making efficiency, reducing errors and biases, and generating sustainable and innovative solutions [23]. Studies have clearly demonstrated the dynamic interaction between an individual's internal environment and the external environment, highlighting the importance of using technology to facilitate faster and wider information dissemination and updating digital technology to achieve sustainable development goals [25]. The role of educational frameworks in addressing current sustainability challenges from a transformative perspective should not be neglected, through the classification of teacher competencies and the analysis of educational strategies applied for their development. Although there are few researchers critically dealing with sustainability and recognizing its contradictions, they share in this broad approach to sustainable development [25].

Digital transformation, powered by advancements in digital technologies, is a continuous process with significant and lasting impacts on both the economy and society. It serves as a key driver of ongoing change, particularly in the context of sustainable development. Artificial intelligence (AI) technologies, including machine learning, deep learning, and predictive analytics, play vital roles in sustainable development efforts. However, integrating AI into sustainable development faces challenges such as ensuring data quality, protecting privacy, and promoting collaboration among stakeholders. Despite these challenges, AI has shown considerable progress and is driving innovation and development in the field of sustainable development [26].

In conclusion, this work serves as a prelude to a broader action plan or basis for future research, aiming to enhance sustainable development goals and design and develop products aimed at promoting sustainability in the educational context [27].

In recent years, over the past five years, a specific set of countries has shown a notable interest in education for sustainable development. These countries include Greece, Norway, Finland, Germany, Portugal, China, Spain, Colombia, India, and Romania. These countries have attracted global attention due to their dedication to scientific research in this field, reflecting their serious commitment to achieving sustainable development while conserving resources for current and future generations.

Despite Morocco's efforts in sustainable development, many African and Arab countries have not shown the same level of interest in the issue during the same period. This disparity can be attributed to multiple factors, including national priorities and economic and environmental challenges. However, this situation may change in the future with increased awareness of the importance of sustainable development and the need

to adopt sustainable strategies to achieve comprehensive development through teaching AI mechanisms worldwide. After reviewing all the literature, the recommendations put forward agree that advancing the application of technology in education for sustainable development in the era of artificial intelligence requires comprehensive and inclusive review in this field. Future studies should focus on the interactions between technology and various fundamental trends of sustainable development, with a focus on specific educational areas or goals that achieve inclusivity. Additionally, future studies should focus on ensuring the security and safety of critical infrastructure and balancing the economic, environmental, and social benefits of technology application in education.

Furthermore, there should be encouragement of collaboration among researchers with diverse backgrounds and experiences, and the development of common standards and measures for evaluating performance and progress in this field. Moreover, emphasis should be placed on specific areas such as employment, labor markets, and healthcare, especially education, by analyzing the positive impact of AI technologies. Ethical, social, and environmental aspects of technology use in achieving sustainable development goals should not be neglected. Ultimately, future research should seek to enhance global understanding and cooperation among concerned groups, expanding cooperation between countries and international organizations. Future studies should focus on raising awareness of opportunities and challenges related to technology and providing the necessary mechanisms to achieve sustainable development.

5 Conclusion

In our current era, we find that technological advancement, particularly in the field of artificial intelligence, opens new horizons and incredible opportunities for achieving sustainable development in education, aiming to meet the current and future needs of individuals and societies. Through a comprehensive review of the available literature in this field over recent years, there has been a deep understanding of the impact of artificial intelligence and its effective role in improving learning and teaching processes, as well as in developing educational curricula, integrating them to suit the needs of the modern age.

However, scientific research in Arab and African countries, particularly in the Kingdom of Morocco, remains at low levels. Despite progress, we are still at the beginning of this path, necessitating greater efforts and enhanced research by increasing focus on technology to improve outcomes in sustainability through education. Therefore, it is advisable to conduct more in-depth studies and precise analyses of the impact of technology, especially artificial intelligence, on the educational process and the enhancement of education quality, in line with sustainable development goals.

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