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Research Article

Reflections on Enhancing Higher Education Classroom Effectiveness Through the Introduction of Large Language Models

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Abstract

Objective: The objective of this study is to explore the potential of integrating Large language models (LLMs) into higher education to enhance teaching effectiveness. It investigates how LLMs can support personalized learning, improve teacher - student interaction, and foster content innovation. The study also addresses the challenges associated with the use of LLMs, including the transformation of the teacher's role, data privacy concerns, and technical limitations in handling complex cognitive tasks.

Methods: A mixed - method approach was used, combining a literature review, survey, and case study analysis. The literature review focused on artificial intelligence applications in education, while a survey was conducted among 120 professors and 533 students from five universities in China to gather quantitative data on their experiences with AI in education. Case studies were also analyzed to assess the effectiveness of LLM - supported learning platforms in enhancing classroom engagement, interaction, and teaching outcomes.

Results: The survey results revealed that 68% of professors and 74% of students found LLMs beneficial for personalized learning and improved classroom engagement. However, 58% of professors raised concerns regarding the changing role of teachers and data privacy issues, while 49% of students worried about over - reliance on AI affecting their independent learning. Case studies showed a 30% improvement in teacher - student interaction and a 25% increase in student engagement, although LLMs struggled with advanced cognitive tasks in specialized fields such as mathematics.

Conclusion: The study concludes that while LLMs offer significant advantages in improving personalized learning and enhancing interaction, their integration into higher education must be managed carefully. Teacher training, ethical considerations, and data privacy safeguards are essential. Future research should focus on optimizing LLMs for specialized academic fields and exploring their combination with emerging technologies like virtual reality and augmented reality to create more interactive learning environments.

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Keywords: large language model, artificial intelligence, higher education, classroom effectiveness, personalized learning, data privacy, teacher - student interaction

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1 INTRODUCTION

With the ongoing digital transformation in education, the expectations placed on higher education institutions are rapidly evolving. Universities are transitioning from static environments of knowledge transmission to dynamic, student - centered learning platforms. This shift is being driven by the need for personalized learning experiences, increased student engagement, and more interactive educational models. However, this transformation also brings about significant challenges, such as the difficulty in catering to diverse student needs, varying learning paces, and balancing personalized education with the traditional one - size - fits - all teaching model.

Recent advances in artificial intelligence (AI), particularly in the development of large language models (LLMs), present a potential solution to these challenges. LLMs, such as Generative Pre - trained Transformer and Bidirectional Encoder Representations from Transformers, are designed to understand and generate natural human language. These AI models can serve as intelligent assistants in educational environments, offering personalized learning paths, automating tasks like grading and feedback, and enhancing teacher - student interaction. The integration of LLMs into university classrooms could potentially revolutionize the way education is delivered, creating more personalized, interactive, and efficient learning experiences.

This study aims to investigate the practical applications of LLMs in higher education and assess their impact on teaching effectiveness. Specifically, we explore how LLMs can address common challenges in education, such as the need for individualized learning experiences, improved teacher - student communication, and innovative teaching content. We also examine the limitations and risks associated with the integration of LLMs, including data privacy concerns, ethical issues, and the changing role of teachers in the classroom.

2 MATERIALS AND METHODS

2.1 Literature Review

In recent years, the rapid development of AI technology, particularly the widespread application of LLMs, has sparked extensive discussions in academia regarding their potential in education. LLMs, as AI tools based on natural language processing, can understand and generate natural language, making them applicable to tasks such as automated Q&A, personalized teaching, and feedback systems[1]. This section reviews existing research on LLMs in areas such as personalized learning, teacher - student interaction, innovation in teaching content, and the challenges they face, aiming to provide theoretical support for their application in higher education.

Personalized learning is one of the core applications of LLM technology in the educational field. The literature generally suggests that LLMs can recommend personalized resources and plan learning paths based on students' progress and interests, thereby improving learning outcomes. Chen J et al.[2] noted that LLMs can analyze students' assignments, classroom performance, and learning habits to generate personalized learning suggestions and feedback, helping students master knowledge at their own pace. This data - driven personalized teaching significantly enhances students' autonomy and learning experience.

However, research on personalized learning also reveals technological limitations and potential risks. Zhou X[3] pointed out that LLMs' personalized recommendation systems may be constrained by the quality and diversity of training data, making it difficult to provide accurate learning suggestions in certain subject areas. Additionally, over - reliance on automated systems for personalized learning could weaken students' independent thinking and problem - solving skills, leading to a phenomenon of "technological dependence".

Another key application of LLMs is enhancing teacher - student interaction, especially in large classrooms or online learning environments[4]. Jia X[5] emphasized that LLMs can provide instant feedback and support through automated Q&A systems, both inside and outside the classroom. This immediate and continuous feedback mechanism not only increases the frequency of teacher - student interactions but also alleviates teachers' workloads, allowing them to focus more on personalized guidance and higher - order thinking training for students.

Moreover, Wang F and Li J[6] found that LLM - generated content enriches classroom discussions by providing diverse topics and problem - solving approaches, stimulating students' creativity. However, Ng TK[7] cautioned that LLM - generated content is not always accurate, particularly in open - ended or complex situations, where it may mislead students. Ensuring adequate supervision and control over LLM - generated content is crucial for improving teacher - student interaction.

In terms of designing and updating teaching content, LLM technology also shows strong potential. Chen G and Woolf BP[1] pointed out that LLMs can generate real - time, course - relevant case studies and practical problems, helping teachers incorporate dynamic societal changes and industry trends into their curriculum. This real - time updating capability makes teaching content more timely and relevant, sparking students' interest and participation.

Additionally, LLMs' natural language processing capabilities can assist teachers in designing new teaching materials, automatically generating course outlines, instructional materials, and exercises. Jia X et al.[4] suggested that LLMs could adjust content based on student feedback, making course materials more aligned with students' comprehension and learning needs. However, Wang Z[8] warned that LLMs may lack sufficient expertise in certain fields (e.g., arts and social sciences), making it difficult for them to generate deep and creative teaching content. Therefore, the application of LLM - generated content must be cautiously evaluated in specific disciplines.

Despite the significant potential of LLMs in higher education classrooms, the literature also highlights challenges and limitations during their implementation. First, the transformation of the teacher's role has become a focal point of research. Baker MJ[9] noted that with LLM assistance, teachers' focus will shift from traditional knowledge transmission to learning facilitation. This requires teachers to acquire new technical skills to effectively utilize LLMs in teaching and monitor and correct the content generated by LLMs.

Second, data privacy and ethical issues are critical challenges in the application of LLMs. Zhao Y and Liu X emphasized that LLMs rely heavily on large amounts of student data[10], which may raise concerns regarding data privacy and security. In personalized learning scenarios, ensuring the legal and compliant use of student data and preventing data breaches are key issues for universities to address when introducing LLMs. Moreover, Huang noted that algorithmic bias in LLMs could disadvantage certain groups in terms of learning resource recommendations and feedback, potentially affecting educational equity.

Finally, the adaptability of LLMs in certain disciplines has also drawn scholars' attention. Ng TK[8] pointed out that LLMs perform poorly in specific fields, such as advanced mathematics or complex engineering, primarily due to limitations in training data and a lack of domain - specific knowledge. Future research should explore how to optimize training data and model design to enhance the adaptability of LLMs in complex subject areas.

In summary, LLMs show significant potential for improving classroom effectiveness in higher education, particularly in personalized teaching, teacher - student interaction, and innovation in teaching content. However, the literature also points out that the application of LLMs faces challenges related to the transformation of the teacher's role, data privacy concerns, and technical limitations. Future research can focus on optimizing LLM applications in different academic fields and addressing data privacy and ethical issues to ensure the sustainable development of LLMs in education.

2.2 Survey Design and Implementation

A survey was designed to gather quantitative data from educators and students regarding their perceptions of AI, specifically LLMs, in classroom settings. The survey was distributed to 120 university professors and 533 students from five major universities across China, covering various disciplines, including engineering, management, and the humanities. The survey comprised questions on the current use of AI tools, anticipated benefits of LLMs, and concerns related to their implementation.

The survey sought to assess the readiness of educators to adopt AI technologies and their perceived challenges, such as changes in teaching roles and the ethical implications of AI use. Students were asked about their experiences with AI tools in the classroom, including their views on AI's potential to enhance learning, improve feedback mechanisms, and provide personalized learning experiences.

2.3 Case Study Analysis

The case study analysis aimed to evaluate the practical application and impact of LLM - supported learning environments in higher education. Specifically, we focused on the use of LLMs to improve teaching effectiveness through personalized learning, enhanced teacher - student interaction, and real - time content generation. Several universities and educational institutions that had integrated LLMs into their teaching processes were selected for analysis. These case studies were drawn from a diverse range of disciplines, including computer science, economics, and engineering.

2.3.1 Case Study 1: LLMs in Engineering Education

In a major engineering school in China, LLMs were integrated into introductory courses in mechanical and electrical engineering. The LLMs were primarily used for automating grading tasks, generating personalized learning resources, and offering automated Q&A services. The implementation led to a reduction in the time teachers spent on routine tasks like grading assignments, allowing them to focus more on in - depth student engagement and problem - solving during lab sessions and lectures.

Moreover, the LLM - based system provided students with instant feedback on their assignments, which improved

their understanding of core concepts. According to feedback from both teachers and students, the automated system generated precise and timely explanations for complex engineering problems, particularly in introductory courses where problem - solving typically follows established patterns. However, as students advanced to more complex design - oriented courses, LLMs struggled to provide in - depth analysis or guidance for creative tasks that required original thought or novel solutions. This limitation underscores the current inability of LLMs to handle higher - order cognitive tasks that involve creativity and the synthesis of new ideas.

2.3.2 Case Study 2: LLMs in Economics

In an economics department at a leading Chinese university, LLMs were introduced into macroeconomics and international trade courses. The LLMs were tasked with generating real - time case studies, which were based on the latest global market trends and policies. For example, in a course on international trade, LLMs analyzed recent trade policy changes between the USA and China, providing students with timely case studies to enhance classroom discussions. These real - time updates helped students link theoretical knowledge to current global economic phenomena, thus improving the relevance and timeliness of the course content.

LLMs also proved to be highly effective in generating personalized learning recommendations for students. By analyzing each student's performance, the LLMs recommended additional resources such as articles, reports, and exercises tailored to their learning needs. As a result, students reported feeling more engaged and better prepared for discussions and exams.

However, the instructors observed that LLM - generated content sometimes lacked depth when addressing complex economic theories that required critical thinking and historical context. In such instances, teachers had to step in to guide students through deeper discussions. This highlights the necessity of maintaining human oversight in classrooms where LLMs are used, particularly in subjects that demand critical and analytical thinking.

2.3.3 Case Study 3: LLMs in Computer Science

In the computer science department of a North American university, LLMs were deployed to assist in both introductory and advanced programming courses. The LLMs functioned as intelligent assistants, helping students debug code, answer programming - related questions, and provide personalized project suggestions based on the students' progress.

For introductory courses, LLMs were particularly useful in offering real - time feedback on coding assignments. Students could instantly identify and correct mistakes in their code, which significantly reduced the time spent on troubleshooting basic errors. Teachers reported a notable improvement in assignment completion rates and a higher level of engagement in practical lab sessions.

In advanced courses, however, LLMs faced challenges. While they could suggest solutions for common coding errors and offer assistance with predefined algorithms, they struggled with more complex tasks that required creative problem - solving and optimization techniques. For example, in courses on AI and machine learning, where students had to design unique algorithms or innovate solutions to novel problems, LLMs were unable to provide meaningful assistance. Additionally, students noted that LLMs often generated code that was not optimized for efficiency or performance, highlighting the limitations of LLMs in fields where creative thinking and high - level technical expertise are essential.

2.3.4 Case Study 4: LLMs in Humanities and Social Sciences

An interesting application of LLMs was observed in the humanities and social sciences at a European university. Here, LLMs were used to support students in history, philosophy, and sociology courses. The LLMs assisted students by summarizing lengthy academic texts, generating essay outlines based on course content, and suggesting relevant sources for research papers.

For history courses, the LLMs could quickly summarize important events, providing students with concise study materials to prepare for exams. In philosophy, LLMs helped students outline their essays by suggesting logical structures and pointing out key arguments to support their thesis statements. In sociology, students were able to use LLMs to access data - driven insights, particularly when writing papers on contemporary social issues.

Despite the convenience of these features, some students reported over - reliance on LLM - generated content, particularly in essay writing. Professors noted that while LLMs helped students organize their thoughts, the quality of the arguments often lacked originality and depth. This raised concerns about academic integrity and the need for students to engage in independent critical thinking rather than relying too heavily on AI - generated content. Consequently, the university implemented stricter guidelines to ensure that students used LLMs only as supplemental tools and not as substitutes for their own intellectual efforts.

2.3.5 Overall Impact and Challenges from Case Studies

Across all the case studies, LLMs demonstrated significant potential to enhance personalized learning and reduce the workload of teachers, particularly for tasks like grading, content generation, and real - time feedback. LLMs

improved classroom efficiency and student engagement, particularly in courses with repetitive tasks or well - structured problem - solving approaches. However, their limitations became evident when higher - order cognitive tasks were required, such as in advanced courses that emphasized creativity, critical analysis, or problem - solving in uncertain scenarios.

Additionally, one of the key findings across disciplines was the necessity for human oversight. Teachers had to remain actively involved to ensure that the AI - generated content was accurate and contextually appropriate, especially in complex subject areas. Furthermore, concerns over data privacy, ethical considerations, and the risk of student over - reliance on AI tools emerged as important challenges that must be addressed before widespread adoption.

The case studies also revealed that LLMs are highly adaptable to fields that rely on structured information and clear rules, such as introductory courses in engineering, programming, or economics. However, in fields that require abstract thinking, creativity, and original contributions, such as philosophy, advanced programming, and upper - level economics, LLMs were less effective and often required supplemental support from human educators.

3 RESULTS

3.1 Survey Findings

3.1.1 Educators' Perspectives

The survey, distributed to 120 university professors across five major universities in China, revealed that a significant proportion (68%) of educators were optimistic about the potential of AI tools, particularly LLMs, in enhancing classroom teaching. Many educators noted that AI could assist in personalized learning by providing real - time feedback, allowing for more targeted instruction. They also appreciated the time - saving aspects of LLMs, particularly in automating administrative tasks like grading and responding to frequently asked questions.

One professor commented, "LLMs allow us to focus more on the intellectual development of students rather than administrative burdens. By automating basic tasks, I can dedicate more time to developing critical thinking exercises and engaging students in deeper discussions".

However, concerns were raised by 58% of the surveyed professors, particularly around the potential shift in the teacher's role. Educators expressed fears that AI could diminish the need for human intervention, leading to a more transactional model of education, where AI handles most interactions with students. As one respondent pointed out, "While LLMs are great tools, they cannot replace the nuances of human interaction in teaching. Students need guidance that goes beyond algorithmic responses".

Data privacy emerged as another key concern. Several educators highlighted that the use of AI and LLMs requires the collection of large amounts of student data, which raises issues regarding compliance with privacy laws, data security, and the ethical implications of using student data to personalize learning. "Ensuring that data is secure and used ethically should be a priority before we fully integrate AI tools in our classrooms", noted one educator.

Additionally, ethical concerns about bias in AI - generated content were expressed by a number of professors. Since AI models like LLMs rely on historical data, there is a risk that the AI could perpetuate existing biases, leading to disparities in the quality of educational content offered to different groups of students. As a result, many educators emphasized the importance of maintaining human oversight when using AI in education to ensure equitable learning outcomes for all students.

3.1.2 Students' Perspectives

The survey responses from 533 students across five universities showed that the majority (74%) felt that AI tools, particularly LLMs, had a positive impact on their learning experiences. Many students reported that the personalized learning resources generated by AI, along with the ability to receive instant feedback on assignments, helped them to better grasp difficult concepts and track their progress. One student remarked, "The AI is like having a tutor available 24/7. Whenever I'm stuck, I can get immediate feedback, which keeps me from falling behind".

However, despite the overall positive reception, 49% of students expressed concerns about becoming overly reliant on AI tools. Students worried that the convenience of AI - generated answers might discourage them from engaging in deeper cognitive processes, such as independent problem - solving or critical thinking. "AI is helpful, but sometimes I feel like it's too easy to just accept the answer it provides without questioning it", one student explained. Others mentioned that while LLMs could clarify basic concepts, they were not always effective when students needed to critically analyze or apply knowledge in complex scenarios.

There were also concerns about academic integrity. A few students mentioned that the easy access to AI - generated content could tempt some of their peers to use it as a substitute for their own work. "I'm worried that relying too much on AI might encourage students to bypass the learning process, leading to a superficial understanding of the material", one student noted. This indicates a need for clear guidelines around the use of AI tools in academic settings, ensuring that students use them responsibly to enhance learning rather than as shortcuts.

Additionally, students in more specialized disciplines, such as the arts and humanities, reported that while LLMs

were helpful for certain types of content (e.g., summarizing articles or providing factual information), they found the AI less useful when dealing with abstract concepts or when engaging in creative writing. "The AI can summarize a historical event or suggest research articles, but it can't really help me develop a nuanced argument in a philosophy paper", one student in the humanities remarked. This highlights the need for further development of LLMs to better support students in subjects that require higher - order thinking and creativity.

3.2 Case Study Results

The analysis of the case studies demonstrated the potential for LLM - supported platforms to significantly improve classroom engagement and teaching efficiency. Across the case studies, classrooms that utilized LLM technology showed a 30% improvement in teacher - student interaction and a 25% increase in overall student engagement, compared to traditional teaching environments. These improvements were particularly notable in large class settings where individualized attention from teachers is often limited.

3.2.1 Improvement in Teacher - Student Interaction

One of the standout benefits of LLMs was their ability to facilitate real - time interactions between students and teachers. In many of the case studies, LLMs were used to provide instant feedback on assignments, answer frequently asked questions, and generate real - time content that could be adjusted to suit the pace of the class. Teachers reported that this allowed them to focus more on engaging students in higher - order thinking exercises, rather than spending time on routine administrative tasks.

In particular, the use of LLMs for automated Q&A services was highly effective in addressing student questions outside of class time. One case study from an engineering program revealed that students who previously hesitated to ask questions during class felt more comfortable seeking help through the AI system. The LLM's ability to provide instant, context - specific answers helped to bridge the gap between formal class time and self - directed learning. "Students felt less intimidated by asking the AI for help", noted one professor, and "as a result, they came to class better prepared and more confident in their understanding of the material".

3.2.2 Enhanced Student Engagement

Student engagement also saw a marked improvement in classrooms that integrated LLMs. In one of the economics courses studied, LLMs were used to generate real - time case studies based on current global market trends. This dynamic content kept students engaged with the course material, as they could see the immediate relevance of their studies to real - world events. Students reported that the AI - generated case studies helped them stay interested in the subject matter and provided valuable context for abstract economic theories.

The personalization capabilities of LLMs were another factor that contributed to increased student engagement. By analyzing student performance data, LLMs were able to recommend specific learning resources or exercises tailored to each student's individual needs. This personalized approach was particularly beneficial in courses with large student populations, where it is often difficult for teachers to provide one - on - one support. "The AI helped me focus on areas where I was struggling, without having to wait for feedback from the professor", said one student.

3.2.3 Limitations in Advanced Cognitive Tasks

Despite the clear benefits, the case studies also highlighted the limitations of LLMs, particularly in disciplines that require advanced cognitive skills. For example, in upper - level mathematics and engineering courses, teachers noted that while LLMs were effective at generating responses to standard problems, they struggled when tasked with more complex or abstract concepts. In one case study from an advanced engineering course, students found that the AI - generated solutions to design problems were often too simplistic or failed to consider the real - world constraints that are critical in engineering practice.

Similarly, in a philosophy course, LLMs were able to summarize key texts and provide useful background information, but they were less effective when students needed to engage in critical analysis or develop original arguments. "The AI can help with the basics, but it doesn't have the depth to assist with deeper philosophical debates", one professor noted. This suggests that while LLMs can play a valuable role in supporting foundational learning, they are not yet capable of handling the complexities involved in advanced academic work.

3.2.4 Challenges in Creative and Critical Thinking

LLMs also faced challenges when applied to subjects that required creative and critical thinking. In a creative writing class, for example, students found that while LLMs could help generate prompts or suggest ideas, the quality of AI - generated content was often formulaic and lacked originality. Similarly, in a history course, the AI was effective in providing factual summaries but fell short when students needed to synthesize historical events into broader narratives. As one student remarked, "The AI can give me all the facts, but it can't help me make sense of them in a meaningful way".

These findings suggest that while LLMs have the potential to enhance certain aspects of learning, particularly in terms of automating repetitive tasks and providing personalized resources, they cannot fully replace the role of

human educators in fostering creativity and critical thinking. As a result, teachers still need to guide students through more complex tasks that involve independent thought, problem - solving, and original contributions.

4 DISCUSSION

The results of our study highlight both the potential benefits and the limitations of introducing LLMs into higher education classrooms.

4.1 Potential Benefits of LLM Integration

4.1.1 Personalized Learning

One of the most significant benefits of LLM integration is the potential to enhance personalized learning. LLMs can analyze vast amounts of data on individual students, allowing for the creation of customized learning paths. Students with stronger academic abilities can be offered more challenging content, while those who struggle can receive simplified materials and additional explanations. The automated grading of assignments by LLMs also allows for quicker, more consistent feedback, giving students real - time insights into their performance and enabling them to adjust their learning strategies accordingly.

4.1.2 Enhanced Teacher - Student Interaction

In large classrooms or online learning environments, LLMs can significantly improve teacher - student interaction. Automated Q&A systems allow students to ask questions and receive answers in real - time, both during and outside of class. This increased interaction helps bridge the gap between students and teachers, particularly when direct communication is limited. Additionally, LLMs can generate discussion prompts and engage students in dialogue, fostering deeper classroom interactions and enhancing collaborative learning.

4.1.3 Innovation in Teaching Content

LLMs also offer opportunities for innovating teaching content. Their ability to generate real - time case studies and practical examples based on the latest social or technological developments ensures that course materials are timely and relevant. In fields such as economics or computer science, this dynamic content generation helps students connect theoretical knowledge with real - world applications. Moreover, LLMs can assist teachers in creating new instructional materials, such as course outlines, lecture notes, and interactive exercises, tailored to student feedback and performance.

4.2 Challenges and Limitations

4.2.1 Transformation of the Teacher's Role

The introduction of LLMs necessitates a transformation in the role of teachers. Traditional teaching models position the teacher as the primary knowledge transmitter, but with LLMs, this role shifts toward that of a facilitator of learning. Teachers must now guide students on how to utilize AI tools effectively, focus more on critical thinking, and provide deeper insights that AI cannot deliver. This shift requires teachers to develop new skills, including familiarity with AI systems, data analysis, and a deeper understanding of how to collaborate with AI in the classroom.

4.2.2 Data Privacy and Ethical Concerns

Data privacy is one of the most significant challenges associated with LLM integration. Personalized learning systems require large amounts of student data to provide tailored content, which raises concerns about data security and misuse. Educators and institutions must ensure that adequate measures are in place to protect student privacy, comply with data protection regulations, and prevent unauthorized access or data breaches. Additionally, ethical concerns arise from the potential biases inherent in AI algorithms, which could disproportionately impact certain student groups.

4.2.3 Technical Limitations

While LLMs excel at automating basic tasks and generating content from existing data, they struggle with tasks that require creativity, critical thinking, or advanced problem - solving. In fields such as advanced mathematics or engineering, LLMs often fail to provide the depth of understanding or accuracy needed for complex academic tasks. Their performance is limited by the quality and diversity of the training data they receive, making them less effective in niche or highly specialized academic fields.

5 CONCLUSION

This study highlights the potential of LLMs to significantly improve teaching effectiveness in higher education by enhancing personalized learning, improving teacher - student interaction, and fostering innovation in teaching content. The survey and case study results demonstrate that LLMs can relieve educators of routine tasks, allowing them to focus on fostering critical thinking and deep learning among students.

However, the integration of LLMs also poses challenges, particularly concerning the transformation of the teacher's role, the need for new skills and training, and concerns over data privacy and ethical issues. Additionally, LLMs still face technical limitations, particularly in complex academic fields where higher - order cognitive tasks are required.

To ensure the successful integration of LLMs into higher education, institutions must adopt a balanced approach, providing the necessary support for teachers while addressing the ethical and technical challenges that arise. Further research is needed to explore how LLMs can be optimized for specialized disciplines and how they can be combined with emerging technologies, such as virtual reality and augmented reality, to create even more intelligent and interactive learning environments.

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Conflicts of Interest
The authors declared no conflict of interest.

Author Contribution
Zhang X was the primary researcher and wrote the manuscript. Zhang X provided research and editing assistance to the manuscript. Liu H contributed to overall article design, data collection as well as revising and approving the manuscript.

Abbreviation List
AI, Artificial intelligence
LLMs, Large language models

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