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Research

Exploring the Role of Educational Technology in Multigrade Classrooms: Focusing on Artificial Intelligence

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Abstract:

This study investigates the role of educational technology, including artificial intelligence (AI), in improving learning outcomes and addressing the complexities of multi-grade classrooms. A qualitative research method based on the analysis of scientific papers was employed. The findings of the study include an examination of the role of AI in multi-grade classrooms, personalized learning with AI, and the challenges it faces, such as data privacy and security, addressing bias and ensuring fairness, as well as equity and accessibility, co-developing guidelines, and enhancing AI literacy. This study also explores the application of AI in assessment and feedback, AI-enhanced classrooms, challenges and future directions, and ethical considerations associated with AI. The reviewed literature demonstrates the impact of AI-based educational technology in improving teaching and learning in multi-grade classrooms. The findings emphasize the necessity of a thorough examination of ethical implications and potential issues in the use of AI and suggest that future studies should carefully address the ethical considerations and challenges related to the implementation of AI in multi-grade classrooms.

Keywords: Education, multi-grade classroom, educational technology, artificial intelligence

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INTRODUCTION

Multi-grade classrooms are educational settings where students of different grades are taught together by a single teacher. This approach is often found in rural areas and developing countries, where small schools typically lack the financial resources to operate separate classes for each grade level. In these environments, students work independently or in groups on their academic objectives while learning in a shared space (Recla & Potane, 2023).

One of the defining characteristics of multi-grade classrooms is the diversity of students, often encompassing various ages within a single educational level. This diversity poses unique pedagogical challenges for teachers, such as difficulties in classroom management, time constraints, insufficient training, lack of resources, the management of diverse educational needs, curriculum planning, and classroom organization (Bharti et al., 2024). Teachers must implement innovative instructional strategies to effectively engage students and facilitate group learning, while also addressing individual learning needs of each student. The inherent complexities of managing multi-grade environments can lead to unfavorable educational outcomes if not appropriately addressed (Alhajeri & Safian, 2023).

Despite these challenges, multi-grade classrooms offer opportunities for group learning and the development of mentoring relationships among students. These classrooms can foster the socio-emotional development of older students by providing opportunities for supporting their younger peers (Fatima et al., 2024). Furthermore, the integration of technology into classrooms can enhance instructional methods, increase student engagement, and make education more relevant and accessible in today's digital age (Mirjat et al., 2024). In this regard, it has been indicated that teachers see the inclusion of AI as an opportunity to personalize learning, reduce workload, and facilitate teaching in multigrade classrooms, without perceiving it as a job threat. At the same time, they emphasize the need for technological and didactic resources aligned with the specific characteristics of their contexts, such as offline resources and adaptable AI curricula to address the prevalent issue of limited or absent internet connectivity in many rural schoolsthe (Castro et al., 2025).

The integration of technology into multi-grade classes allows the personalization of learning experiences. Adaptive learning platforms can assess each student's strengths and weaknesses, enabling teachers to tailor instruction to meet their specific needs. For instance, younger learners can engage with interactive educational games that strengthen foundational skills such as literacy and mathematics, while older students can utilize online resources to explore more complex topics in greater depth (Recla & Potane, 2023). Additionally, technology facilitates group learning by allowing students to share ideas and resources across different age groups. This interaction enhances motivation and promotes peer mentoring. The use of technology in multi-grade classrooms also fosters students' essential digital literacy skills. By working with various digital tools, learners develop the

ability to manage information, critically evaluate sources, and communicate effectively in digital environments. These skills are becoming increasingly vital in today's technology-driven world, preparing students for future academic and professional success (Taole, 2024).

A wide range of web-based educational technologies can be used in multi-grade classrooms. Learning management systems (LMS) such as Google Classroom and Moodle provide platforms for resource sharing and effective communication, while interactive tools like Edmodo are powerful aids for student collaboration and assignment feedback. Other technologies, such as gamification, videoconferencing for virtual field trips, and educational apps, cater to diverse learning styles and enrich educational experiences (Magallanes et al., 2024). Teachers in multi-grade classrooms play a pivotal role in the effective use of technology. Students must engage responsibly with digital tools and develop essential information literacy skills. By integrating technology into curricula and assessments, teachers can create a dynamic and interactive learning environment that not only aligns with educational goals but also prepares students for an evolving digital landscape (Fatima et al., 2024).

Furthermore, research has shown that the effective integration of educational technology, including artificial intelligence (AI), plays a significant role in addressing some of the challenges faced by teachers in multi-grade classrooms. For instance, the introduction of learning management systems (LMS) has demonstrated potential for improving student progress despite challenges related to user acceptance and engagement. These systems facilitate multi-directional communication, resource sharing, tracking, and feedback (Chounta et al., 2022). The application of AI in educational settings is recognized as a promising avenue for enhancing teaching methods and personalizing learning experiences, which can help alleviate the burdens faced by teachers in multi-grade classrooms (Imasiku et al., 2022).

Despite these numerous advantages, teachers in multi-grade classrooms face several challenges. The successful integration of technology and AI can help mitigate these challenges; however, it also raises ethical considerations related to data privacy, equitable access, and potential biases. Addressing these issues is crucial for ensuring the growth and success of all students in these digital learning environments (Rana et al., 2024).

As the educational landscape evolves, the role of AI in multi-grade classrooms is expected to grow, offering opportunities to enhance teaching methods and student engagement. However, it is essential to carefully examine ethical implications and commit to equitable access to fully leverage AI's potential while safeguarding the rights and needs of all learners. Overall, diverse learning needs in multi-grade classrooms require innovative teaching strategies and effective use of educational technologies. This study explores the role of educational technology, with a particular focus on AI, in improving learning outcomes and addressing the complexities of multi-grade classrooms.

METHOD

This study employs a qualitative research method based on the analysis and review of academic papers. Initially, a comprehensive search was conducted across academic databases such as Google Scholar, Science Direct, Semantic Scholar, SAGE, ProQuest, Scopus, and Springer to gather relevant literature. Keywords such as "educational technology," "artificial intelligence," "multi-grade classrooms," "AI in education," and "advanced learning technologies" were used for this search. The inclusion criteria for the papers focused on those that were published between 2020 and 2023, were written in English, and directly addressed the intersection of AI, educational technology, and learning environments. A total of 52 articles were reviewed, and ultimately, the findings of 26 articles were used in this study. These papers were categorized based on themes such as the applications of AI in education, challenges in multi-grade classrooms, benefits of educational technology, and future research directions. Finally, the key findings of the study were extracted and organized as presented in the following sections.

DISCUSSION

In multi-grade classrooms, where students of varying ages and abilities learn together, the integration of educational technology plays a crucial role in creating engaging and personalized learning environments. This approach not only enhances instructional strategies but also supports students' diverse needs by offering tailored educational experiences (Naparan & Alinsug, 2021). The integration of educational technology, particularly AI, is crucial for improving the effectiveness of multi-grade classrooms. AI provides personalized learning experiences and enables teachers to address students' diverse needs through adaptive learning platforms and interactive tools. These digital resources not only cater to different learning styles but also create opportunities for peer mentoring, where older students assist younger ones, thus enriching the learning environment (Fatima et al., 2024). Subsequent sections explore topics such as personalized learning with AI and its challenges, the application of AI in assessment, grading, and feedback, AI-enhanced classroom environments, future challenges and directions, and the ethical considerations associated with AI integration.

1.1. Personalized Learning with AI in Multi-Grade Classrooms

AI is playing an increasingly transformative role in education, particularly in multi-grade classrooms. Through the implementation of intelligent tutoring systems, AI can provide personalized instruction tailored to individual student needs. These systems can dynamically adjust the content and difficulty level of assignments based on the learner's performance, making them particularly effective for subjects such as mathematics, language learning, and science. The use of intelligent tutoring systems ensures that students can progress at their own pace while receiving immediate feedback and support. This approach

helps bridge gaps among struggling learners and challenges advanced students with more complex materials (Walter, 2024).

AI-based tools enable remarkable personalization in learning environments. By leveraging machine learning algorithms, teachers can create personalized learning profiles for students that consider each learner's preferences, abilities, and prior knowledge. This personalization not only enhances student engagement but also improves academic performance because learners are presented with tasks tailored to their individual capabilities and interests (Aldosari, 2020).

Therefore, one of the most significant advantages of AI in education is its ability to personalize learning experiences. Personalized learning is particularly important in multi-grade classrooms, where students have varying skill levels and learning styles. AI-based intelligent tutoring systems can address individual student needs and provide tailored instruction and feedback (Mehnen & Pohn, 2024). These systems can identify knowledge gaps, adjust task difficulty levels, and offer targeted support to help students progress (Mallik & Gangopadhyay, 2023). For example, the "LearnStreamAI" project at the Vienna Institute of Technology integrates an AI-powered chatbot into the Moodle learning environment. This chatbot leverages advanced technologies, such as ChatGPT and Gemini, to deliver personalized feedback aligned with each student's individual knowledge level (Mehnen & Pohn, 2024). This personalized approach can significantly address students' diverse learning needs in multi-grade classrooms. The potential of AI to create personalized learning pathways was further supported by Mallik and Gangopadhyay (2023), who highlighted AI's role in proactive educational planning to manage varied educational requirements effectively.

Moreover, AI-based tools, such as chatbots, provide immediate feedback and support, which makes the learning environment more interactive and engaging. Multilingual support enabled by AI technologies also enhances accessibility for students from diverse linguistic backgrounds, a feature particularly valuable in multi-grade classrooms where students speak various languages. Additionally, the use of AI technologies can save teachers' time by automating the creation of educational content, streamlining lesson planning, and allowing educators to focus more on addressing individual student needs. Early feedback from pilot studies indicated that AI-generated content aligns well with educational objectives and enhances the quality of teaching resources (Ma, 2024).

1.2. Challenges in Implementing AI-Powered Personalized Learning

1.3. Data Privacy and Security

One of the primary ethical concerns associated with AI in education is data management. AI systems often require large volumes of data to function effectively, which raises critical questions about privacy and security. It is essential for educators to comply with legal frameworks, such as the Family Educational Rights and Privacy Act (FERPA) and the General Data Protection Regulation (GDPR), to protect student information from

privacy breaches and unauthorized access. Regular security audits and a clear understanding of data management policies are crucial for maintaining the integrity and reliability of educational practices. Furthermore, educators must ensure that no sensitive student information is uploaded to AI systems without appropriate protective measures in place (Akgun & Greenhow, 2022).

1.4. Addressing Bias and Ensuring Fairness

AI systems may unintentionally reflect and perpetuate biases in their training data. If the data used to train these models contain specific biases, the recommendations and content generated by AI could mirror and amplify those biases, leading to unfair or discriminatory practices in educational settings (Holmes et al., 2022). To mitigate this risk, educators should participate in professional development programs focused on identifying and addressing bias in AI tools. Incorporating diverse and inclusive educational datasets is essential for producing equitable outcomes for all students, particularly marginalized learners (Khreisat et al., 2024).

1.5. Equity and Accessibility

Ensuring equitable access to AI tools is critical for addressing the digital divide, which can intensify educational inequality. Not all students and schools have equal access to the necessary technologies, potentially preventing some learners from fully benefiting from AI resources. Addressing this disparity requires thoughtful planning and the proper distribution of resources to ensure equal chances for every student (Mallik & Gangopadhyay, 2023). Educators and policymakers should advocate for policies that ensure access to AI technologies for all students and prioritize investments in infrastructure, particularly in underserved areas. Moreover, AI tools should be designed to accommodate diverse learning needs and styles, including those of students with disabilities (Kazim & Koshiyama, 2021).

1.6. Collaborative Development of Guidelines

To promote the responsible use of AI, teachers should involve students in the process of creating ethical guidelines for AI tools. This collaborative approach not only fosters a sense of ownership among students but also enriches guidelines with diverse perspectives. Schools and educational districts should provide opportunities for discussions and workshops where students can voice their concerns and suggestions, thereby cultivating a culture of ethical awareness and accountability (Kamalov et al., 2023).

1.7. Enhancing AI Literacy

Improving AI literacy among teachers and students is essential for understanding the complexities of AI in education. Teachers require adequate training and support to effectively integrate AI tools into their teaching practices (Mehnen & Pohn, 2024). Without proper training, educators may face challenges when using AI tools, thus limiting their impact on student learning. Teachers should also provide explicit instruction on the ethical

implications of AI, emphasizing transparency and the responsible use of these tools. Additionally, educational support strategies can help students develop critical thinking skills that are necessary for effectively engaging with AI technologies. By prioritizing these ethical considerations and adopting best practices, educators can harness AI's potential to enhance learning experiences while safeguarding students' rights (Chen et al., 2020).

1.8. Application of AI in Assessment, Grading, and Feedback

Beyond educational support, AI is transforming assessment and grading processes. AI systems automate administrative tasks, such as graded assignments, enabling teachers to dedicate more time to student interactions and personalized support. Furthermore, AI's ability to analyze data and provide immediate feedback helps educators gain deeper insights into student progress and identify areas that require additional attention. This, in turn, facilitates more informed educational decision-making (Shi et al., 2024).

AI revolutionizes assessment and feedback mechanisms in education. In multi-grade classrooms, accurate and efficient assessment is crucial for monitoring student progress and providing timely interventions (Ma, 2024). AI-based automated grading systems can effectively evaluate student writing, deliver instant feedback, and free teachers' time for personalized instruction (Zhang et al., 2024). These systems analyze various aspects of writing, including grammar, style, and organization, and offer precise feedback on students' strengths and weaknesses. In addition, AI algorithms can compare machine learning models, highlighting their adaptability and accuracy for educational assessments. For instance, the LSTM RNN-RF model has demonstrated high consistency and accuracy in estimating student performance, making it a valuable tool for educational interventions (Ma, 2024).

The application of AI in assessment extends beyond graded assignments. Intelligent systems can analyze student performance data to identify patterns and trends, inform educational decision-making, and provide insights into areas that require additional support. AI can also facilitate proactive planning in education by predicting student performance and identifying at-risk learners, thus allowing teachers to intervene early and prevent academic difficulties (Mallik & Gangopadhyay, 2023). However, it is important to recognize that the use of AI in assessment and feedback is not without challenges. Teachers must have a comprehensive understanding of the potential issues associated with implementing AI in classrooms to ensure its effective and responsible use.

1.9. AI-Enhanced Classroom

Beyond personalized learning and assessment, AI plays a significant role in enhancing engagement and classroom participation (Agasi, 2024). Sensor technologies integrated with AI can monitor student behavior and physiological data to inform personalized learning strategies. These insights can be used to adjust the pace of instruction, provide targeted support, and create responsive and engaging learning environments (Zhang et al., 2024). AI can also be used to develop interactive educational objects and simulations, making learning

more engaging and effective. For instance, the use of tools like ChatGPT, Canva, and Renderforest to create multimodal educational content has received positive feedback from students, demonstrating its effectiveness in raising awareness about water pollution (Alfiani & Sulisworo, 2023).

The integration of AI tools in classroom environments can also enhance collaborative learning (Wang & Liu, 2021). AI-based platforms can facilitate communication and collaboration among students, providing opportunities for peer learning and knowledge sharing (Agasi, 2024). Additionally, AI can help teachers analyze student interactions during collaborative problem-solving, offering insights into areas of conflict and identifying opportunities for intervention. Visual analysis of cognitive conflict during collaborative problem-solving can inform AI-driven instructional strategies, enabling teachers to provide timely feedback and support (Lu et al., 2023). However, the implementation of AI-enhanced classroom environments also presents challenges. Data privacy and security are critical concerns that require robust measures to protect student data and prevent misuse. The cost of implementing AI technologies in classrooms, particularly in resource-constrained settings, can also be a significant barrier (Zhang et al., 2024).

1.10. Challenges and Future Directions

The integration of AI into multi-grade classrooms not only enhances the learning experience but also prepares students for a future dominated by technology. By fostering critical thinking, problem-solving, and collaboration skills, AI-equipped educational environments prepare students for success in the digital era. However, the successful implementation of AI tools requires careful planning, training, and commitment to equitable access to ensure that all students thrive in these settings (Shi et al., 2024).

Although AI has significant potential in transforming multi-grade classrooms, several challenges remain. The digital divide, teacher readiness, ethical considerations, and implementation costs are major barriers to widespread adoption (Yu & Guo, 2023). Addressing these challenges requires a multifaceted approach that includes investing in infrastructure to ensure equitable access to technology, providing comprehensive teacher training programs, developing ethical guidelines for AI use in education, and exploring cost-effective solutions for AI technology implementation. The need for complementary research initiatives to effectively integrate AI tools into educational settings was highlighted in Chichekian and Benteux's (2022) study, which emphasized the importance of teacher involvement in the learning process and the necessity of establishing theoretical foundations in the development of AI-based tools.

Accordingly, future research should focus on several key areas. First, further studies are required to assess the long-term impact of AI on student learning outcomes in multigrade environments. Longitudinal studies are essential to track student progress over time and evaluate the effectiveness of AI-based interventions. Second, more research is required on the development and implementation of effective training programs for

teachers (Schina et al., 2021). These programs should address not only the technical aspects of using AI tools but also the pedagogical approaches necessary for effectively integrating AI into teaching. Third, further investigation into ethical considerations, including data privacy and AI's potential to intensify existing inequalities, is critical (Yu & Guo, 2023). Developing ethical guidelines and best practices for the use of AI in education is vital for ensuring responsible and equitable implementation. Finally, future research should explore the use of AI to support collaboration and communication in multi-grade classrooms. AI-based platforms can facilitate interactions between students and teachers and promote peer learning and knowledge sharing (Agasi, 2024).

1.11. Ethical Considerations

As educational technologies, particularly AI, continue to evolve, educators must be aware of the ethical implications of their use in classrooms. Issues such as data privacy, equitable access to technology, challenges related to data collection, limitations in data availability, bias and representation, data ownership and control, data autonomy, and the authenticity of learning experiences must be addressed in order to ensure that all students benefit from AI integration. The Digital Education Action Plan 2021-2027 emphasizes the importance of developing ethical guidelines for AI in education and highlights the need for teachers to be aware of and manage these complexities (Akgun & Greenhow, 2022; Miao et al., 2021; Nguyen et al., 2023). Therefore, a comprehensive understanding of these values and principles is critical before making ethical and accountable decisions, and being aware of even the potential unforeseen implications in education.

CONCLUSION

Traditional teaching methods may no longer be sufficient to address the diverse learning styles and paces in multigrade classrooms (Bharti et al., 2024). In this context, educational technologies, particularly AI, can transform multigrade classrooms through personalized learning, improved assessment, and enhanced classroom environments. However, realizing this potential requires addressing several challenges related to access, teacher training, ethics, and cost. By investing in infrastructure, providing comprehensive teacher training, developing ethical guidelines, and conducting further research, the power of AI can be harnessed to create effective, equitable, and engaging learning experiences for all students in multigrade classrooms. The integration of AI into educational technology requires ongoing research and development to fully understand and address the potential benefits and challenges of AI in diverse educational settings.

AI-based educational technology promises significant improvements in teaching and learning in multigrade classrooms. AI can facilitate personalized learning, automate tasks, and provide data-driven insights and recommendations on student progress. Thus, the integration of AI must always prioritize student well-being and equitable access to high-quality education (Mustafa et al., 2024). However, while the potential benefits of this

technology are substantial, a thorough examination of its ethical implications and possible biases is crucial for its responsible and effective implementation. Ethical considerations and challenges related to AI deployment require careful scrutiny (Farahani & Ghasmi, 2024; Rana et al., 2024).

Recent advancements in AI are poised to significantly transform educational practices within multi-grade classrooms across the globe. The core potential of AI lies in its capacity to facilitate personalized learning and differentiated instruction at scale, which are the cornerstones of effective teaching in these unique environments. AI-driven tools can create individualized learning pathways by dynamically assessing each student's knowledge, offering various educational resources tailored to different ability levels. By automating assessment processes and providing immediate feedback, this technology frees up valuable teacher time to enable more direct student interaction while simultaneously functioning as an intelligent tutoring assistant to answer student queries. Furthermore, AI can streamline administrative duties such as lesson planning and reporting, enabling educators to transition from being mere purveyors of information to facilitators of the learning process. Despite challenges such as the digital divide, AI holds the potential to effectively address the complex needs of multi-grade settings by delivering personalized support and fostering a more efficient learning experience for every child (Miao et al., 2021).

Therefore, implementing AI in multigrade classrooms, while promising, presents unique challenges that warrant careful consideration in our conclusions. A primary concern revolves around equitable access and infrastructure. Many multigrade schools, particularly in rural or underserved areas, may lack the necessary high-speed internet, reliable power, and up-to-date devices to effectively support AI-driven tools. This digital divide could exacerbate existing educational inequalities, making it crucial to explore strategies for inclusive implementation. Furthermore, the training and professional development of teachers are paramount. Educators in multigrade settings often manage diverse learning needs and a broad curriculum, integrating AI effectively requires specialized training not only in operating these technologies but also in adapting them to the specific pedagogical demands of a multigrade environment. Without adequate support, teachers may struggle to leverage AI's full potential. Finally, curriculum integration and content relevance pose a challenge. AI tools must be carefully selected and adapted to align with the varied learning objectives across multiple grade levels within a single classroom. Developing or curating AI-powered content that is simultaneously engaging and appropriate for a wide age range is complex, requiring significant foresight and collaboration between educators and technology developers. Addressing these challenges through targeted policy, infrastructure development, and teacher empowerment will be critical for the successful and impactful adoption of AI in multigrade settings (Ng et al., 2025; Walter, 2024).

Addressing the challenges associated with AI integration, including the digital divide and the need for comprehensive teacher training, requires a multifaceted approach. This requires collaborative efforts from researchers, educators, and policymakers to navigate the

complexities of AI integration in diverse educational environments. Additionally, further research should consider the specific needs of diverse learners and learning environments (Lin et al., 2024). The role of teachers remains essential, with AI serving as a supportive tool rather than a replacement for human interaction and teacher expertise. Ongoing research is necessary to fully understand the long-term impact of AI on student learning and teacher performance, ensuring that AI can be used to promote educational equity and enhance learning outcomes for all students.

With a focus on equitable access, responsible development, and effective implementation strategies, AI can be used to create more inclusive and efficient learning environments for all students in multi-grade classrooms. Future research should therefore focus on the long-term impacts of AI on student learning, the development of ethical guidelines, and the support for teachers in effectively integrating AI into classrooms. Regardless of students' age, learning style, or background, the ultimate goal should be to harness the power of AI to create fairer and more effective learning environments. This requires a continuous process of evaluation, adaptation, and improvement to ensure that AI continues to be a tool for positive transformation in education.

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Data Availability Declaration

While the primary datasets utilized in this study are not publicly accessible due to certain constraints, they are available to researchers upon a formal request. The authors have emphasized maintaining the integrity of the data and its analytical rigor. To access the datasets or seek further clarifications, kindly reach out to the corresponding author. Our aim is to foster collaborative academic efforts while upholding the highest standards of research integrity.

Author Contributions

The sole author of this research, Abbas Poursalim, was responsible for the conceptualization, methodology formulation, data collection, analysis, and interpretation. Furthermore, Abbas Poursalim took charge of drafting the initial manuscript, revising it critically for vital intellectual content, and finalizing it for publication. The author has read and approved the final manuscript and takes full accountability for the accuracy and integrity of the work presented.

Author(s)' statements on ethics and conflict of interest

Ethics statement: I hereby declare that research/publication ethics and citing principles have been considered in all the stages of the study. I take full responsibility for the content of the paper in case of dispute.

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