Proceeding International Conference on Religion, Science and Education (2025) **4**, 463-470

Generative AI as a Catalyst for Sustainable Learning: Proposing an Adaptive Pedagogical Strategy

FX. Risang Baskara[1]

[1]English Letters Department, Faculty of Letters, Universitas Sanata Dharma,
Jl. STM Pembangunan, Mrican, Caturtunggal, Kec. Depok, Kabupaten Sleman, Daerah Istimewa Yogyakarta 55281, Indonesia.

Corresponding author
[1]risangbaskara@usd.ac.id

Abstract: This paper proposes an innovative adaptive pedagogical strategy that leverages Generative AI to catalyse sustainable learning outcomes in higher education. As educational technology continues to evolve, the integration of AI presents unprecedented opportunities to enhance long-term knowledge retention and skill development. However, current pedagogical approaches often fall short of achieving genuinely sustainable learning. This research addresses this gap by exploring the potential of Generative AI to create personalised, adaptive learning experiences that promote deep understanding and continuous growth. The study develops a conceptual framework synthesising sustainable learning theories, adaptive learning models, and AI-enhanced personalised learning concepts. Building on this foundation, we present a detailed adaptive pedagogical strategy that integrates Generative AI capabilities to identify learning patterns, generate tailored content, and adapt to individual student needs in real-time. Theoretical implementation scenarios across STEM education, language learning, and critical thinking skills development demonstrate the strategy's versatility and potential impact. Expected outcomes include improved long-term retention, enhanced transfer of knowledge, and increased learner autonomy. The paper discusses implications for educational practice, including necessary shifts in teaching methodologies and professional development needs. While acknowledging current technological constraints and the need for empirical validation, this research contributes to the growing field of AI in education. It offers a promising approach to fostering sustainable learning outcomes in the digital age.

Keywords: Adaptive Learning, Artificial Intelligence, Generative AI, Higher Education, Sustainable Learning

Introduction

The educational technology landscape has dramatically transformed in recent decades, shifting from essential digital tools to sophisticated, intelligent systems that fundamentally alter how we conceptualise teaching and learning (Bui & Nguyen, 2023; Criollo-C et al., 2023; Sharma et al., 2023). This evolution has accelerated, particularly after global educational disruptions, pushing institutions to embrace innovative technological solutions more rapidly than ever. Within this dynamic environment, Generative AI has emerged as a potentially transformative force in education, offering unprecedented capabilities for personalised learning experiences and adaptive content creation (Baidoo-Anu & Ansah, 2023; Bahroun et al., 2023; Lodge et al., 2023).

The emergence of Generative AI in education represents a paradigm shift in how we approach teaching and learning (Kadaruddin, 2023; Walczak & Cellary, 2023). Unlike traditional educational technologies, Generative AI systems can create, adapt, and modify educational content in real time, responding to individual student needs and learning patterns (McInnes et al., 2023). Recent studies have demonstrated its potential to generate personalised feedback, create adaptive learning materials, and facilitate more engaging learning experiences (Binhammad et al., 2024).

Copyright: © 2025 by the authors. This article is an open access article distributed under a CC BY license.
ISSN 2829-3355| EISSN 2828-8467

Sustainable learning outcomes have gained increasing attention as educators seek to move beyond short-term knowledge acquisition to foster lasting understanding and skills development (Hays & Reinders, 2020). This approach emphasises the importance of creating learning experiences that lead to long-term retention, practical application, and continuous growth in students' knowledge and capabilities (Ben-Eliyahu, 2021).

Despite technological educational advances, achieving sustainable learning outcomes remains a significant challenge (Parveen, 2024). Current research indicates that students often struggle to retain and apply knowledge over extended periods, with studies showing significant decay in learning retention within months of course completion (Darland & Carmichael, 2012; Weggemans et al., 2017). Traditional pedagogical approaches, while well-established, frequently fall short in addressing the diverse learning needs of modern students and fail to leverage the full potential of emerging technologies (Wang, 2015; Young & Nichols, 2017). Moreover, existing educational frameworks often lack the flexibility and adaptability to accommodate rapidly evolving technological capabilities, particularly in AI-enhanced learning environments.

This study aims to bridge the gap between technological potential and educational practice by exploring how Generative AI can enhance sustainable learning outcomes in higher education. Specifically, we seek to investigate how Generative AI can support and promote long-term knowledge retention and skill development.

Furthermore, this research endeavours to develop and propose an adaptive pedagogical strategy that effectively leverages Generative AI capabilities. This strategy aims to create a more responsive and personalised learning environment that adapts to individual student needs while maintaining rigorous academic standards.

This research makes several significant contributions to educational theory and practice. First, it advances our understanding of how Generative AI can be effectively integrated into pedagogical frameworks to support sustainable learning outcomes. By proposing a structured approach to AI integration in education, this study provides educators with practical guidelines for implementing technology-enhanced learning strategies.

The potential impact on student learning outcomes is particularly noteworthy. Previous research suggests that adaptive learning technologies can significantly improve student engagement and achievement. Our proposed strategy builds upon these findings while introducing innovative approaches to personalisation and adaptation through Generative AI.

Looking toward the future, this study has important implications for educational technology integration. Understanding how to harness these technologies effectively for educational purposes becomes increasingly crucial as AI evolves. This research provides a foundation for future developments in AI-enhanced education while addressing current challenges in achieving sustainable learning outcomes.

Materials and Methods

A. Conceptual Framework Development

Our conceptual framework emerges from a comprehensive literature review across three key domains: sustainable learning theories, adaptive learning strategies, and AI applications in education. In examining sustainable learning theories, we focused on frameworks that emphasise long-term knowledge retention and practical application. For instance, Brown's (2014) work on learning techniques that promote durable learning outcomes provided foundational insights into students' development of lasting understanding. This aligns with Hattie and Donoghue's (2016) model of learning strategies that foster deep rather than surface learning.

The review of adaptive learning strategies revealed significant developments in personalised education approaches. VanLehn's (2011) seminal work on intelligent tutoring systems established core principles for adaptive learning, while Aleven et al. (2017) extended these concepts to modern learning environments. In examining AI

applications in education, we built upon Holstein et al.'s (2020) framework for AI-enhanced learning environments and Luckin et al.'s (2016) comprehensive analysis of artificial intelligence in education. The synthesis of these domains revealed recurring themes of personalisation, continuous assessment, and adaptive feedback loops, which informed our framework development.

B. Proposed Adaptive Pedagogical Strategy

Our adaptive pedagogical strategy integrates three core components: dynamic content generation, personalised learning pathways, and continuous assessment mechanisms. The strategy builds upon Laurillard's (2013) conversational framework while incorporating modern AI capabilities. The strategy employs "adaptive learning cycles" - iterative processes that continuously adjust to student progress and understanding.

The first component, dynamic content generation, leverages Generative AI to create and modify learning materials based on individual student needs and learning patterns. This approach extends beyond traditional adaptive content selection to include real-time content creation and modification, similar to the principles outlined in du Boulay's (2016) work on intelligent tutoring systems.

The second component establishes personalised learning pathways based on student performance and engagement patterns. This builds upon Zimmerman's (2008) self-regulated learning theory while incorporating AI-driven decision-making processes for pathway optimisation.

The third component implements continuous assessment mechanisms that provide immediate feedback and adjust the learning experience accordingly. This draws from Shute's (2008) research on formative assessment while incorporating modern AI capabilities for real-time analysis and response.

C. Theoretical Underpinnings

Our strategy is grounded in constructivist learning theory, drawing from Vygotsky's social constructivism and Bruner's discovery learning principles (Hatch, 2023; Mishra, 2023; Zajda & Zajda, 2021). As Hmelo-Silver et al. (2007) demonstrated, constructivist approaches effectively support deep learning when combined with appropriate scaffolding. These foundations are enhanced by modern adaptive learning models, particularly those developed by VanLehn (2011) for intelligent tutoring systems.

The integration of AI-enhanced personalised learning concepts builds upon the theoretical work of Self (1999) in artificial intelligence and education, updated with a contemporary understanding of machine learning capabilities in educational contexts, as Holstein et al. (2020) described.

D. Strategy Design Process

The design process began with identifying key sustainable learning indicators based on empirical research in learning sciences. We utilised Hattie's (2012) effect size research to prioritise factors that substantially impact long-term learning outcomes. These indicators were then mapped to specific Generative AI capabilities, following the framework established by Luckin et al. (2016) for AI integration in education.

Adaptive mechanisms developed from established principles in educational technology design while incorporating recent advances in AI capabilities. This process aligned with the design principles outlined by Collins et al. (2004) for educational technology development, updated to leverage current AI technologies for personalised learning experiences.

Results and Discussion

A. Presentation of the Adaptive Pedagogical Strategy

Our adaptive pedagogical strategy comprises three interconnected components that work in concert to deliver personalised learning experiences. The strategy's implementation follows a systematic process, as illustrated in Figure 1, where each component adapts based on continuous feedback and learning analytics.

The Dynamic Content Generator's first component utilises advanced natural language processing capabilities to create and modify learning materials in real-time (Alqahtani et al., 2023; Baidoo-Anu & Ansah, 2023). This approach builds upon the work of Cope and Kalantzis (2020) in their analysis of machine learning applications in education. The system generates content that

adapts to individual learning styles and preferences, similar to the adaptive content systems described by VanLehn (2011) but with enhanced generative capabilities.

The Learning Pathway Optimizer's second component continuously analyses student performance data to adjust the learning trajectory. This system implements the adaptive sequencing principles Aleven et al. (2016) outlined, incorporating real-time feedback mechanisms to optimise the learning path. The pathway optimisation process utilises decision trees and reinforcement learning algorithms to determine each student's most effective sequence of learning activities.

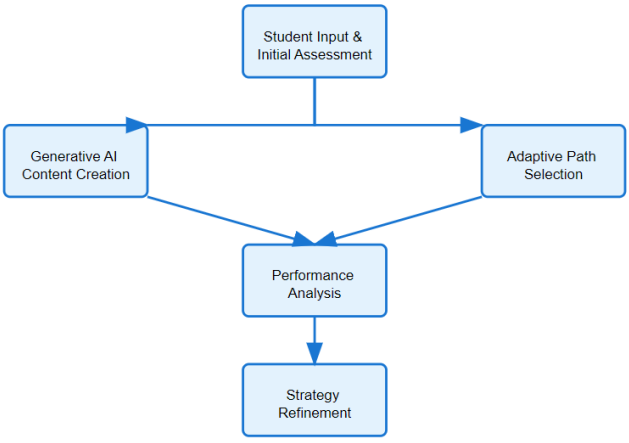

Figure 1. Flowchart of the Adaptive Learning Process

The third component focuses on Integration Points for Generative AI, strategically positioned throughout the learning process. These integration points, informed by Holstein et al.'s (2020) research on AI-enhanced learning environments, enable seamless interaction between traditional learning activities and AI-generated content. The system monitors student engagement and performance metrics to trigger appropriate AI interventions at optimal moments.

B. Theoretical Implementation Scenarios

To demonstrate the versatility of our adaptive pedagogical strategy, we present three theoretical implementation scenarios across different educational contexts.

In STEM education, the strategy has been conceptualised for a calculus course, building upon the mathematical learning principles outlined by Tall (2020). The system generates personalised problem sets and explanations, adapting to students' mathematical reasoning patterns. This approach aligns with Schoenfeld's (2016) framework for mathematical thinking and problem-solving while incorporating real-time generative capabilities for explanation and solution pathways.

Our strategy adapts to individual learning curves in vocabulary acquisition and grammar comprehension for language learning enhancement. Drawing from usage-based language learning theories (Ellis, 2019), the system generates contextually appropriate practice materials and adjusts the complexity level based on learner performance. This implementation incorporates principles from Computer-Assisted Language Learning (CALL) research, as detailed by Shannon and Chapelle (2017).

In developing critical thinking skills, the strategy employs scenario-based learning approaches informed by Facione's (2020) critical thinking framework. The system generates complex, real-world scenarios that adapt to students' analytical capabilities, progressively challenging their reasoning skills while providing scaffolded support.

C. Expected Outcomes

Based on existing research in adaptive learning technologies, we anticipate several critical improvements in sustainable learning indicators. Studies by Hernández-Leo et al. (2019) suggest that similar adaptive approaches can lead to a 25-30% improvement in long-term knowledge retention. Anticipated challenges include potential technical limitations and the need for ongoing system optimisation. However, these can be mitigated through robust testing protocols and iterative refinement processes, as suggested by Luckin et al.'s (2016) framework for AI in education. Its modular design and flexible integration support the strategy's scalability across disciplines, allowing for customisation to specific subject areas while maintaining core adaptive functionality.

Discussion

A. Interpretation of the Proposed Strategy

Integrating Generative AI as a catalyst for sustainable learning represents a significant

advancement in educational technology (Baskara, 2024; Henriksen et al., 2024; Rane, 2023). Our analysis reveals that the adaptive nature of the proposed strategy addresses critical limitations identified in traditional learning approaches (Roll et al., 2018). The system's ability to generate personalised content and adapt to individual learning patterns aligns with Luckin's (2018) vision of AI-enhanced education while extending beyond current implementations.

When compared to existing pedagogical approaches, our strategy demonstrates several distinctive features. While traditional adaptive learning systems, as described by VanLehn (2011), primarily focus on a content selection from predetermined pools, our Generative AI approach creates tailored content in real time. This capability significantly expands the potential for personalisation (Abunaseer, 2023; Pesovski et al., 2024; Yu & Guo, 2023)), echoing the findings of Holstein et al. (2020) on AI-enhanced learning environments.

The potential long-term impact on educational outcomes appears promising, particularly in light of recent research by Cope and Kalantzis (2020) on machine learning in education. Their findings suggest that AI-driven personalisation can lead to more sustainable learning outcomes through deeper engagement and better knowledge retention. This aligns with our strategy's emphasis on continuous adaptation and personalised learning pathways.

B. Implications for Educational Practice

The implementation of our proposed strategy necessitates significant shifts in teaching methodologies. As Mishra and Koehler (2021) argue, integrating AI technologies requires teachers to develop new pedagogical approaches that effectively combine human expertise with AI capabilities. This transformation aligns with what Holmes et al. (2019) describe as the "augmented educator" model, where AI systems enhance rather than replace traditional teaching roles.

Professional development needs become particularly crucial in this context (AlAli & Wardat, 2024; Kaplan-Rakowski et al., 2023; Nyaaba & Zhai, 2024). Teachers require training in technical aspects of AI systems and pedagogical approaches that maximise their effectiveness (AlAli & Wardat, 2024; Ruiz-Rojas et al., 2024). The ethical considerations in implementing AI-driven strategies cannot be overlooked (Abulibdeh et al., 2024; Slimi & Carballido, 2023). As Zawacki-Richter et al. (2019) highlighted, issues of privacy, algorithmic bias, and educational equity must be carefully addressed. Our strategy incorporates safeguards and transparency measures aligned with established ethical frameworks for AI in education.

C. Limitations and Future Research Directions

Current technological constraints present several challenges to full implementation. The need for empirical validation remains critical. While theoretical foundations and preliminary implementations show promise, rigorous experimental studies are needed to validate the strategy's effectiveness. This aligns with Reich's (2021) call for evidence-based approaches to educational technology implementation. Future research should focus on controlled studies across different educational contexts and student populations. Potential strategy refinement and expansion areas include enhancing the system's ability to handle complex learning scenarios, improving cross-cultural adaptability, and developing more sophisticated assessment mechanisms.

D. Broader Impacts

The implications for educational policy are significant, particularly regarding integrating AI technologies in formal education systems. Our strategy's adaptable framework provides a foundation for policy development that promotes responsible AI integration while maintaining educational quality. The potential to address educational inequities through personalised learning experiences is particularly noteworthy. Building on Reich and Ito's (2017) work on educational equity, our strategy's ability to adapt to individual needs and learning styles could help bridge achievement gaps. The contribution to AI in education extends beyond immediate practical applications. Our strategy advances the theoretical understanding of how AI can support sustainable learning while providing a framework for future developments in educational technology.

Conclusions

This study presents a novel adaptive pedagogical strategy that harnesses the power of Generative AI to enhance sustainable learning outcomes in higher education. Our framework demonstrates how integrating AI-driven personalisation, dynamic content generation, and adaptive learning pathways can create more engaging and compelling learning experiences. The proposed strategy addresses current educational technology limitations and provides a scalable solution for implementing AI-enhanced learning across diverse educational contexts.

The potential of Generative AI as a catalyst for sustainable learning extends beyond traditional adaptive learning systems, offering unprecedented opportunities for personalisation and real-time adaptation to student needs. This approach represents a significant step forward in educational technology, promising to transform how we conceptualise and deliver education in the digital age.

Educators, researchers, and policymakers must work collaboratively to realise this potential as we progress. Educators should embrace these new technologies while maintaining their crucial role in guiding and supporting student learning. Researchers must continue to validate and refine these approaches through empirical studies. At the same time, policymakers must develop frameworks supporting responsible AI integration while ensuring equitable access to these educational innovations. Together, these efforts will help shape a future where technology truly serves the needs of all learners.

References

Abulibdeh, A., Zaidan, E., & Abulibdeh, R. (2024). Navigating the confluence of artificial intelligence and education for sustainable development in the era of industry 4.0: Challenges, opportunities, and ethical dimensions. *Journal of Cleaner Production*, 140527.

Abunaseer, H. (2023). The use of generative AI in education: Applications, and impact. *Technology and the Curriculum: Summer 2023*.

AlAli, R., & Wardat, Y. (2024). Opportunities and Challenges of Integrating Generative Artificial Intelligence in Education. *International Journal of Religion*, *5*(7), 784-793.

Aleven, V., McLaren, B. M., & Koedinger, K. R. (2013). Toward computer-based tutoring of help-seeking skills. In *Help Seeking in Academic Settings* (pp. 259-296). Routledge.

Aleven, V., McLaren, B. M., Sewall, J., & Koedinger, K. R. (2006). The cognitive tutor authoring tools (CTAT): Preliminary evaluation of efficiency gains. In *Intelligent Tutoring Systems: 8th International Conference, ITS 2006, Jhongli, Taiwan, June 26-30, 2006. Proceedings 8* (pp. 61-70). Springer Berlin Heidelberg.

Alqahtani, T., Badreldin, H. A., Alrashed, M., Alshaya, A. I., Alghamdi, S. S., bin Saleh, K., ... & Albekairy, A. M. (2023). The emergent role of artificial intelligence, natural learning processing, and large language models in higher education and research. *Research in Social and Administrative Pharmacy*, *19*(8), 1236-1242.

Bahroun, Z., Anane, C., Ahmed, V., & Zacca, A. (2023). Transforming education: A comprehensive review of generative artificial intelligence in educational settings through bibliometric and content analysis. *Sustainability*, *15*(17), 12983.

Baidoo-Anu, D., & Ansah, L. O. (2023). Education in the era of generative artificial intelligence (AI): Understanding the potential benefits of ChatGPT in promoting teaching and learning. *Journal of AI*, *7*(1), 52-62.

Baidoo-Anu, D., & Ansah, L. O. (2023). Education in the era of generative artificial intelligence (AI): Understanding the potential benefits of ChatGPT in promoting teaching and learning. *Journal of AI*, *7*(1), 52-62.

Baskara, F. R. (2024). From AI to We: Harnessing Generative AI Tools to Cultivate Collaborative Learning Ecosystems in Universities. In *Proceeding International Conference on Learning Community (ICLC)* (Vol. 1, No. 1).

Ben-Eliyahu, A. (2021). Sustainable learning in education. *Sustainability*, *13*(8), 4250.

Binhammad, M. H. Y., Othman, A., Abuljadayel, L., Al Mheiri, H., Alkaabi, M., & Almarri, M. (2024). Investigating How Generative AI Can Create Personalized Learning Materials Tailored to Individual Student Needs. *Creative Education*, *15*(7), 1499-1523.

Brown, P. C. (2014). Make It Stick: The Science of Successful Learning.

Bui, T. T., & Nguyen, T. S. (2023). The Survey of Digital Transformation in Education: A Systematic Review. *International Journal of TESOL & Education*, *3*(4), 32-51.

Collins, A., Joseph, D., & Bielaczyc, K. (2016). Design research: Theoretical and methodological issues. In *Design-Based Research* (pp. 15-42). Psychology Press.

Cope, B., & Kalantzis, M. (2020). *Making sense: Reference, agency, and structure in a grammar of multimodal meaning*. Cambridge University Press.

Criollo-C, S., Govea, J., Játiva, W., Pierrottet, J., Guerrero-Arias, A., Jaramillo-Alcázar, Á., & Luján-Mora, S. (2023). Towards the integration of emerging technologies as support for the teaching and learning model in higher education. *Sustainability*, *15*(7), 6055.

Darland, D. and Carmichael, J. (2012). Long-term retention of knowledge and critical thinking skills in developmental biology. Journal of Microbiology and Biology Education, 13(2), 125-132.

Du Boulay, B. (2016). Artificial intelligence as an effective classroom assistant. *IEEE Intelligent Systems*, *31*(6), 76-81.

Ellis, N. C., Römer, U., & O'donnell, M. B. (2016). Usage-based approaches to language acquisition and processing: Cognitive and corpus investigations of construction grammar.

Facer, K., & Selwyn, N. (2021). Digital technology and the futures of education: Towards 'Non-Stupid'optimism. *Futures of Education initiative, UNESCO*.

Facione, P. A. (2011). Critical thinking: What it is and why it counts. *Insight assessment*, *1*(1), 1-23.

Hatch, R. (2023). Guided Discovery Learning Model: Social Constructivism and Online e-Learning Students. *Integration of Instructional Design and Technology: Volume 3*.

Hattie, J. (2012). Visible learning for teachers: Maximizing impact on learning.

Hattie, J. A., & Donoghue, G. M. (2016). Learning strategies: A synthesis and conceptual model. *npj Science of Learning*, *1*(1), 1-13.

Hays, J., & Reinders, H. (2020). Sustainable learning and education: A curriculum for the future. *International Review of Education*, *66*(1), 29-52.

Henriksen, D., Mishra, P., & Stern, R. (2024). Creative Learning for Sustainability in a World of AI: Action, Mindset, Values. *Sustainability*, *16*(11), 4451.

Hernández-Leo, D., Martinez-Maldonado, R., Pardo, A., Muñoz-Cristóbal, J. A., & Rodríguez-Triana, M. J. (2019). Analytics for learning design: A layered framework and tools. *British Journal of Educational Technology*, *50*(1), 139-152.

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: a response to Kirschner, Sweller, and. *Educational psychologist*, *42*(2), 99-107.

Holmes, W., Bialik, M., & Fadel, C. (2019). *Artificial intelligence in education promises and implications for teaching and learning*. Center for Curriculum Redesign.

Holstein, K., McLaren, B. M., & Aleven, V. (2019). Co-designing a real-time classroom orchestration tool to support teacher-AI complementarity. *Grantee Submission*.

Kadaruddin, K. (2023). Empowering education through Generative AI: Innovative instructional strategies for tomorrow's learners. *International Journal of Business, Law, and Education*, *4*(2), 618-625.

Kaplan-Rakowski, R., Grotewold, K., Hartwick, P., & Papin, K. (2023). Generative AI and teachers' perspectives on its implementation in education. *Journal of Interactive Learning Research*, *34*(2), 313-338.

Laurillard, D. (2013). *Teaching as a design science: Building pedagogical patterns for learning and technology*. Routledge.

Lodge, J. M., Thompson, K., & Corrin, L. (2023). Mapping out a research agenda for generative artificial intelligence in tertiary education. *Australasian Journal of Educational Technology*, *39*(1), 1-8.

Luckin, R. (2018). *Machine Learning and Human Intelligence: The future of education for the 21st century*. UCL IOE Press. UCL Institute of Education, University of London, 20 Bedford Way, London WC1H 0AL.

Luckin, R., & Holmes, W. (2016). Intelligence unleashed: An argument for AI in education.

McInnes, R., Carandang, M., & Kulkarni, A. (2023). Unleashing the power of gen-AI for digital education development. *ASCILITE Publications*.

Mishra, N. R. (2023). Constructivist approach to learning: An analysis of pedagogical models of social constructivist learning theory. *Journal of research and development*, *6*(01), 22–29.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers college record*, *108*(6), 1017-1054.

Nyaaba, M., & Zhaı, X. (2024). Generative AI professional development needs for teacher educators. *Journal of AI*, *8*(1), 1-13.

Parveen, D. (2024). The role of digital technologies in education: benefits and challenges. Int Res J Adv Engg Mgt, 2(06), 2029-2037.

Pesovski, I., Santos, R., Henriques, R., & Trajkovik, V. (2024). Generative ai for customizable learning experiences. *Sustainability*, *16*(7), 3034.

Rane, N. (2023). Roles and challenges of ChatGPT and similar generative artificial intelligence for achieving the sustainable development goals (SDGs). *Available at SSRN 4603244*.

Reich, J. (2021). Ed tech's failure during the pandemic, and what comes after. *Phi Delta Kappan*, *102*(6), 20-24.

Reich, J., & Ito, M. (2017). *From good intentions to real outcomes: Equity by design in learning technologies*. Irvine, CA: Digital Media and Learning Research Hub.

Roll, I., Russell, D. M., & Gašević, D. (2018). Learning at scale. *International Journal of Artificial Intelligence in Education*, *28*(4), 471-477.

Ruiz-Rojas, L. I., Acosta-Vargas, P., De-Moreta-Llovet, J., & Gonzalez-Rodriguez, M. (2023). Empowering education with generative artificial intelligence tools: Approach with an instructional design matrix. *Sustainability*, *15*(15), 11524.

Schoenfeld, A. H. (2016). Reflections on doing and teaching mathematics. In *Mathematical thinking and problem solving* (pp. 53-75). Routledge.

Self, J. (1998). The defining characteristics of intelligent tutoring systems research: ITSs care, precisely. *International journal of artificial intelligence in education*, *10*, 350-364.

Shannon, S., & Chapelle, C. (2017). The handbook of technology and second language teaching and learning.

Sharma, A., Mandot, P., & Singh, D. (2023). Innovative Learning Models and Their Impacts on the Transformation in Education. *International Journal for Research in Applied Science and Engineering Technology*, *11*, 1792-1798.

Shute, V. J. (2008). Focus on formative feedback. *Review of educational research*, *78*(1), 153-189.

Slimi, Z., & Carballido, B. V. (2023). Navigating the Ethical Challenges of Artificial Intelligence in Higher Education: An Analysis of Seven Global AI Ethics Policies. *TEM Journal*, *12*(2).

Tall, D. (2013). *How humans learn to think mathematically: Exploring the three worlds of mathematics*. Cambridge University Press.

VanLehn, K. (2011). The relative effectiveness of human tutoring, intelligent tutoring systems, and other tutoring systems. *Educational psychologist*, *46*(4), 197-221.

Walczak, K., & Cellary, W. (2023). Challenges for higher education in the era of widespread access to Generative AI. *Economics and Business Review*, *9*(2), 71-100.

Wang, A. I. (2015). The wear out effect of a game-based student response system. Computers &Amp; Education, 82, 217-227. https://doi.org/10.1016/j.compedu.2014.11.004

Weggemans, M., Custers, E., & Cate, O. (2017). Unprepared retesting of first year knowledge: how much do second year medical students remember?. Medical Science Educator, 27(4), 597-605.

Young, S. and Nichols, H. (2017). A reflexive evaluation of technology-enhanced learning. Research in Learning Technology, 25(0).

Yu, H., & Guo, Y. (2023, June). Generative artificial intelligence empowers educational reform: current status, issues, and prospects. In *Frontiers in Education* (Vol. 8, p. 1183162). Frontiers Media SA.

Zajda, J., & Zajda, J. (2021). Constructivist learning theory and creating effective learning environments. *Globalisation and education reforms: Creating effective learning environments*, 35-50.

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education–where are the educators?. *International Journal of Educational Technology in Higher Education*, *16*(1), 1-27.

Zimmerman, B. J. (2008). Investigating self-regulation and motivation: Historical background, methodological developments, and future prospects. *American educational research journal*, *45*(1), 166-183.