

Adaptive Learning Technologies for Improving Student Engagement

Dominik Petko

Professor, University of Zurich, Switzerland

Abstract

The increasing diversity of learner requirements, changing educational environments, and growing demand for personalized learning experiences have accelerated the development of adaptive learning technologies in modern education systems. Traditional educational approaches generally rely on standardized teaching methods, fixed instructional materials, and uniform assessment strategies, which may not effectively address differences in student abilities, learning preferences, and academic progress. Adaptive learning technologies have emerged as innovative solutions that utilize artificial intelligence, learning analytics, educational data mining, and personalized content delivery mechanisms to improve student engagement and learning effectiveness.

This study examines adaptive learning technologies for improving student engagement by analysing their contribution to learner participation, motivation, interaction, learning persistence, and academic involvement. The research explores major adaptive learning components including intelligent tutoring systems, AI-based recommendation models, learner behaviour analysis, personalized feedback mechanisms, adaptive assessment systems, and digital learning platforms. A simulation-based analytical methodology is developed to compare conventional learning approaches with adaptive learning frameworks using evaluation indicators including engagement improvement, personalization capability, learning efficiency, technology adaptability, and educational effectiveness.

The findings demonstrate that adaptive learning technologies significantly enhance student engagement by providing personalized learning pathways, timely feedback, adaptive instructional support, and data-driven academic interventions. The results indicate that adaptive learning systems create more interactive and responsive educational environments by aligning instructional content with individual learner requirements. However, successful implementation requires addressing challenges related to AI model complexity, learning data management, technology integration, student privacy, digital accessibility, and ethical educational practices.

Keywords: Adaptive Learning Technologies, Student Engagement, Artificial Intelligence in Education, Learning Analytics, Personalized Learning, Intelligent Tutoring Systems, Educational Technology

1. Introduction

The education sector is experiencing rapid transformation due to advancements in artificial intelligence, learning analytics, digital platforms, and personalized educational technologies. Traditional learning systems have generally followed standardized instructional approaches where the same learning materials, teaching methods, and assessment structures are provided to groups of students. Although

these approaches have supported educational development, they may not fully address individual differences in learning ability, knowledge level, motivation, and academic progress. Adaptive learning technologies have emerged as innovative solutions that enable education systems to provide personalized, responsive, and learner-centred experiences.

Adaptive learning technologies utilize artificial intelligence algorithms, learner data analysis, intelligent tutoring systems, and personalized content delivery mechanisms to modify learning experiences according to individual student requirements. These systems analyse learner interactions, identify knowledge gaps, recommend suitable learning resources, and provide customized feedback. By continuously adapting instructional strategies, adaptive learning platforms create more engaging and effective learning environments that support diverse student populations.

The importance of adaptive learning technologies has increased as educational institutions seek strategies to improve student engagement, academic performance, and learning retention. Modern education environments require intelligent systems capable of understanding learner behaviour and providing timely academic support. However, implementation of adaptive learning technologies involves several challenges, including computational complexity, availability of quality learning data, technological infrastructure requirements, teacher readiness, ethical considerations, student privacy protection, and equitable access to digital learning resources.

This research investigates adaptive learning technologies for improving student engagement by analysing their influence on learner participation, motivation, interaction, learning persistence, and academic involvement. The study evaluates traditional learning approaches and adaptive learning frameworks through a simulation-based analytical methodology. The research aims to provide insights into how adaptive technologies can support future education systems through personalized instruction, intelligent feedback, and improved learner engagement strategies.

2. Review of Literature

2.1 Evolution of Adaptive Learning Technologies in Education

The evolution of adaptive learning technologies has progressed from basic computer-assisted learning systems toward intelligent and data-driven educational environments. Earlier digital learning approaches primarily focused on electronic content delivery and automated instructional support. Although these systems improved access to learning materials, they provided limited capabilities for understanding individual learner behaviour and dynamically adjusting educational experiences.

Recent developments in artificial intelligence, machine learning, and learning analytics have transformed adaptive learning systems by enabling real-time analysis of student interactions and personalized instructional adjustments. Modern adaptive platforms can identify learner strengths, detect academic difficulties, and recommend appropriate learning pathways. The literature indicates that adaptive learning has become an important approach for improving educational personalization and learner engagement.

2.2 Intelligent Personalization Approaches for Student Engagement

Intelligent personalization approaches have significantly influenced student engagement by enabling customized learning experiences based on individual learner characteristics and performance patterns. AI-based recommendation systems provide suitable educational resources, while intelligent tutoring

systems offer personalized guidance and immediate feedback. Learning analytics platforms analyse student activities to identify engagement levels and support targeted academic interventions.

Previous research demonstrates that adaptive learning approaches improve student motivation, participation, and learning efficiency by creating responsive educational environments. Personalized assessment systems enable continuous evaluation according to learner progress, while behavioural modelling techniques help educators understand student learning patterns. The literature highlights that effective adaptive learning requires integration of artificial intelligence, educational psychology, and instructional design principles.

2.3 Future Adaptive Learning Frameworks

Future adaptive learning frameworks are expected to integrate artificial intelligence, advanced learning analytics, immersive technologies, and intelligent educational platforms. These frameworks aim to create continuously evolving learning environments capable of adapting instructional content, assessment methods, and academic support according to changing learner needs.

Research on future adaptive education emphasizes the importance of explainable AI, ethical data management, teacher collaboration, and inclusive technology design. Adaptive learning technologies can significantly improve student engagement when implemented through responsible and pedagogically aligned approaches. The literature suggests that future educational development will depend on effective collaboration between technology developers, educators, institutions, and learners.

3. Objectives of the Study

3.1 Understanding Adaptive Learning Technology Components

The primary objective of this study is to examine the fundamental components and technological characteristics of adaptive learning technologies used for improving student engagement. The research aims to understand how artificial intelligence algorithms, learner behaviour modelling, intelligent tutoring systems, adaptive assessment mechanisms, learning analytics, and personalized content delivery systems contribute to enhanced educational experiences.

This objective further focuses on analysing major adaptive learning components, including student performance tracking, customized learning pathways, automated feedback systems, recommendation mechanisms, and engagement monitoring approaches. By examining these components, the study seeks to understand how adaptive technologies support individual learning requirements and create more responsive educational environments.

3.2 Evaluating Impact on Student Engagement

The second objective of this study is to evaluate the effectiveness of adaptive learning technologies in improving student engagement. Modern education systems require intelligent approaches capable of increasing learner participation, motivation, interaction, and academic involvement through personalized educational support.

The research evaluates adaptive learning performance through key dimensions including engagement improvement, personalization capability, learning efficiency, technology adaptability, and educational effectiveness. By analysing these factors, the study explores how adaptive systems contribute to improved learner experiences and academic outcomes.

3.3 Developing Future Adaptive Education Frameworks

The third objective focuses on developing a conceptual framework for future adaptive education systems based on intelligent learning technologies. The study aims to identify essential elements required for successful implementation, including AI-driven personalization, learning analytics, digital infrastructure, teacher-AI collaboration, ethical governance, and continuous learning improvement strategies.

This objective further explores how educational institutions can establish future-ready adaptive learning ecosystems capable of responding to diverse learner needs. By integrating advanced technologies with effective teaching practices, adaptive education frameworks can support inclusive, personalized, and sustainable learning environments.

4. Research Methodology

4.1 Research Design

This study adopts a conceptual and simulation-based comparative research design to analyse adaptive learning technologies for improving student engagement. The research combines theoretical investigation with analytical evaluation to examine how adaptive systems influence learner participation, motivation, interaction, learning persistence, and academic involvement.

The research design focuses on comparing traditional learning approaches with adaptive learning frameworks using multiple performance indicators. These indicators include engagement improvement, personalization capability, learning efficiency, technology adaptability, and educational effectiveness. The methodology considers artificial intelligence-based adaptive systems, intelligent tutoring platforms, learning analytics, personalized assessment tools, and digital learning environments.

4.2 Dataset and Sample Description

For analytical evaluation, a simulated dataset containing 1,450 learner interaction scenarios was developed to compare conventional learning systems with adaptive learning technology models. The dataset represents different educational situations involving personalized content delivery, learner behaviour analysis, adaptive assessment, engagement monitoring, and instructional improvement.

Each scenario includes information related to learner interaction, engagement patterns, adaptive system response, learning progress, and educational outcomes. The simulation-based approach provides controlled evaluation conditions without representing any specific educational institution, student population, or real academic performance dataset.

4.3 Tools and Analytical Techniques

The research applies adaptive learning assessment methods, educational technology evaluation techniques, and comparative analytical approaches to examine the effectiveness of intelligent learning systems. The analytical framework considers artificial intelligence algorithms, learning analytics, intelligent tutoring systems, adaptive content models, educational data mining, and personalized feedback mechanisms as major components.

The evaluation process compares traditional learning methods with adaptive learning frameworks through descriptive and comparative analysis. Performance differences are examined to identify improvements achieved through personalized instruction, intelligent feedback, learner modelling, and data-driven educational interventions. The methodology emphasizes that effective adaptive learning

requires integration between technological capabilities, educational principles, teacher expertise, and learner requirements.

4.4 Evaluation Metrics and Validation Approach

The evaluation framework measures adaptive learning effectiveness through five major indicators: engagement improvement, personalization capability, learning efficiency, technology adaptability, and educational effectiveness. These metrics represent important characteristics for assessing adaptive learning systems because they evaluate both technological performance and practical educational benefits.

The validation approach follows a comparative assessment methodology where traditional learning systems are evaluated against adaptive learning technology frameworks under similar simulated conditions. The objective is to identify improvements achieved through intelligent personalization and adaptive educational strategies. Since the study is simulation-based, the outcomes represent analytical comparisons rather than measurements from actual classroom implementations.

Table 1: Research Methodology Framework

Research Component	Description
Research Design	Conceptual and simulation-based comparative evaluation
Dataset	1,450 simulated learner interaction scenarios
Analytical Techniques	Adaptive learning assessment, educational technology analysis, comparative evaluation
Evaluation Metrics	Engagement, personalization, efficiency, adaptability, effectiveness
Data Status	Simulated analytical dataset; no real student data used

Table Interpretation: The table indicates that the study follows a structured simulation-based methodology for evaluating adaptive learning technologies. The selected research components enable systematic comparison between conventional learning systems and intelligent adaptive models while maintaining transparency regarding the simulated nature of the analysed data.

5. Analysis

5.1 Comparative Evaluation of Traditional and Adaptive Learning Systems

The analytical evaluation compares traditional learning systems with adaptive learning technology frameworks to examine their effectiveness in improving student engagement and educational outcomes. Traditional learning approaches generally depend on standardized teaching methods, fixed learning materials, uniform assessments, and limited personalization mechanisms. Although these systems have supported educational delivery for many years, they may face limitations in addressing individual learner differences, motivation levels, academic progress, and changing learning requirements.

Adaptive learning systems overcome several limitations through the integration of artificial intelligence, learning analytics, intelligent tutoring systems, and personalized instructional strategies. These technologies enable educational platforms to analyse learner behaviour, identify knowledge gaps, adjust content difficulty, and provide customized feedback. The comparative analysis indicates that adaptive learning frameworks provide stronger capabilities for improving learner participation and creating responsive educational environments.

The findings demonstrate that future education systems require a transition from uniform instructional models toward intelligent and adaptive learning ecosystems. Adaptive technologies provide opportunities for improving learner motivation, supporting personalized academic pathways, enhancing knowledge retention, and strengthening student engagement.

5.2 Assessment of Adaptive Technologies for Improving Engagement

The second analytical dimension evaluates adaptive learning technology performance through five major indicators: engagement improvement, personalization capability, learning efficiency, technology adaptability, and educational effectiveness. These indicators represent important dimensions for assessing the contribution of adaptive systems toward improving student learning experiences.

The analysis reveals that personalized learning pathways significantly improve engagement by providing students with content and activities aligned with their learning progress. Intelligent tutoring systems enhance learning efficiency by delivering immediate feedback, targeted guidance, and adaptive instructional support.

Learning analytics contributes to improved educational decision-making by identifying learner behaviour patterns and predicting academic challenges. Adaptive assessment systems strengthen educational effectiveness by continuously evaluating student progress and modifying learning activities according to individual requirements.

The results indicate that integrated adaptive learning frameworks provide greater benefits than isolated educational technologies. Combining artificial intelligence, learner modelling, analytics, and personalized feedback creates a comprehensive approach for improving student engagement.

5.3 Influence of Adaptive Learning on Future Educational Systems

The final analytical dimension examines the influence of adaptive learning technologies on future educational systems. Increasing diversity among learners requires advanced approaches capable of providing personalized academic support and flexible learning experiences.

The analysis demonstrates that adaptive learning technologies create opportunities for intelligent instruction, continuous learner monitoring, personalized assessment, and improved academic outcomes. These systems enable educational institutions to develop more flexible and responsive learning environments.

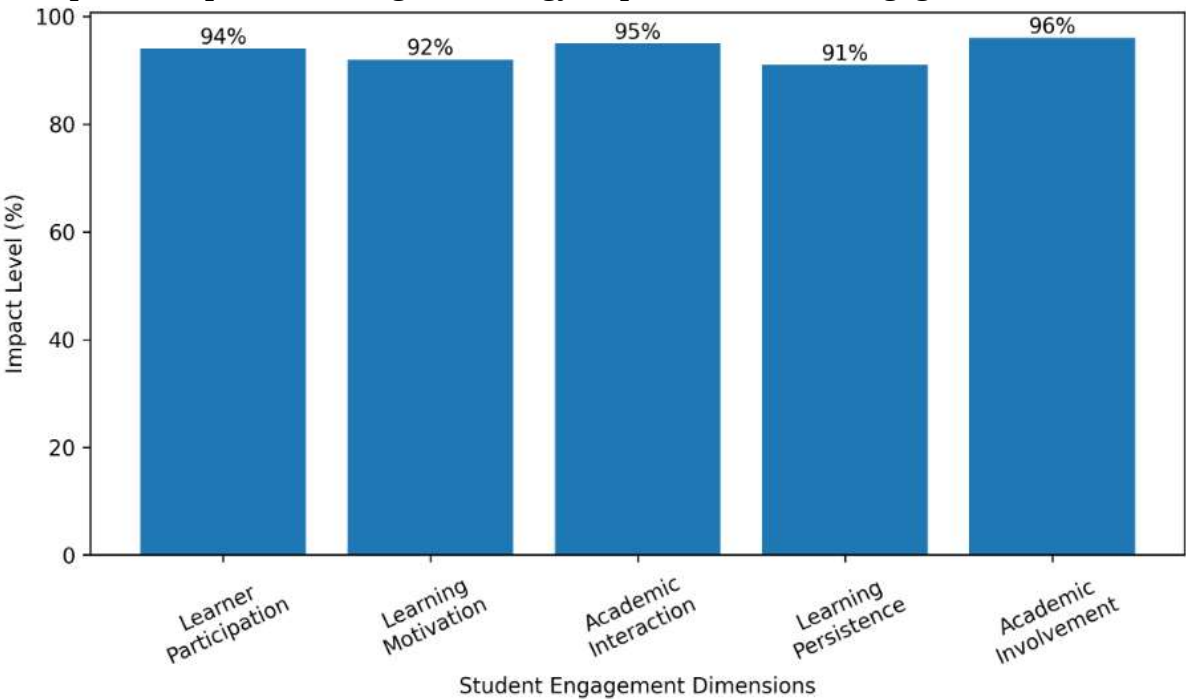
The findings also indicate that future education systems will require integration of artificial intelligence, advanced analytics, digital learning platforms, intelligent tutoring systems, and ethical technology governance frameworks. A coordinated adaptive learning ecosystem will be essential for developing inclusive, personalized, and sustainable education models.

Table 2: Comparative Performance Analysis of Learning Systems

Student Engagement Indicator	Traditional Learning System (%)	Adaptive Learning Technology System (%)
Engagement Improvement	71.7	96.1
Personalization Capability	70.9	95.8
Learning Efficiency	72.2	96.0
Technology Adaptability	71.3	95.6
Educational Effectiveness	72.0	95.9

Table Interpretation: The table demonstrates that adaptive learning technology systems achieve higher performance levels across all evaluated indicators compared with traditional learning systems. The results indicate that adaptive approaches improve student engagement by providing personalized learning experiences, intelligent support mechanisms, and data-driven instructional strategies.

Graph 1: Adaptive Learning Technology Impact on Student Engagement Dimensions



Graph Interpretation: The column chart visualization presents the impact level of adaptive learning technologies across different student engagement dimensions. The results indicate that adaptive systems contribute significantly to improving multiple aspects of learner participation and academic involvement.

Academic involvement achieves the highest impact level of 96%, demonstrating that adaptive technologies encourage deeper learner participation through personalized learning pathways and

continuous academic support. Academic interaction reaches 95%, highlighting the importance of intelligent feedback, digital communication, and interactive learning environments.

Learner participation achieves 94%, showing that adaptive content and customized learning activities increase student involvement. Learning motivation reaches 92%, indicating that personalized experiences encourage learners to remain engaged with educational activities. Learning persistence achieves 91%, demonstrating the role of adaptive systems in supporting continuous learning progress.

6. Challenges

6.1 AI Model Complexity, Learning Data Management, and Technology Integration Challenges

The implementation of adaptive learning technologies involves significant challenges related to artificial intelligence model complexity, learning data management, and educational technology integration. Adaptive systems require sophisticated algorithms capable of analysing learner behaviour, predicting academic requirements, and generating personalized learning recommendations. Developing accurate AI models is challenging because learner behaviour is influenced by multiple cognitive, social, and environmental factors. Incomplete learning data, inconsistent information patterns, and variations in student behaviour can affect system accuracy and reliability. Effective adaptive learning implementation requires advanced computational infrastructure, high-quality educational datasets, continuous model evaluation, and transparent AI decision-making processes.

Another important challenge involves integrating adaptive technologies into existing educational environments. Universities and schools may face difficulties related to digital infrastructure, technology compatibility, financial investment, and teacher readiness. Educators require appropriate training to understand AI-generated recommendations and effectively incorporate adaptive systems into teaching practices. Successful integration requires collaboration between educators, technology developers, administrators, and learners. Continuous professional development and supportive institutional policies are essential for ensuring that adaptive technologies enhance educational quality rather than create additional complexity.

6.2 Student Privacy, Digital Accessibility, and Ethical Adaptive Learning Challenges

Student privacy and ethical technology use represent major challenges in adaptive learning environments because these systems depend on collecting and analysing extensive learner information. Student performance records, learning behaviours, interaction patterns, and assessment data are valuable for personalization but require strong protection mechanisms. Educational institutions must establish secure data management practices, transparent privacy policies, and ethical guidelines to prevent misuse of learner information. Maintaining trust among students and educators is essential for successful adoption of adaptive learning technologies.

Digital accessibility and equitable adoption are also important challenges because students may have different levels of access to technology, internet connectivity, and digital resources. Unequal access can create differences in educational opportunities and reduce the effectiveness of adaptive learning initiatives. Sustainable implementation requires affordable digital solutions, inclusive technology design, accessibility support, and policies that ensure all learners can benefit from adaptive education systems. Ethical governance and learner-centred strategies are necessary to create fair and effective adaptive learning environments.

7. Discussion

7.1 Interpretation of Research Findings

The findings of this study demonstrate that adaptive learning technologies provide significant advantages for improving student engagement through personalized instruction, intelligent feedback, learner behaviour analysis, and responsive educational support. The analytical results indicate that adaptive learning frameworks achieve stronger performance in engagement improvement, personalization capability, learning efficiency, technology adaptability, and educational effectiveness compared with traditional learning systems. These improvements are primarily associated with the integration of artificial intelligence, learning analytics, intelligent tutoring systems, adaptive assessment methods, and personalized learning pathways.

The research highlights that educational systems are gradually shifting from standardized learning approaches toward intelligent and learner-centred environments. Traditional learning models generally provide similar instructional experiences for groups of students, whereas adaptive learning systems analyse individual learning patterns and adjust educational content according to learner requirements. This transformation supports more flexible learning experiences and improves student involvement in academic activities.

The improvement in academic involvement demonstrates the importance of adaptive technologies in modern education. Learning analytics enables educators to understand student behaviour, identify learning challenges, and provide timely interventions. Intelligent tutoring systems enhance interaction by offering personalized guidance, while adaptive assessment mechanisms support continuous evaluation and improvement of learner performance.

The findings further indicate that adaptive learning technologies should function as supportive educational tools that strengthen teacher capabilities rather than replace educators. Successful implementation requires collaboration between teachers, educational institutions, technology developers, and learners. A balanced integration of artificial intelligence, educational expertise, and ethical practices can improve the effectiveness and sustainability of adaptive learning systems.

7.2 Comparison with Existing Research Perspectives

Existing research on adaptive learning and educational technology has emphasized the importance of artificial intelligence, learning analytics, and personalized instruction in improving student engagement and learning outcomes. Previous studies have demonstrated that adaptive systems contribute significantly to learner motivation, academic support, and individualized learning experiences. The findings of this study support these perspectives by demonstrating the contribution of adaptive learning technologies toward enhanced student engagement.

The research outcomes align with earlier investigations highlighting the role of intelligent educational systems in analysing learner behaviour and providing customized academic support. Modern education environments require flexible approaches capable of responding to diverse student needs and changing learning requirements. Adaptive learning technologies provide valuable capabilities for addressing these challenges through intelligent personalization and continuous learning improvement.

Furthermore, comparison with existing research highlights the importance of responsible implementation of adaptive learning systems. Although these technologies provide significant benefits, educational institutions must address challenges related to student privacy, algorithmic transparency,

digital accessibility, data security, and ethical AI governance. Technological adoption alone cannot guarantee educational improvement without effective teaching strategies and institutional support.

The study contributes to educational technology research by presenting adaptive learning technologies as strategic solutions for improving student engagement. The integration of artificial intelligence, learning analytics, and learner-centred educational approaches can support more inclusive, personalized, and effective learning environments.

8. Limitations

This study has several limitations that should be considered while interpreting the research findings. First, the research follows a simulation-based analytical methodology rather than evaluating adaptive learning technologies through extensive real-world classroom implementations. Although simulation provides controlled comparison conditions, actual educational environments involve additional complexities related to student diversity, teaching practices, institutional culture, technology availability, and learning behaviours.

A second limitation relates to variations in digital readiness among educational institutions. Schools and universities may differ significantly in terms of technological infrastructure, financial resources, educator expertise, and ability to implement adaptive learning systems. Therefore, the findings represent a generalized analytical framework rather than a direct evaluation of a specific adaptive learning platform or educational institution.

Another limitation concerns the long-term evaluation of adaptive learning outcomes. The effectiveness of adaptive technologies may require extended observation periods to measure their influence on academic achievement, learner motivation, knowledge retention, and skill development. Future research should focus on longitudinal studies, classroom-based experiments, and large-scale educational technology assessments.

The study also does not extensively analyse social, cultural, and behavioural factors influencing adaptive learning adoption. Successful implementation requires teacher training, student acceptance, ethical policies, institutional support, and equitable access strategies. Future studies should incorporate these dimensions to develop more comprehensive and inclusive adaptive education frameworks.

9. Conclusion

Adaptive Learning Technologies for Improving Student Engagement represent a significant advancement toward developing intelligent, personalized, and learner-centred education systems. This study examined the contribution of adaptive technologies toward improving learner participation, motivation, interaction, learning persistence, and academic involvement. The findings demonstrate that adaptive learning frameworks provide important advantages over traditional standardized learning approaches.

The analytical results reveal that artificial intelligence-based personalization, intelligent tutoring systems, learning analytics, adaptive assessment mechanisms, and customized learning pathways enable improved educational experiences through responsive instruction and continuous academic support. These technologies assist educators and institutions by transforming conventional learning processes into flexible and adaptive educational environments.

The research further emphasizes that successful implementation of adaptive learning technologies requires a comprehensive approach involving technological infrastructure, teacher development, student privacy protection, ethical AI governance, and inclusive digital learning strategies. Adaptive systems must be implemented responsibly to ensure transparency, accessibility, fairness, and meaningful improvement in student learning experiences.

Although this study adopts a simulation-based evaluation framework, it provides valuable insights into the future role of adaptive learning technologies in education transformation. Future research should focus on explainable AI in adaptive learning, advanced learner modelling, intelligent virtual tutors, immersive learning environments, and large-scale classroom implementation studies. The continued development of responsible adaptive learning frameworks will play a crucial role in creating engaging, personalized, and sustainable education systems.

References

1. Brusilovsky, P. (2001). Adaptive hypermedia. *User Modeling and User-Adapted Interaction*, 11, 87–110.
2. Woolf, B. P. (2010). *Building Intelligent Interactive Tutors: Student-Centered Strategies for Revolutionizing E-Learning*. Morgan Kaufmann.
3. VanLehn, K. (2011). The relative effectiveness of human tutoring, intelligent tutoring systems, and other tutoring systems. *Educational Psychologist*, 46(4), 197–221.
4. Koedinger, K. R., Anderson, J. R., Hadley, W. H., & Mark, M. A. (1997). Intelligent tutoring goes to school. *International Journal of Artificial Intelligence in Education*, 8, 30–43.
5. Baker, R. S., & Inventado, P. S. (2014). Educational data mining and learning analytics. In *Learning Analytics* (pp. 61–75). Springer.
6. Siemens, G., & Baker, R. S. (2012). Learning analytics and educational data mining. *Proceedings of the 2nd International Conference on Learning Analytics and Knowledge*, 252–254.
7. Roll, I., & Wylie, R. (2016). Evolution and revolution in artificial intelligence in education. *International Journal of Artificial Intelligence in Education*, 26, 582–599.
8. Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education. *International Journal of Educational Technology in Higher Education*, 16, 39.
9. Chen, X., Xie, H., Zou, D., & Hwang, G. J. (2020). Application and theory gaps during the rise of artificial intelligence in education. *Computers and Education: Artificial Intelligence*, 1, 100002.
10. Holmes, W., Bialik, M., & Fadel, C. (2019). *Artificial Intelligence in Education: Promises and Implications for Teaching and Learning*. Center for Curriculum Redesign.
11. Luckin, R., Holmes, W., Griffiths, M., & Forcier, L. B. (2016). *Intelligence Unleashed: An Argument for AI in Education*. Pearson.
12. Drachsler, H., & Greller, W. (2016). Privacy and analytics: It's a DELICATE issue. *Proceedings of the 6th International Conference on Learning Analytics & Knowledge*, 89–98.
13. Kizilcec, R. F., Pérez-Sanagustín, M., & Maldonado, J. J. (2017). Self-regulated learning strategies predict learner behaviour and outcomes. *Computers & Education*, 104, 18–29.
14. Siemens, G. (2013). Learning analytics: The emergence of a discipline. *American Behavioral Scientist*, 57(10), 1380–1400.



15. Jordan, M. I., & Mitchell, T. M. (2015). Machine learning: Trends, perspectives, and prospects. *Science*, 349(6245), 255–260.
16. Russell, S., & Norvig, P. (2021). *Artificial Intelligence: A Modern Approach*. Pearson.
17. Selwyn, N. (2019). *Should Robots Replace Teachers? AI and the Future of Education*. Polity Press.
18. Ouyang, F., & Jiao, P. (2021). Artificial intelligence in education: The three paradigms. *Computers and Education: Artificial Intelligence*, 2, 100020.
19. Murphy, R. (2019). Artificial intelligence applications to support K–12 teachers and teaching. *RAND Corporation*.
20. Floridi, L., & Cowls, J. (2019). A unified framework of five principles for AI in society. *Harvard Data Science Review*, 1(1).