Social Sciences and Frontier Technology Forum (SSFT 2025)

Research on the Paths and Challenges of Large Language Models in Promoting Educational Equity

Yuming Sun*
Experimental School Affiliated to Chinese Academy of Sciences, Beijing, China
**Corresponding author.*

Abstract: Large Language Models (LLMs), as a significant breakthrough in the field of artificial intelligence, are reshaping the allocation of educational resources. This paper explores how LLMs can promote educational equity through personalized learning support, multilingual education coverage, and low-cost resource provision, from the dual perspectives of technology empowerment and ethical risks. It also analyzes the challenges they face, such as the widening digital divide, embedded algorithmic bias, and inadequate cultural adaptability. The study proposes a three-dimensional governance framework comprising policy regulation, technological optimization, and social collaboration, providing a theoretical reference for the application of LLMs in promoting educational equity.

Keywords: Allocation of Educational Resources; Multilingual Education; Policy Regulation; Social Collaboration

1. Introduction

The realization of global educational equity is facing numerous structural challenges, with uneven resource allocation being a particularly prominent issue. According to a 2022 report by the United Nations Educational, Scientific and Cultural Organization (UNESCO), the distribution of educational resources is extremely unbalanced globally, with some regions enjoying abundant resources while many remote and impoverished areas severely lacking them [1]. This imbalance greatly hinders the achievement of educational equity. In addition to uneven resource allocation, teacher shortage is another significant factor constraining global educational equity. In many countries and regions, especially in rural and remote areas, there is a severe shortage of qualified teachers, resulting in difficulty in ensuring teaching quality and fully meeting students' learning needs. This issue not only affects students' personal development but also exacerbates educational inequality. Furthermore, language barriers pose a major challenge to global educational equity. Different countries and regions use their own languages, making the sharing and exchange of educational resources difficult. Many students are unable to access high-quality educational resources due to language difficulties, thereby limiting their learning opportunities and development space [2] (Crystal, 2018).

However, with the continuous development of artificial intelligence technology, particularly the emergence of Large Language Models (LLMs), new tools have become available to address the aforementioned challenges of educational equity. LLMs possess powerful conversational generation capabilities, enabling natural and smooth interactions with students and providing personalized learning tutoring and Q&A services. This not only helps alleviate the problem of teacher shortage but also enhances students' learning efficiency and interest. Additionally, LLMs exhibit excellent knowledge reasoning abilities, allowing them to intelligently adjust teaching content and difficulty based on students' learning progress and feedback, thereby providing more precise and effective learning guidance. This intelligent teaching approach helps break down barriers in resource allocation, enabling more students to enjoy high-quality educational resources. More importantly, LLMs support multilingual processing, overcoming language barriers and providing a unified and convenient learning platform for students from different countries and regions. This makes the sharing and exchange of educational resources easier, contributing to the promotion of global educational equity. The conversational generation, knowledge reasoning, and multilingual processing capabilities of LLMs

offer new ideas and solutions for addressing the structural challenges of uneven resource allocation, teacher shortage, and language barriers faced by global educational equity. With continuous technological advancements and expanding application scenarios, LLMs are expected to play an increasingly important role in the realization of global educational equity.

2. Pathways and Challenges

2.1 Pathways

Large Language Models (LLMs), as the latest breakthrough in the field of artificial intelligence, offer a new pathway to lowering the barriers to education. With their powerful natural language processing capabilities and extensive knowledge reserves, LLMs can provide users with personalized learning resources and tutoring. Specifically, LLMs can intelligently recommend relevant learning materials and exercises based on users' learning needs, interests, and ability levels, thereby enabling individualized instruction. Furthermore, LLMs support multilingual interaction, breaking down language barriers and enabling users worldwide to easily access educational resources. More importantly, compared to traditional educational models, the deployment and maintenance costs of LLMs are relatively low, which helps extend educational resources to more remote and impoverished areas, further lowering the barriers to education [3].

2.2 Challenges

Despite the promising application prospects of LLMs in the education sector, their technological application may also exacerbate some inequalities. Firstly, the digital divide cannot be ignored. Due to differences in economic conditions, infrastructure, and technological literacy, there may be significant disparities in access to and use of LLMs among different regions and groups, which could lead to further concentration and differentiation of educational resources [4]. Secondly, algorithm bias is also a potential risk. The training data for LLMs often comes from specific social and cultural backgrounds, which may result in bias in the model's recommendations for learning resources and assessments of learning outcomes, thereby disadvantaging certain groups in terms of fair development. Lastly, insufficient cultural adaptability may also become an obstacle to the promotion of LLMs in the education sector. Differences exist in educational systems, cultural traditions, and learning habits among different countries and regions, and if LLMs cannot adapt well to these differences, it may affect their application effectiveness and user acceptance in those locations.

2.3 Countermeasures

To fully leverage the potential of LLMs in the education sector while avoiding the inequalities they may bring, we need to establish a comprehensive governance mechanism. Firstly, at the policy regulation level, guidance and norms for the application of LLMs should be strengthened to ensure they align with the principles and goals of educational equity. Governments can introduce relevant policies to encourage and support innovative applications of LLMs in education, while strengthening supervision over model training data, algorithm design, and evaluation standards to prevent algorithm bias and discrimination. Secondly, at the technical optimization level, the intelligence level and cultural adaptability of LLMs should be continuously improved. By introducing more diverse data and advanced algorithm technologies, the ability of LLMs to recognize and understand different cultural backgrounds and learning habits can be enhanced, better meeting the needs of different users. Additionally, more intelligent learning assessment systems can be developed to achieve objective and fair evaluations of students' learning outcomes. Finally, at the social collaboration level, cooperation and coordination among governments, schools, enterprises, and communities should be strengthened to jointly promote the widespread application and in-depth development of LLMs in the education sector. By strengthening information sharing, resource integration, and interest coordination, a strong synergy can be formed to promote educational equity.

3. Technical Characteristics of LLMs

LLMs possess powerful knowledge generalization capabilities, with their knowledge system covering various fields from Science, Technology, Engineering, and Mathematics (STEM) to Humanities and Social Sciences. This means that LLMs can process and understand cross-disciplinary knowledge content, providing users with comprehensive and

integrated information support. In the field of education, this characteristic enables LLMs to serve as versatile learning assistants for students, whether it's solving math problems, analyzing scientific experiments, discussing literary works, or analyzing historical events, LLMs can provide accurate and in-depth knowledge responses. Furthermore, LLMs can maintain the timeliness and accuracy of their knowledge system through continuous learning and updates, ensuring that users can access the latest and most comprehensive information.

The natural language interaction capability of LLMs is key to achieving low-threshold human-machine collaborative learning. Through natural language processing technology, LLMs can understand users' verbal or written expressions and respond in natural language, thereby enabling smooth dialogue with users. This interaction method greatly reduces the threshold for human-machine interaction, allowing users to communicate and learn efficiently with LLMs without needing professional programming or technical knowledge. In the field of education, this characteristic enables LLMs to serve as private tutors or learning partners for students, providing personalized learning guidance and support to users anytime, anywhere. At the same time, natural language interaction enhances the fun and interactivity of learning, helping to stimulate students' interest and enthusiasm for learning (Kasneci et al., 2023).

The multimodal extensibility of LLMs allows them to integrate various learning scenarios such as text, speech, and vision, providing users with a richer and more diverse learning experience. By combining technologies such as text generation, speech recognition, and image recognition, LLMs can process and understand various types of learning content, such as e-books, audio courses, and video tutorials. This multimodal approach to learning helps meet the learning needs and preferences of different students, improving learning effectiveness and efficiency. In the field of education, the multimodal extensibility of LLMs enables them to serve as cross-platform, cross-device learning tools, providing users with a seamless learning experience. At the same time, multimodal learning helps enhance students' memory and comprehension abilities, promoting deep processing and integration of knowledge [5] (OpenAI, 2023).

4. Practical Pathways for LLMs to Promote Educational Equity

In leveraging Large Language Models (LLMs) to advance educational equity, personalization of the learning process is a crucial aspect. With their powerful data processing and pattern recognition capabilities, LLMs can deeply analyze students' learning behaviors and cognitive trajectories, thereby providing more precise and personalized learning support. Through LLM-driven adaptive learning systems, educators can track students' learning progress and comprehension levels in real time. These systems can dynamically adjust the difficulty of exercises based on students' performance, ensuring that learning challenges are neither too difficult nor too easy, thereby maximizing learning outcomes. For example, some online learning platforms have already integrated LLM technology, which can intelligently recommend the next stage of learning content and exercises based on students' feedback during problem-solving, achieving true "individualized instruction". For non-native language learners, language barriers often pose a significant challenge in the learning process. However, with the widespread application of LLMs in the field of language translation, this problem is gradually being resolved. Taking Google Translate as an example, the translation system integrated with LLMs has improved accuracy by 40% when dealing with translations of less commonly spoken languages. This means that students can utilize these advanced translation tools to more easily access and understand learning materials from different language backgrounds, thereby breaking down language barriers and enjoying more diverse and abundant educational resources. Educational evaluation is an indispensable part of the educational process, directly related to students' learning motivation and sense of achievement. However, traditional standardized tests often suffer from issues such as cultural bias and subjectivity, making it difficult to comprehensively and fairly reflect students' actual abilities. In the area of essay grading, LLMs have demonstrated impressive capabilities. Research shows that the consistency between automatic scoring by LLMs and manual scoring by teachers is as high as 0.81. This means that through LLM technology, we can achieve automation and objectivity in essay grading, reducing the influence of human factors

and improving the accuracy and fairness of evaluations. At the same time, LLMs can provide detailed grading feedback, helping students better understand their strengths and weaknesses, so they can improve their writing skills in a targeted manner.

In addition to essay grading, LLMs can also be used for dialogue-based cognitive ability assessment. This assessment method collects information on students' thought processes and strategy choices during problem-solving through natural language interaction with them, thereby providing a more comprehensive and in-depth diagnosis of their cognitive abilities. Compared with standardized tests, this assessment method pays more attention to students' individual differences and thought processes, helping to reduce cultural bias and improve the fairness and effectiveness of evaluations.

5. Fairness Challenges in the Application of LLMs

5.1 Unequal Access to Technology

Despite the enormous potential and value of Large Language Models (LLMs) in the field of education, their practical application also faces many challenges. The following elaborates on the three major challenges faced by LLMs in educational applications: unequal access to technology, algorithmic bias and ethical risks, and impact on the educational ecosystem. Unequal access to technology is the primary challenge faced by LLMs in educational applications. This is mainly reflected in two aspects: the hardware gap and differences in digital literacy: 1) Globally, a large number of students still lack the smart devices required to run LLMs. It is estimated that about 1.7 billion students worldwide do not have access to sufficient smart devices to support their online learning and the use of advanced technologies such as LLMs. This hardware inequality limits the popularization and application of LLMs in the field of education, preventing many students from enjoying the learning convenience and advantages brought by LLMs. 2) In addition to the hardware gap, differences in digital literacy are also a significant cause of unequal access to technology. Teachers in high-income countries generally have a higher usage rate of AI tools compared to those in low-income countries, with a difference that can be as high as sixfold. This difference in digital literacy not only affects teachers' acceptance and ability to use advanced technologies like LLMs but also limits the possibility of students benefiting from these technologies.

5.2 Algorithmic Bias and Ethical Risk

Algorithmic bias and ethical risks are another major challenge faced by LLMs in educational applications. This is mainly reflected in two aspects: data bias and cultural misalignment: 1) In the training data of mainstream LLMs, English content accounts for more than 90% [6] (Bender et al., 2021). This data bias results in poor output quality when LLMs process non-English content, failing to meet the learning needs in multilingual environments. Furthermore, data bias may trigger algorithmic discrimination and prejudice, further exacerbating educational inequality. 2) As the training data of LLMs mainly comes from texts in specific cultural contexts and languages, they may not accurately understand and adapt to knowledge and information from other cultural backgrounds. For example, ChatGPT has an error rate of 58% when answering questions about historical events in Africa. This cultural misalignment not only affects the accuracy and reliability of LLMs but may also mislead students' learning and understanding.

5.3 Impact on the Educational Ecosystem

The impact on the educational ecosystem is another important challenge faced by LLMs in educational applications. This is mainly reflected in the weakening of the teacher's role and the crisis of academic integrity. With the popularization and application of advanced technologies like LLMs, the role of teachers in the teaching process may gradually weaken. Over-reliance on LLMs may lead to a weakening of the emotional connection in interpersonal teaching, thereby affecting students' learning experience and effectiveness. In addition, the widespread use of LLMs may also pose challenges and uncertainties for teachers' career development. The powerful generative capabilities of LLMs allow students to easily obtain and generate large amounts of text content. However, this has also triggered a crisis of academic integrity. Some students may use LLMs to write essays on their behalf or plagiarize others' work, thereby damaging the authenticity and credibility of academic research. The surge in this phenomenon not only affects

the reputation and credibility of the academic community but may also have a negative impact on students' personal growth and future development [7] (Cotton et al., 2023).

6. Governance Framework and Countermeasure Suggestions

In the context of the widespread application of Large Language Models (LLMs) in the field of education and the multiple challenges they face, constructing a comprehensive and effective governance framework and proposing feasible countermeasure suggestions are crucial for promoting the healthy development of LLMs in the field of education.

6.1 Technical Optimization Path

Technical optimization is a key aspect of addressing the challenges faced by LLMs in the field of education. By developing lightweight models and conducting culturally adaptive training, the prevalence and accuracy of LLMs can be significantly improved, thereby better serving educational equity. To address the hardware gap, efforts should be made to develop lightweight models. For example, Meta's LLaMA-7B model is already capable of running on low-end phones, providing possibilities for the popularization of LLMs in resource-constrained areas. In the future, research and investment in lightweight models should be increased to reduce the dependence of LLMs on hardware devices, enabling more students to enjoy the learning convenience brought by LLMs. To address algorithmic bias and cultural misalignment, localized corpus should be constructed, and culturally adaptive LLMs should be trained. For example, specialized LLMs such as "Jais" can be developed for Arabic and other less commonly spoken languages to improve their accuracy and applicability in specific cultural contexts. Through culturally adaptive training, LLMs can better understand and adapt to knowledge and information from different cultural backgrounds, thereby reducing cultural misalignment.

6.2 Policy Regulatory System

Policy regulation is a necessary means to ensure the healthy development of LLMs in the field of education. By formulating clear access standards and resource allocation mechanisms, the application behavior of LLMs can be regulated to ensure they comply with educational equity and ethical requirements. Strict access standards should be formulated, and LLMs entering the field of education should undergo rigorous review and testing. For example, the EU's Artificial Intelligence Act requires educational AI systems to pass bias tests to ensure they do not trigger algorithmic discrimination and prejudice. By formulating similar access standards, it can be ensured that the application of LLMs in the field of education complies with fairness, impartiality, and ethical requirements [8] (EU, 2023). A reasonable resource allocation mechanism should be established to ensure that LLMs can serve all students fairly. For example, India has integrated LLMs into the national digital education platform "DIKSHA," providing equal access to LLM resources for a wide range of students. Through similar resource allocation mechanisms, educational gaps between different regions and schools can be narrowed, promoting the realization of educational equity.

6.3 Social Collaboration Network

A social collaboration network is an important guarantee for promoting the widespread application of LLMs in the field of education. Through teacher-AI collaborative training and community computing power sharing, the deep integration of LLMs and the field of education can be strengthened, enhancing their practical application effects. Training for teachers on the use of AI tools should be strengthened to improve their digital literacy and AI application capabilities. For example, Singapore's "AI-Enabled Teacher Development Plan" aims to enhance teachers' understanding and application of AI technologies, thereby better integrating advanced technologies such as LLMs into the teaching process. Through similar training programs, a team of AI-literate teachers can be cultivated, providing strong support for the widespread application of LLMs in the field of education [9] (MOE, 2022). Community computing power sharing should be encouraged to lower the threshold and cost of LLM applications. For example, in resource-constrained areas such as favelas in Brazil, localized LLM nodes based on low-cost devices like Raspberry Pi can be deployed to provide convenient learning resources and services for local residents. Through community computing power sharing, the digital divide can be narrowed, allowing more students to benefit from the learning convenience brought by

advanced technologies such as LLMs.

7. Conclusion

Large language models (LLMs), as a significant breakthrough in the field of artificial intelligence, are gradually transforming the allocation of educational resources and providing new opportunities for achieving educational equity. By offering personalized learning support, multilingual education coverage, and low-cost resource provision, LLMs effectively lower the barriers to accessing education, enabling more students to enjoy high-quality educational resources. However, the application of LLMs in the education sector also faces multiple challenges, including unequal technology access, algorithmic bias and ethical risks, as well as disruptions to the educational ecosystem. To fully harness the potential of LLMs in education while addressing the challenges they pose, this paper proposes a three-dimensional governance framework comprising technical optimization pathways, policy regulatory systems, and social collaboration networks. In terms of technical optimization, the development of lightweight models and cultural adaptability training can enhance the prevalence and accuracy of LLMs, thereby better serving educational equity. At the policy regulatory level, strict access standards and reasonable resource allocation mechanisms can regulate the application of LLMs and ensure they align with educational equity and ethical requirements. In terms of social collaboration networks, measures such as teacher-AI collaborative training and community computing power sharing can strengthen the deep integration of LLMs into the education sector and improve their practical application effects.

Specifically, lightweight models enable LLMs to be popularized in resource-constrained areas, while localized corpus and cultural adaptability training can reduce algorithmic bias and cultural misalignment. On the policy front, practices such as the EU's Artificial Intelligence Act and India's DIKSHA platform provide useful references for establishing access standards and resource allocation mechanisms. In terms of social collaboration, examples like Singapore's "AI-Empowered Teacher Development Program" and the deployment of localized LLM nodes in Brazilian slums demonstrate the importance of community computing power sharing and enhancing teachers' AI literacy. In summary, LLMs hold great promise for application in the education sector, but they also come with a series of challenges. By constructing a comprehensive and effective governance framework and adopting corresponding countermeasures, we can fully leverage the potential of LLMs, promote the realization of educational equity, and create a more equitable, inclusive, and sustainable educational environment for learners worldwide. In the future, as technology continues to advance and application scenarios expand, LLMs are expected to play an increasingly important role in promoting educational equity.

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