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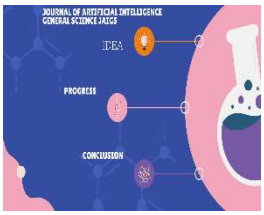

Exploring the Challenges and Future Directions of Big Data and AI in Education

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ABSTRACT

The integration of Big Data and Artificial Intelligence (AI) in education holds transformative potential, promising enhanced personalized learning experiences, improved administrative efficiency, and advanced predictive analytics. However, the adoption of these technologies also presents significant challenges. This paper explores the current landscape of Big Data and AI in education, identifying key challenges such as data privacy concerns, the digital divide, the need for teacher training, and the integration of AI with existing educational frameworks. Additionally, it examines potential future directions, including the development of ethical guidelines, advancements in adaptive learning technologies, and the creation of more inclusive and equitable AI systems. By addressing these challenges and leveraging future opportunities, the educational sector can harness the full potential of Big Data and AI to improve learning outcomes and operational efficiencies.

Introduction:

The advent of Big Data and Artificial Intelligence (AI) has ushered in a new era of technological innovation across various sectors, with education being no exception. These technologies promise to revolutionize the educational landscape by providing personalized learning experiences, enhancing administrative efficiency, and enabling data-driven decision-making. Big Data allows for the collection and analysis of vast amounts of educational data, offering insights into student performance, learning behaviors, and institutional effectiveness. Concurrently, AI technologies, including machine learning algorithms and natural language processing, are being deployed to develop intelligent tutoring systems, predictive analytics for student success, and automated administrative processes.

Despite the promising benefits, the integration of Big Data and AI in education is fraught with challenges. Data privacy concerns are paramount, as educational institutions must ensure the protection of sensitive student information. The digital divide also poses a significant barrier, with unequal access to technology exacerbating educational inequalities. Furthermore, the successful implementation of these technologies requires substantial teacher training and support, as educators must be adept at utilizing new tools and interpreting data insights. Additionally, integrating AI and Big Data into existing educational frameworks presents practical and logistical challenges.

This paper aims to explore these challenges comprehensively and discuss potential future directions for the use of Big Data and AI in education. By examining the current state of these technologies and identifying both obstacles and opportunities, we seek to provide a roadmap for educators, policymakers, and technologists to navigate the complexities of integrating Big Data and AI into educational environments. Through careful consideration of ethical implications and a focus on inclusivity, the educational sector can harness the power of these technologies to enhance learning outcomes and operational efficiencies, paving the way for a more informed and equitable future.

Objectives:

1. Identify and Analyze Key Challenges: To comprehensively identify and analyze the key challenges associated with integrating Big Data and Artificial Intelligence in education, including data privacy concerns, the digital divide, the need for teacher training, and the logistical complexities of incorporating these technologies into existing educational frameworks.

2. Explore Future Directions and Opportunities: To explore potential future directions and opportunities for leveraging Big Data and AI in education, focusing on the development of ethical guidelines, advancements in adaptive learning technologies, and the creation of more inclusive and equitable AI systems.

3. Provide Strategic Recommendations: To provide strategic recommendations for educators, policymakers, and technologists on how to effectively navigate the complexities of integrating Big Data and AI in education, ensuring that these technologies are used to enhance learning outcomes and operational efficiencies while addressing ethical and equity concerns.

Research Method

To explore the challenges and future directions of Big Data and Artificial Intelligence (AI) in education, a mixed-methods research approach will be employed. This method integrates both qualitative and quantitative research techniques to provide a comprehensive understanding of the topic.

1. Case Studies:

- Perform in-depth case studies of educational institutions that have successfully integrated Big Data and AI into their practices.
- Analyze their implementation strategies, outcomes, and the challenges they encountered.
- Compare and contrast these case studies to identify best practices and effective solutions.

2. Interviews:

- Conduct semi-structured interviews with key stakeholders, including educational leaders, policymakers, AI developers, and data privacy experts.
- Gather qualitative insights into the practical challenges and ethical considerations of implementing Big Data and AI in educational settings.
- Use thematic analysis to identify recurring themes and deep insights from the interview data.

3. Workshops and Focus Groups:

- Organize workshops and focus group discussions with educators, students, and AI practitioners to explore specific issues in greater detail.

- Facilitate discussions on potential future directions and innovative solutions for overcoming identified challenges.

- Record and analyze the discussions to capture diverse perspectives and practical suggestions.

4. Data Analysis:

- Combine qualitative and quantitative data using a triangulation approach to validate findings and provide a holistic view of the research problem.

- Employ statistical software for quantitative data analysis and coding software for qualitative data analysis to ensure rigorous and systematic examination of the data.

By utilizing this mixed-methods approach, the research aims to provide a thorough understanding of the current challenges and future directions of Big Data and AI in education, offering actionable insights and recommendations for stakeholders.

Background:

The purpose of this position paper is to present the current status, opportunities, and challenges of Big Data and Artificial Intelligence (AI) in education. This work originates from the opinions and panel discussion minutes of the International Learning Sciences Forum 2019, where prominent researchers and experts from various disciplines such as education, psychology, data science, AI, and cognitive neuroscience exchanged their knowledge and ideas. This article is organized as follows: we begin with an overview of recent progress in Big Data and AI in education, followed by a presentation of major challenges and emerging trends. Finally, based on our discussions of Big Data and AI in education, we provide conclusions and suggest future directions.

Rapid advancements in Big Data and AI technologies have had a profound impact on all areas of human society, including the economy, politics, science, and education. These developments have enabled the continuation of many social activities during the COVID-19 pandemic. Digital tools, platforms, applications, and communications among people have generated vast amounts of data, often referred to as 'big data'. Big Data technologies aim to harness the power of extensive data in real-time or otherwise (Daniel, 2019). The characteristic attributes of Big Data are often referred to as the four V's: volume (amount of data), variety (diversity of sources and types of data), velocity (speed of data transmission and generation), and veracity (accuracy and trustworthiness of data) (Laney, 2001; Schroeck et al., 2012; Geczy, 2014). Recently, a fifth V, value, has been added to indicate that data could be monetized (Dijcks, 2013). Due to these intrinsic characteristics, large and complex datasets are challenging to process and utilize using traditional data management techniques. Thus, innovative computational technologies are required for the acquisition, storage, distribution, analysis, and management of Big Data (Lazer et al., 2014; Geczy, 2015).

Big Data analytics commonly encompass the processes of gathering, analyzing, and evaluating large datasets. Extracting actionable knowledge and viable patterns from data is often viewed as a core benefit of the Big Data revolution (Mayer-Schönberger and Cukier, 2013; Jagadish et al., 2014). Big Data analytics employ various technologies and tools, such as statistical analysis, data mining, data visualization, text analytics, social network analysis, signal processing, and machine learning (Chen and Zhang, 2014).

As a subset of AI, machine learning focuses on building computer systems that can learn from and adapt to data automatically without explicit programming (Jordan and Mitchell, 2015). Machine learning algorithms can provide new insights, predictions, and solutions tailored to the needs and circumstances of each individual. With the availability of large quantities of high-quality input training data, machine learning processes can achieve accurate results and facilitate informed decision-making (Manyika et al., 2011; Gobert et al., 2012, 2013; Gobert and Sao Pedro, 2017). These data-intensive, machine learning methods are positioned at the intersection of Big Data and AI and are capable of improving services and productivity in education, as well as in other fields such as commerce, science, and government.

In the context of education, the application of AI technologies can be traced back approximately 50 years. The first Intelligent Tutoring System, "SCHOLAR," was designed to support geography learning and was capable of generating interactive responses to student statements (Carbonell, 1970). While the amount of data was relatively small at that time, it was comparable to the data collected in other traditional educational and psychological studies. Over the past few decades, research on AI in education has been dedicated to advancing intelligent computing technologies such as intelligent tutoring systems (Graesser et al., 2005; Gobert et al., 2013; Nye, 2015), robotic systems (Toh et al., 2016; Anwar et al., 2019), and chatbots (Smutny and Schreiberova, 2020).

With breakthroughs in information technologies in the last decade, educational psychologists have had greater access to Big Data. Social media (e.g., Facebook, Twitter), online learning environments [e.g., Massive Open Online Courses (MOOCs)], intelligent tutoring systems (e.g., AutoTutor), learning management systems (LMSs), sensors, and mobile devices are generating ever-growing amounts of dynamic and complex data, including students' personal records, physiological data, learning logs and activities, and learning performance and outcomes (Daniel, 2015). Learning analytics, described as “the measurement, collection, analysis, and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs” (Long and Siemens, 2011, p. 34), are often implemented to analyze these vast amounts of data (Aldowah et al., 2019). Machine learning and AI techniques further expand the capabilities of learning analytics (Zawacki-Richter et al., 2019). The essential information extracted from Big Data can be utilized to optimize learning, teaching, and administration (Daniel, 2015). Therefore, research on Big Data and AI is gaining increasing significance in education (Johnson et al., 2011; Becker et al., 2017; Hwang et al., 2018) and psychology (Harlow and Oswald, 2016; Yarkoni and Westfall, 2017; Adjerid and Kelley, 2018; Cheung and Jak, 2018). Recently, the adoption of Big Data and AI in the psychology of learning and teaching has been trending as a novel method in cutting-edge educational research (Daniel, 2015; Starcic, 2019).

The Position Formulation

A growing body of literature has attempted to uncover the value of Big Data at different education levels, from preschool to higher education (Chen N.-S. et al., 2020). Numerous journal articles and book chapters have provided retrospective descriptions and the latest advances in this rapidly expanding research area from various perspectives, including systematic literature reviews (Zawacki-Richter et al., 2019; Quadir et al., 2020), bibliometric studies (Hinojo-Lucena et al., 2019), qualitative analyses (Malik et al., 2019; Chen L. et al., 2020), and social network analyses (Goksel and Bozkurt, 2019). More details can be found in the previously mentioned reviews. This paper aims to present the current progress of the application of Big Data and AI in education.

On the learner side, research has focused on identifying students' learning and affective behavior patterns, improving methods of assessment and evaluation, predicting individual students' learning performance or dropouts, and providing adaptive systems for personalized support (Papamitsiou and Economides, 2014; Zawacki-Richter et al., 2019). For teachers, numerous studies have aimed to enhance course planning, curriculum development, evaluation of teaching, and teaching support (Zawacki-Richter et al., 2019; Quadir et al., 2020). Additionally, teacher dashboards, such as Inq-Blotter, driven by Big Data techniques, are being used to inform teachers' instruction in real-time while students simultaneously work in Inq-ITS (Gobert and Sao Pedro, 2017; Mislevy et al., 2020). Big Data technologies employing learning analytics and machine learning have demonstrated high predictive accuracy of students' academic performance (Huang et al., 2020). Only a small number of studies have focused on the effectiveness of learning analytics programs and AI applications. However, recent findings have shown encouraging results in terms of improving students' academic performance and retention, as well as supporting teachers in learning design and teaching strategy refinement (Viberg et al., 2018; Li et al., 2019; Sonderlund et al., 2019; Mislevy et al., 2020).

Despite the growing number of reports and methods outlining implementations of Big Data and AI technologies in educational environments, there remains a notable gap between contemporary technological capabilities and their utilization in education. The fast-growing education industry has developed numerous data processing techniques and AI applications, which may not be guided by current theoretical frameworks and research findings from the psychology of learning and teaching. The rapid pace of technological progress and the relatively slow adoption in education have contributed to this widening gap (Macfadyen, 2017). There is a pressing need to reduce this gap and stimulate technological adoption in education.

This work presents varying viewpoints, contemporary research, and prospective future developments in the adoption of Big Data and AI in education. We advocate for an interdisciplinary approach that encompasses educational, technological, and governmental spheres of influence. In the educational domain, there is a relative lack of knowledge and skills in AI and Big Data applications. On the technological side, few data scientists and AI developers are familiar with advancements in educational psychology, though this is changing with the advent of graduate programs at the intersection of Learning Sciences and Computer Science. Finally, in terms of government policies, the main challenges faced are the regulatory and ethical dilemmas between supporting educational reforms and restricting the adoption of data-oriented technologies.

An Interdisciplinary Approach to Educational Adoption of Big Data and AI

In response to the new opportunities and challenges brought by the Big Data explosion and AI revolution, academics, educators, policymakers, and professionals need to engage in productive collaboration. They must work together to cultivate the necessary competencies and essential skills in our learners, crucial for the 21st-century workforce driven by the knowledge economy (Bereiter, 2002). Collaboration across diverse disciplines and sectors

is a demanding task, especially when each side lacks a clear vision of their mutually beneficial interests and the necessary knowledge and skills to realize that vision.

We highlight several overlapping spheres of interest at the intersection of research, policymaking, and industry engagements. Researchers and the industry would benefit from targeted educational technology development and its efficient transfer to commercial products. Businesses and governments would benefit from legislation that stimulates technology markets while suitably protecting data and users' privacy. Academics and policymakers would benefit from prioritizing educational reforms that enable greater adoption of technology-enhanced curricula.

The recent developments and evolving future trends at the intersections between researchers, policymakers, and industry stakeholders arising from advancements and deployments of Big Data and AI technologies in education are illustrated in Figure 1. The constructive domains among stakeholders progressively evolve along with scientific and technological developments. Therefore, it is important to reflect on longer-term projections and challenges. The following sections highlight the novel challenges and future directions of Big Data and AI technologies at the intersection of education research, policymaking, and industry.

Big Data and AI in Education: Research

Understanding individual differences is crucial for developing pedagogical tools that can effectively target specific students and tailor education to individual needs across different stages of learning. Intelligent educational systems employing Big Data and AI techniques have the capacity to collect accurate and comprehensive personal data. Data analytics can reveal students' learning patterns and identify their specific needs (Gobert and Sao Pedro, 2017; Mislevy et al., 2020). Therefore, Big Data and AI hold the potential to enable personalized learning at scale to achieve precision education (Lu et al., 2018).

Liu et al. (2024)[8] propose a novel approach for enhancing infrared image resolution using the Lightweight Information Split Network. Their method demonstrates significant improvements in image quality and detail reconstruction, showcasing its potential for practical applications in infrared imaging technology.

Several emerging trends, research gaps, and controversies highlight the integration of Big Data and AI into education research, aiming for a profound and rigorous understanding of individual differences to personalize learning in real-time:

1. Transition to Precision Education: Education is progressively shifting from a one-size-fits-all approach to precision education or personalized learning (Lu et al., 2018; Tsai et al., 2020). The traditional approach tailored to average students contrasts with precision education, which considers individual learner differences within their unique learning environments and strategies. Analogous to "precision medicine," precision education utilizes Big Data to identify relevant patterns specific to students, enabling customized prevention, treatment, and learning optimization. Research gaps include the development of adaptive tools and flexible learning systems to accommodate diverse learner interactions, paces, and needs, such as those of students with learning disabilities (Xie et al., 2019; Zawacki-Richter et al., 2019).

2. Shift Towards Cognitive AI: The research focus on deploying AI in education is shifting from a computational approach demonstrating use cases of new technology to a cognitive focus that integrates cognition into its design (VanRullen, 2017; Song et al., 2016; Bramley et al., 2017). This evolution includes multidisciplinary collaboration and domain transfers, facilitating transitions from deterministic learning (focused on deductive/inductive reasoning and inference engines) to dynamic and stochastic learning that embraces uncertainty and randomness in modern machine learning techniques (Spikol et al., 2018; Krouska et al., 2019; Abed Ibrahim and Fekete, 2019; Cutumisu and Guo, 2019).

These shifts and advancements underscore the ongoing evolution of Big Data and AI in education research, aiming to enhance personalized learning experiences and educational outcomes through innovative technological applications and interdisciplinary collaborations.

(3) Designing Machine-Generated Data and Algorithms:

The format and purpose of machine-generated data and machine learning algorithms must be carefully designed to bridge the gap between theoretical models and practical applicability (Gobert et al., 2013; Hew et al., 2019). It is crucial to develop theoretical models that guide the development, interpretation, and validation of algorithms. For instance, efforts to algorithmically detect mental states such as boredom, frustration, and confusion (Baker et al., 2010) require robust operational definitions and constructs that have been rigorously evaluated. Additionally, AI systems collecting affective data should consider cultural differences, contextual factors, teachers' observations, and students' opinions to ensure balanced and informative data that avoids implicit biases influencing algorithms (Yadegaridehkordi et al., 2019; Staats, 2016).

Lin and Cao (2020)[9] introduce a touch interactive system designed around an intelligent vase for psychotherapy tailored to Alzheimer's disease patients. Published in Designs, their work explores innovative approaches to integrating technology and therapeutic practices for enhancing patient engagement and wellbeing in Alzheimer's care.

(4) Ethical and Algorithmic Challenges in Learning: Balancing human-provided learning with machine-assisted learning poses ethical challenges. The significant influence of AI and contemporary technologies can enhance usability and drive progress while potentially introducing algorithmic biases and diminishing essential student skills (Khechine and Lakhal, 2018). In creativity- or experience-based learning, overreliance on technology might hinder firsthand experiences critical for learning (Cuthbertson et al., 2004). Achieving a balanced adoption of technology and human involvement across diverse educational contexts remains a future challenge. Nonetheless, the integration of human and machine learning has the potential to significantly enhance teaching and learning outcomes beyond individual capabilities (Topol, 2019).

Jiang et al. (2021)[10] introduce a novel perspective on Recurrent Neural Networks (RNNs) termed Carry-Lookahead RNN, inspired by adder structures. Their study, published in Neural Networks, explores enhancements in RNN efficiency and computational performance through this innovative architectural approach.

(5) Addressing Algorithmic Bias: Algorithmic bias is a contentious issue as AI algorithms heavily rely on data, and their performance is shaped by the quality and quantity of data available (Obermeyer et al., 2019). Biases in data can lead to systematic errors disadvantaging minorities if algorithms are trained on unbalanced datasets. Rigorous studies and validation in real learning environments are necessary to address these issues before widespread implementation in educational practices (Sao Pedro et al., 2013).

(6) Technological Expansion and Inequalities in Learning Opportunities: The rapid expansion of technology, particularly in Big Data and AI, has transformed learning landscapes and raised concerns about inequalities in access to learning opportunities (GSMA Intelligence, 2020). The COVID-19 pandemic accelerated the deployment of

online and e-learning platforms globally, generating vast amounts of learning data. Extracting meaningful patterns from this data using learning analytics and AI techniques is essential for shaping future learning cultures and classroom dynamics (United Nations, 2020). It is imperative to adopt appropriate learning theories from educational psychology and empower learners to actively participate in their educational journey rather than passively consume information (Loftus and Madden, 2020). For instance, under the constructionist framework (Tsai, 2000), technology-enhanced or AI-powered education can empower students to predict their learning outcomes and strategically regulate their learning behavior (Koh et al., 2014; Loftus and Madden, 2020).

Addressing the digital divide and reducing inequalities requires concerted efforts from international organizations like UNESCO and the World Bank to support developing countries in establishing robust communication infrastructures (UNESCO, 2015). Ultimately, the goal is not to replace human learning with technology but to harness new technologies intelligently to facilitate knowledge transfer and acquisition (Azevedo et al., 2019).

An overarching theme emerging from current research is the necessity for theories rooted in cognitive and educational psychology to guide our understanding of individual learners and their unique differences. This foundational understanding is essential for developing optimal tools, algorithms, and practices that support personalized learning.

Cao et al. (2017) [11] present a structurally enhanced intelligent seat system designed to improve ergonomics and human-computer interaction. Their research, published in Designs, explores innovations aimed at enhancing user comfort and interaction with intelligent seating technologies.

Consider the rapid advancement of Virtual Reality (VR) and Augmented Reality (AR) technologies in education. While the industry has introduced numerous VR/AR applications, such as Google Expeditions offering over 100 virtual field trips, these innovations are often driven by technological capabilities rather than insights from educational psychology regarding how students learn effectively. To maximize the educational potential of VR/AR, it is crucial to disentangle technological features from human experiences and abilities, including cognitive, linguistic, and spatial capacities of learners (Li et al., 2020).

For example, VR offers immersive 3D environments intended to provide learners with perceptual grounding akin to real-life experiences. According to theories like 'embodied cognition' (Barsalou, 2008), VR environments are expected to enhance learning outcomes compared to traditional classroom settings. However, empirical evidence indicates significant individual variations in how students benefit from VR learning. Some learners with higher cognitive and perceptual abilities may not require additional visuospatial information provided by VR to succeed in learning tasks. Therefore, understanding how these embodied experiences interact with learners' unique abilities, prior knowledge, and backgrounds is essential for effectively integrating VR/AR technologies into education.

Big Data And Ai In Education: Policy-Making

In response to the transformative impact of advancements in big data and AI technologies, policymakers have been actively developing strategies and policies aimed at integrating these innovations into primary, secondary, and tertiary education (Pedró et al., 2019). However, several significant challenges and evolving trends must be

addressed to effectively incorporate big data and AI into educational practices. The following segments outline key policy-oriented challenges, gaps, and emerging trends:

1. In the era of digitally-driven knowledge economies, traditional formal education systems are undergoing profound changes, if not a paradigm shift (Peters, 2018). There is a rapid adoption of lifelong learning frameworks implemented through online or project-based learning models that support diverse teaching methodologies (Lenschow, 1998; Sharples, 2000; Field, 2001; Koper and Tattersall, 2004). This shift towards continuous education necessitates the establishment of micro-credits or micro-degrees to sustain learners' ongoing efforts (Manuel Moreno-Marcos et al., 2019). Future educational frameworks will require new instructional methods, engagement strategies, and assessment approaches to effectively support lifelong learning.

2. Despite the evident benefits of integrating cutting-edge research and innovative curricula driven by emerging technologies into student learning, there exists a notable gap between the readiness of pre-service and in-service teachers to adopt these technologies (Pedró et al., 2019). Pre-service teachers typically demonstrate greater familiarity and willingness to adopt modern technologies, while in-service teachers often rely more on their practical experience. Bridging this gap necessitates the development of robust teacher education and continuing professional development programs that effectively support the adoption and implementation of new educational technologies, particularly crucial in the context of prolonged disruptions such as the COVID-19 pandemic.

3. Establishing a robust legislative framework is crucial to safeguard personal data from unauthorized collection, disclosure, commercial exploitation, and other forms of misuse (Boyd and Crawford, 2012; Pardo and Siemens, 2014). Educational records and personal data are highly sensitive, posing significant risks related to privacy and security. Educational institutions must implement stringent security measures to protect students' educational profiles and personal data. Moreover, as commercial educational system providers increasingly adopt data-driven business models, legislative bodies at national and local levels play a critical role in enacting and enforcing privacy and data protection laws. Balancing the legitimate use of personal data for educational purposes with preventing its commercial exploitation remains a pressing challenge.

In conclusion, addressing these policy-oriented challenges and adapting to evolving trends are essential steps towards harnessing the full potential of big data and AI in enhancing educational practices and outcomes.

Big Data And Ai In Education: Industry

Just as scientific and academic aspects of big data and AI in education present unique challenges, so does the commercialization of educational tools and systems (Renz et al., 2020). Across various countries, efforts have been made to promote innovation-driven growth by enhancing technology transfer and fostering collaboration between academia and industry (Huggins and Thompson, 2015). In the United States, the Bayh-Dole Act was instrumental in initiating this approach (Mowery et al., 2001). Establishing a reciprocal and sustained partnership between academia and industry is crucial as it facilitates technology transfer and strengthens ties between educational research and commercial application. Here are several considerations regarding academia-industry collaboration, highlighting overlapping benefits, existing gaps, and future prospects:

1. Commercializing intelligent educational tools and systems that incorporate the latest scientific and technological advancements can empower educators to develop more effective curricula, pedagogical frameworks, assessments, and programs (Renz and Hilbig, 2020). Timely integration of educational research advances into commercial platforms is essential for vendors to enhance product development, marketing strategies, and revenue generation. Aligning industry practices with academic research can bridge gaps and ensure that innovations are effectively implemented in educational settings. Furthermore, novel features developed through such collaborations can create new revenue streams, thus fostering innovation and market growth.

2. The availability of a broad spectrum of commercially and freely available tools promotes healthy market competition, prevents monopolies or oligopolies that stifle innovation, and expands choices for educators and researchers (Popenici and Kerr, 2017). Platforms like Moodle and various Learning Management Systems (LMS) have demonstrated potential market dominance, particularly during the COVID-19 pandemic. Diverse tool availability encourages exploration of new educational approaches, such as multimodal virtual environments, which are not feasible in traditional physical settings. Expansion of educational markets and commerce inevitably leads to increased resources for research and development, facilitated by collaborative projects sponsored by industry to support academic advancements.

3. Vocational and practical education presents significant opportunities for fruitful academia-industry collaboration, particularly in response to evolving job market demands and technological advancements (World Development Report, 2019). Combining domain knowledge provided by educators with AI-assisted learning environments enhances practical skills development. Hands-on experiences in industrial settings, supported by human trainers and technological tools, equip students with essential skills for their careers. Effective vocational training necessitates a balanced approach integrating human teaching methods with machine learning environments, fostering collaborative efforts between academia and industry to meet evolving educational needs.

In conclusion, fostering robust academia-industry collaborations, promoting innovation through diverse educational tools, and balancing human and machine learning approaches are critical for advancing education in the digital age. These efforts not only enhance educational outcomes but also prepare students for the challenges of an increasingly technology-driven world.

Discussion And Conclusion

Big data and AI hold significant promise for revolutionizing learning and teaching practices. They introduce new research avenues, leverage innovative technologies and tools for data collection and analysis, and are rapidly becoming a mainstream research paradigm (Daniel, 2019). Despite their potential, these technologies remain unfamiliar to many educators and researchers. This paper has provided an overview of their background, core concepts, recent advancements, and the emerging challenges in educational contexts. Alongside the opportunities, we have emphasized critical challenges and trends in big data and AI in education, spanning educational research, policy-making, and industry. Table 1 succinctly outlines the major challenges and potential solutions in this domain.

Looking forward, future studies should prioritize theory-based precision education, foster cross-disciplinary applications, and ensure judicious use of educational technologies. Governments play a pivotal role in supporting

lifelong learning initiatives, enhancing teacher education programs, and safeguarding personal data. Meanwhile, fostering reciprocal and mutually beneficial partnerships between academia and industry is essential to advance collaborative efforts.

In envisioning the future of big data and AI, we advocate for a balanced dialogue between advocates of technology-driven solutions and proponents of human-centric education. It is crucial that technology serves as an enabler rather than a threat to livelihoods. Furthermore, we must recognize and strengthen the social and affective dimensions of learning, alongside cognitive processing, as integral to student success. Education serves as both a great equalizer and a central socializing force, emphasizing the importance of understanding how social and emotional factors influence learning outcomes (Li and Jeong, 2020).

While estimates suggest that nearly half of routine jobs may be automated in the near future, the role of teachers remains irreplaceable (Frey and Osborne, 2017; World Development Report, 2019). The teacher-student relationship is fundamental to learning and personal growth (Roorda et al., 2011; Cheng and Tsai, 2019), underscoring the enduring human element in education. Simultaneously, advancements in technology enable the collection and analysis of large-scale, multimodal, and real-time data. Such data-driven insights can assist educators in tailoring teaching strategies, identifying student learning patterns, and addressing complex challenges, thereby enhancing educational outcomes (Klašnja-Milićević et al., 2017; Gierl and Lai, 2018).

As we navigate the early stages of adopting big data and AI in education, we confront technological and mindset barriers. However, the convergence of psychology, data science, and computer science holds immense potential to transform educational research, practice, and industry. By embracing AI and technology, and adequately preparing educators and students for these advancements, we can effectively navigate towards a future of enhanced and sustainable educational development.

This paper aims to contribute to the collective effort of advancing learning and teaching practices in an era defined by rapid technological innovation and evolving educational needs.

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