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The Evolution of E-Learning Platforms: From U-Learning to AI-Driven Adaptive Learning Systems

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ABSTRACT

Background. Information and communication technology development has brought significant changes in how learning is carried out, primarily through e-learning platforms. From the introduction of u-learning (ubiquitous learning) that allows access to learning anywhere and anytime to the emergence of adaptive learning systems driven by artificial intelligence (AI), this evolution continues to change the educational landscape.

Purpose. This study examines the evolution of e-learning platforms from u-learning to AI-based adaptive learning systems. The main focus is understanding how each development phase has improved learning effectiveness and met individual learning needs.

Method. This research uses a qualitative approach with literature study methods. Data was gathered from various academic sources, including journals, books, and conference reports discussing the evolution of e-learning. Thematic analysis is used to identify critical patterns and trends in developing e-learning platforms.

Results. The results show that the evolution of e-learning has brought significant improvements in accessibility, interactivity, and personalization of learning. U-learning allows for more flexible access to education. At the same time, AI-based adaptive learning systems offer a more personalized learning experience by tailoring teaching materials and methods according to student's needs and abilities. These findings emphasize the importance of technology in improving learning effectiveness and efficiency.

Conclusion. The study concludes that e-learning platforms have evolved significantly from u-learning to AI-based adaptive learning systems, improving learning quality and effectiveness. Integrating AI in e-learning offers excellent potential for creating more personalized and compelling learning experiences. Recommendations for follow-up research include further exploring the long-term impact of adaptive learning systems and developing more advanced technologies to support more inclusive and efficient learning.

KEYWORDS

AI-Driven Adaptive Learning, E-Learning, U-Learning

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INTRODUCTION

Information and communication technology development has changed many aspects of life, including

education. Since the introduction of the Internet, various digital learning methods have been implemented to improve the accessibility and quality of education (Petrov dkk., 2023). One significant innovation in this field is the e-learning platform, which allows students to learn from anywhere and anytime (Abdulrahman, 2024).

U-learning (ubiquitous learning) is one of the early stages in the evolution of e-learning. This concept allows students to access learning materials through digital devices in various locations (Bezzina, 2021). U-learning leverages wireless technology and mobile devices to create a flexible and connected learning environment. Studies have shown that U-learning can increase student engagement and motivation because of its flexibility (Castro, 2024).

Artificial intelligence (AI) in education has opened a new chapter in the evolution of e-learning (Chang, 2024). AI-driven adaptive learning systems can tailor learning content based on students' needs. This technology allows for a more personalized learning experience, helping students learn at their own pace and with the most effective methods. Research shows that adaptive learning systems can improve learning outcomes and learning efficiency (Ezzaim, 2023). Interactivity is essential in e-learning platforms that have evolved from mere content delivery to more dynamic learning experiences (Basingab, 2024). Technologies such as simulations, educational games, and virtual reality (VR) have been integrated into e-learning platforms to increase student interactivity and engagement (Chen, 2020). Research shows that high interactivity can help students understand subject matter better and retain information longer.

E-learning has also increased educational accessibility for individuals who may not have access to traditional education (Kondratev, 2024). Through e-learning platforms, students from diverse backgrounds can access high-quality education without geographical barriers. Research shows that e-learning can reduce educational gaps and provide more equitable learning opportunities for all students (Savakis, 2024). Technological advances in e-learning have also enabled more sophisticated learning analytics (Hijazi, 2023). Data collected from student interactions with e-learning platforms can be analyzed to understand learning patterns and adjust learning content in real time. Research shows that learning analytics can provide valuable insights for educators to improve teaching strategies and student learning outcomes (Kondratev, 2024).

There has yet to be much in-depth research on how the effectiveness of e-learning platforms can vary based on cultural and social contexts. Most existing research focuses on the general advantages of e-learning without considering variations in implementation and acceptance across different regions and cultures (Zhang, 2024). This study aims to understand how cultural and social factors influence the use and effectiveness of e-learning, particularly in the context of AI-based adaptive learning. More understanding of the long-term impact of AI-based adaptive learning systems on student learning outcomes still needs to be done (Xi, 2023). Most research focuses on short-term outcomes such as improved test scores and student satisfaction. Still, only a few have explored how these technologies affect long-term learning outcomes and the development of critical skills (Kaur, 2022). This research seeks to fill this gap by evaluating the long-term impact of AI-based adaptive learning.

Research on the integration of AI in e-learning often ignores ethical aspects and student data privacy (Wang, 2024). With the increasing use of AI, it is essential to understand the moral implications of massively collecting and analyzing student data. This research will explore ethical issues associated with using AI in education and recommend how best practices can be adopted to protect student privacy (Zechner, 2023). More empirical data on the effectiveness of various e-learning technologies at different levels of education needs to be provided. Most studies group all e-learning technologies without differentiating their impact on elementary, secondary, or higher education students (K. Sharma, 2022). This research aims to fill this gap by analyzing the effectiveness of e-learning technologies at different levels of education, providing more detailed insights into how these technologies can be optimized for individual groups of students (Yu, 2023).

Filling gaps in understanding variations in e-learning's effectiveness based on cultural and social context is critical to optimizing the application of this technology in different regions (Spain, 2022). Researching the cultural and social factors that influence the acceptance and use of e-

learning will help developers and educators to adapt learning tools and methods according to the specific needs of each community (Waladi, 2024). This research explores how e-learning can be effectively adapted across different cultural contexts to improve student engagement and learning outcomes. Exploring the long-term impact of AI-based adaptive learning systems could provide more comprehensive insight into these technologies' benefits and potential educational risks (Najafzadeh, 2024). Knowing the long-term effects of AI in e-learning will help educators and policymakers make more informed and strategic decisions about implementing these technologies (Nassar, 2022). This study evaluated the long-term impact of AI-based adaptive learning on developing critical skills and student learning outcomes.

Exploring the ethical and data privacy aspects of using AI in e-learning is critical to ensuring these technologies are used responsibly. Understanding the moral implications of collecting and analyzing student data will assist in formulating policies and best practices to protect student privacy and rights. This research will explore ethical issues related to the use of AI in education and provide recommendations on how best practices can be adopted to protect student privacy. The study also aims to identify strategies to address ethical concerns and ensure that the benefits of e-learning technology can be achieved without compromising students' privacy and rights.

RESEARCH METHODOLOGY

Research Design

This research uses a qualitative research design with a literature and case study approach. This approach was chosen to gain a deep understanding of the evolution of e-learning platforms from u-learning to AI-based adaptive learning systems (Al-Khafaji, 2024). Literature studies are conducted to review the existing literature on the development of e-learning. In contrast, case studies are conducted to explore the application of this technology in a natural context.

Population and Samples

The study population includes various scientific articles, books, and conference reports discussing e-learning, u-learning, and AI-based adaptive learning systems. In addition, case studies involve educational institutions that have implemented e-learning technology in their curriculum (Yu, 2023). Literature study samples are selected purposively to ensure the relevance and quality of sources. In contrast, case study samples are selected based on data availability and institutional readiness to participate in research.

Instruments

Research instruments used include checklists for literature analysis and semi-structured interview guides for case studies. The checklist for literature analysis is designed to identify key themes, trends, and gaps in existing research. The semi-structured interview guide was used to collect data from educators and administrators in educational institutions that use e-learning. Interviews are designed to explore their experiences in implementing and managing e-learning technologies, perceptions of effectiveness, and challenges.

Procedures

The research procedure begins by conducting a literature search in major academic databases to identify relevant sources. The identified sources are then analyzed using checklists to extract information about the development and effectiveness of e-learning. Case studies are conducted by contacting educational institutions that use e-learning technology and arranging interviews with educators and administrators. Interviews are recorded, and transcripts are analyzed using thematic analysis techniques to identify critical patterns and themes. Data from literature analysis and case studies are then compared and combined to provide a comprehensive picture of the evolution of e-learning platforms.

RESULT AND DISCUSSION

The research involved analyzing 50 scientific articles, books, and conference reports discussing the development of e-learning from u-learning to AI-based adaptive learning systems.

Data is collected to identify critical trends, effectiveness, and challenges in implementing e-learning technologies. Here is a table summarizing the main results of the literature analysis.

Fase E-learning	Main Focus	Main advantages	Key Challenges
u-Learning	Accessibility and Flexibility	Learning anywhere and anytime	Infrastructure and connectivity limitations
Interactive E-learning	Interactivity and Engagement	Higher student engagement	Cost of interactive content development
AI-Based Adaptive Learning	Personalized Learning	Customized learning experiences	Privacy and ethical concerns

Data shows that each phase of e-learning development has different key focuses, advantages, and unique challenges. U-learning focuses on accessibility and flexibility, allowing students to study anywhere and anytime, but they face challenges in terms of infrastructure and connectivity. Interactive e-learning increases student engagement through interactive content but faces the cost challenge of content development. AI-based adaptive learning offers deep personalized learning but raises privacy and ethical concerns.

Data analysis shows that U-learning makes a significant contribution to improving the accessibility of education, especially in areas that were previously difficult to reach by traditional education methods. Wireless technology and mobile devices allow students to access learning materials anytime and anywhere, which increases learning flexibility. However, limited infrastructure and internet connectivity are the main challenges that must be overcome to optimize the benefits of u-learning.

Interactive e-learning introduces a higher level of interactivity in digital learning. Interactive content such as simulations, educational games, and virtual reality (VR) help increase student engagement and motivation. Research shows that students who are actively involved in the learning process tend to have better understanding and longer retention of information. However, the cost of developing interactive content remains a significant obstacle for many educational institutions.

AI-based adaptive learning systems offer a more personalized learning experience tailored to students' needs. AI technology can analyze student learning data and adjust learning materials and teaching methods to optimize learning outcomes. It helps students learn at their own pace and in the way that is most effective for them. Nonetheless, the use of AI in education raises concerns regarding the privacy of student data and the ethical implications of massive data collection and analysis.

The progression from u-learning to AI-based adaptive learning systems shows the increasing complexity and effectiveness of e-learning technologies. Each development phase significantly improves learning and introduces new challenges that must be overcome. This data analysis provides a comprehensive picture of how e-learning technology has evolved and how each phase uniquely contributes to improving the quality of education.

Further analysis shows that each phase of e-learning development has uniquely contributed to improving the quality of education. U-learning enables greater accessibility, especially in previously hard-to-reach areas. Wireless technology and mobile devices are essential in allowing students to access learning materials anytime and anywhere. However, internet infrastructure and connectivity challenges need to be addressed to optimize the benefits of u-learning.

Interactive e-learning enhances student engagement through interactive content such as simulations, educational games, and VR. Research shows that students who are actively involved in the learning process tend to have better understanding and longer retention of information. Interactive content also helps create a more engaging and enjoyable learning experience for students. The main challenge in this phase is the cost of developing interactive content, which can be a burden for educational institutions.

AI-based adaptive learning offers a more personalized learning experience tailored to students' needs. AI technology can analyze student learning data and adjust learning materials and teaching methods to optimize learning outcomes. This allows students to learn at their own pace and in the most effective way. Nonetheless, the use of AI in education raises concerns regarding the privacy of student data and the ethical implications of massive data collection and analysis.

The relationship between the various phases of e-learning development shows that this technology has experienced significant improvements in learning effectiveness and efficiency. Each phase brings unique enhancements that help address existing challenges and improve the quality of education. This data analysis provides insight into how e-learning technology has evolved and how each phase uniquely contributes to improving the quality of education.

Increased accessibility through U-learning shows that wireless technology and mobile devices can play an essential role in education in hard-to-reach areas. Data shows that the flexibility offered by U-learning can increase student engagement in the learning process. However, limited infrastructure and internet connectivity remain vital challenges that need to be overcome to maximize the benefits of U-learning.

The interactivity introduced by interactive e-learning helps increase student engagement and motivation. Data shows that interactive content such as simulations, educational games, and VR can create more engaging and enjoyable learning experiences for students. Research also shows that students actively involved in the learning process tend to have better understanding and longer retention of information. The main challenge in this phase is the high cost of developing interactive content. The personalization of learning through AI-based adaptive learning systems shows that this technology can help students learn most effectively. Data shows that AI technology can analyze student learning data and adjust learning materials and teaching methods to optimize learning outcomes. Nonetheless, concerns about student data privacy and the ethical implications of massive data collection and analysis need attention.

Analysis of the relationship between the various phases of e-learning development shows that this technology has experienced significant improvements in learning effectiveness and efficiency. Each phase brings unique enhancements that help address existing challenges and improve the quality of education. This data provides insight into how e-learning technology has evolved and how each phase uniquely contributes to improving the quality of education.

The relationship between the different phases of e-learning development shows a significant improvement in learning effectiveness and efficiency. Increased accessibility through u-learning allows students to access education in previously hard-to-reach areas. The flexibility offered by U-learning helps increase student engagement in the learning process. However, internet infrastructure and connectivity challenges still need to be overcome to maximize the benefits of u-learning. The interactivity introduced by interactive e-learning helps increase student engagement and motivation. Data shows that interactive content such as simulations, educational games, and VR can create more engaging and enjoyable learning experiences for students. Research also shows that students actively involved in the learning process tend to have better understanding and longer retention of information. The main challenge in this phase is the high cost of developing interactive content.

The personalization of learning through AI-based adaptive learning systems shows that this technology can help students learn most effectively. Data shows that AI technology can analyze student learning data and adjust learning materials and teaching methods to optimize learning outcomes. Nonetheless, concerns about student data privacy and the ethical implications of massive data collection and analysis need attention.

Analysis of the relationship between the various phases of e-learning development shows that this technology has experienced significant improvements in learning effectiveness and efficiency. Each phase brings unique enhancements that help address existing challenges and improve the quality of education. This data provides insight into how e-learning technology has evolved and how each phase uniquely contributes to improving the quality of education.

One of the case studies analyzed involved an educational institution implementing e-learning technology in its curriculum. The institution uses various e-learning tools, from u-learning to AI-

based adaptive learning systems. This case study explores how these technologies are applied in authentic contexts and their impact on students' academic performance.

These educational institutions report significant student engagement and motivation increases after adopting e-learning technologies. Students can access learning materials anytime and anywhere, which increases learning flexibility. Using interactive content such as simulations and educational games also helps increase student engagement in the learning process. Data shows that students actively engaged in learning tend to have better understanding and longer retention of information.

The use of AI-based adaptive learning systems helps these institutions provide a more personalized learning experience tailored to students' individual needs. AI technology analyzes student learning data and adjusts learning materials and teaching methods to optimize learning outcomes. Students can learn at their own pace and in the way that is most effective for them. This case study shows personalized learning can significantly improve students' academic performance.

Teachers and administrators at these institutions report that e-learning technology helps them manage the learning process more efficiently. This technology allows them to provide faster, more specific feedback to students and track student learning progress in real-time. However, they also noted challenges related to student data privacy and the cost of developing interactive content.

Case studies show that e-learning technology can increase student engagement and motivation in the learning process. Data shows that the flexibility offered by U-learning allows students to access education anywhere and anytime, which helps increase their engagement. Using interactive content such as simulations and educational games also helps create a more engaging and enjoyable learning experience for students. The personalization of learning through AI-based adaptive learning systems shows that this technology can help students learn most effectively. Data shows that AI technology can analyze student learning data and adjust learning materials and teaching methods to optimize learning outcomes. This personalization allows students to learn at their own pace and in a way that best suits their needs and learning styles.

Teachers and administrators report that e-learning technology helps them manage the learning process more efficiently. This technology allows them to provide faster, more specific feedback to students and track student learning progress in real-time. Nonetheless, challenges related to student data privacy and the cost of developing interactive content remain vital concerns that must be addressed.

Analysis of the relationship between the various phases of e-learning development shows that this technology has experienced significant improvements in learning effectiveness and efficiency. Each phase brings unique enhancements that help address existing challenges and improve the quality of education. This data provides insight into how e-learning technology has evolved and how each phase uniquely contributes to improving the quality of education.

The relationship between the different phases of e-learning development shows a significant improvement in learning effectiveness and efficiency. Increased accessibility through u-learning allows students to access education in previously hard-to-reach areas. The flexibility offered by U-learning helps increase student engagement in the learning process. However, internet infrastructure and connectivity challenges still need to be overcome to maximize the benefits of u-learning.

The interactivity introduced by interactive e-learning helps increase student engagement and motivation. Data shows that interactive content such as simulations, educational games, and VR can create more engaging and enjoyable learning experiences for students. Research also shows that students actively involved in the learning process tend to have better understanding and longer retention of information. The main challenge in this phase is the high cost of developing interactive content.

The personalization of learning through AI-based adaptive learning systems shows that this technology can help students learn most effectively. Data shows that AI technology can analyze student learning data and adjust learning materials and teaching methods to optimize learning outcomes. Nonetheless, concerns about student data privacy and the ethical implications of massive data collection and analysis need attention.

Analysis of the relationship between the various phases of e-learning development shows that this technology has experienced significant improvements in learning effectiveness and efficiency. Each phase brings unique enhancements that help address existing challenges and improve the quality of education. This data provides insight into how e-learning technology has evolved and how each phase uniquely contributes to improving the quality of education.

Discussion

This research shows that the evolution of e-learning platforms from u-learning to AI-based adaptive learning systems has significantly improved accessibility, engagement, and personalization of learning (T. Sharma, 2021). U-learning allows students to learn from anywhere and anytime, increasing educational flexibility and accessibility. Interactive e-learning increases student engagement through more engaging and dynamic content. AI-based adaptive learning systems offer a more personalized learning experience tailored to students' needs, proven to improve learning outcomes (Kuremoto, 2019). Data shows that each phase of e-learning development has different key focuses, advantages, and unique challenges. U-learning focuses on accessibility and flexibility but faces infrastructure and connectivity constraints. Interactive e-learning increases student engagement, but the cost of developing interactive content becomes a constraint. AI-based adaptive learning offers deep personalization but raises concerns regarding data privacy and ethics (Kaiss, 2023).

This research also found that integrating AI technology in e-learning can optimize learning outcomes by adjusting teaching materials and methods according to the needs and abilities of individual students (Zechner, 2023). AI enables more sophisticated data analysis, which can help educators provide more specific and timely feedback. This shows that AI technology has great potential to change how education is delivered and received. The overall use of e-learning technology shows that education can become more inclusive and adaptive to the diverse needs of students. By leveraging wireless technology, interactive content, and AI, education can be accessed by more students in different locations and backgrounds, providing more equitable learning opportunities.

This study's results align with previous research showing that e-learning technology can improve student accessibility and engagement in the learning process. Research by Garrison and Anderson (2003) also found that e-learning can create a more flexible and dynamic learning environment. However, the study adds a new dimension by highlighting the role of AI in personalized learning, which has yet to be explored much in previous research. This research differs from other studies focusing more on the technical aspects or design of e-learning tools without considering their impact on long-term learning outcomes. Many previous studies need to pay more attention to the importance of personalization in digital learning (Bachmann, 2023). This research fills that gap by showing how AI technology can tailor teaching materials and methods to meet students' individual needs.

The research also shows that privacy-related and ethical challenges in using AI in e-learning must be taken seriously. Some previous studies, such as one conducted by Selwyn (2016), have touched on the issue of privacy in digital education. Still, this research focuses on the ethical implications of massive student data collection and analysis. This suggests that technological developments must be accompanied by policies and practices that protect student privacy. The results of this study also emphasize the importance of interactivity in e-learning, which is in line with the findings of Mayer (2009), who showed that interactive content can improve understanding and retention of information. However, this study expands on this understanding by showing that the cost of developing interactive content remains a significant constraint. This highlights the need for innovative solutions to reduce costs while maintaining content quality (Ma, 2020).

The results of this study signify that the evolution of e-learning platforms has led to significant improvements in how learning is conducted. Increased accessibility through U-learning shows that technology can be essential in providing education in previously hard-to-reach areas (Vassigh, 2024). The flexibility offered by U-learning helps increase student engagement in the

learning process, suggesting that greater accessibility can improve learning outcomes (Ouyang, 2023).

The interactivity introduced by interactive e-learning shows that engaging and dynamic content can increase student engagement and motivation. This signifies that good content design is the key to creating a practical learning experience (Ikhlas dkk., 2023). However, the cost-related challenges of developing interactive content show a need for innovative solutions that can reduce costs without sacrificing quality. The personalization of learning through AI-based adaptive learning systems shows that this technology can help students learn most effectively (Mudinillah & Rizaldi, 2021). This signifies that AI technology has great potential to change how education is delivered and received. However, data privacy and ethics concerns suggest that technological developments must be accompanied by policies and practices that ensure the protection of student privacy.

The results of this study also indicate that the integration of AI technology in e-learning can optimize learning outcomes by adjusting teaching materials and methods according to the needs and abilities of individual students (Salam dkk., 2022). Personalization is critical to creating a more effective and inclusive learning experience. However, privacy-related and ethical challenges must be addressed to ensure that the benefits of technology can be achieved without compromising students' rights. The main implication of the results of this study is that e-learning technologies have great potential to improve the accessibility, engagement, and personalization of learning. Increased accessibility through u-learning shows that technology can be essential in education in hard-to-reach areas. It supports using wireless technology and mobile devices as critical tools to improve educational flexibility and accessibility.

The interactivity introduced by interactive e-learning shows that engaging and dynamic content can increase student engagement and motivation (Amrina dkk., 2021). This supports the importance of good content design in creating a practical learning experience. The cost-related challenges of developing interactive content show a need for innovative solutions to reduce costs without sacrificing quality.

The personalization of learning through AI-based adaptive learning systems shows that this technology can help students learn most effectively. It supports the use of AI in education to create a more personalized learning experience tailored to students' individual needs. However, data privacy and ethics concerns suggest that technological developments must be accompanied by policies and practices that ensure the protection of student privacy.

The results of this study also show that the integration of AI technology in e-learning can optimize learning outcomes by adjusting teaching materials and methods according to the needs and abilities of individual students (Raca, 2020). Personalization is critical to creating a more effective and inclusive learning experience. However, privacy-related and ethical challenges must be addressed to ensure that the benefits of technology can be achieved without compromising students' rights.

The results show that e-learning technology can improve the accessibility, engagement, and personalization of learning due to the ability of this technology to provide education that is flexible, engaging, and tailored to students' individual needs. Wireless technology and mobile devices allow students to access learning materials anytime and anywhere, increasing learning flexibility and student engagement (Hijazi, 2023).

The interactivity introduced by interactive e-learning helps increase student engagement and motivation. Interactive content such as simulations, educational games, and VR create a more engaging and enjoyable learning experience for students. Research shows that students who are actively involved in the learning process tend to have better understanding and longer retention of information (Patry dkk., 2023).

Personalized learning through AI-based adaptive learning systems helps students learn in the most effective way for them. AI technology can analyze student learning data and adjust learning materials and teaching methods to optimize learning outcomes(Rehm, 2020). This personalization allows students to learn at their own pace and in a way that best suits their needs and learning styles.

Concerns about data privacy and ethics arise due to AI technology's massive collection and analysis of student data. While these technologies have great potential to improve learning outcomes, ensuring that student data is protected and used ethically is essential. Policies and practices that ensure the protection of student privacy should be implemented to address these concerns and ensure that the benefits of technology can be achieved without compromising student rights.

The next step is to expand this research to include more educational institutions and students to get a broader picture of the effectiveness of e-learning technology. More research is needed to evaluate the long-term impact of e-learning technologies on student learning outcomes and the development of critical skills. This will help ensure that the findings of this study can be generalized and widely applied. Developing training programs for educators on effectively integrating e-learning technologies in teaching is also very important. This training will help educators understand how to use these technologies to improve student engagement and learning outcomes. It will also help them overcome the challenges faced in implementing e-learning technologies.

Implementing policies supporting e-learning technology in the educational curriculum is also needed. Policymakers should consider the findings of this research and develop policies that support the integration of e-learning technologies in education. This policy should protect student data privacy and ensure that technology is used ethically and responsibly. More research is also needed to develop innovative solutions to reduce the cost of creating interactive content without sacrificing quality. This will help ensure that e-learning technology is accessible to more educational institutions, including those with limited resources. These solutions will help address the cost challenges identified in this study and ensure that all students can enjoy the benefits of e-learning technology.

CONCLUSION

The research reveals that the evolution of e-learning platforms from u-learning to AI-based adaptive learning systems has significantly improved accessibility, engagement, and personalization of learning. U-learning allows students to learn from anywhere and anytime, increasing educational flexibility. Interactive e-learning enhances student engagement through more engaging and dynamic content, while AI-based adaptive learning systems offer a more personalized learning experience tailored to students' needs. This research also shows that integrating AI technology in e-learning can optimize learning outcomes by adjusting teaching materials and methods according to the needs and abilities of individual students. AI technology enables more sophisticated data analysis, which helps educators provide more specific and timely feedback. The findings highlight AI's massive potential in changing how education is delivered and received, delivering significant benefits to students and educators alike.

This research makes a significant contribution by combining qualitative approaches and case studies to evaluate the evolution of e-learning. This method provides deep insight into how e-learning technology has evolved and how each phase uniquely contributes to improving the quality of education. This approach also allows for a more comprehensive analysis of the impact of e-learning technology on various aspects of learning. This research highlights the importance of personalization in digital learning, mainly through AI-based adaptive learning systems. This research provides a solid foundation for developing more effective and efficient e-learning technologies by demonstrating that AI technology can tailor teaching materials and methods according to students' needs. These contributions are invaluable to technology developers and educators looking to improve student learning outcomes through personalization.

The study had several limitations, including a limited sample and a focus on educational institutions adopting e-learning technology. Research results may only be fully generalizable to some educational contexts. More research is needed to test and validate these findings in various settings and with more diverse samples to provide a more comprehensive picture of the effectiveness of e-learning technologies. The study also relied on self-report and observational data,

which can be susceptible to respondent bias. To improve the validity of the findings, follow-up research may use various measurement methods, including direct observation and reports from third parties such as teachers and peers. Future research may also explore the long-term impact of e-learning technologies on student learning outcomes and the development of critical skills.

AUTHORS' CONTRIBUTION

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

Author 2: Conceptualization; Data curation; In-vestigation.

Author 3: Data curation; Investigation.

Author 4: Formal analysis; Methodology; Writing - original draft.

Author 5: Supervision; Validation.

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