

HOW AI PERSONALIZES EDUCATION TO ACHIEVE SUSTAINABLE DEVELOPMENT GOALS

Dang Thi Thu Hang¹, Dinh Ngoc Long²

¹ Department of Economics & Finance, Ho Chi Minh University of Foreign Languages – Information Technologies

² School of Business, International University – Vietnam National University Ho Chi Minh City

hangdtt@huflit.edu.vn, dnlong@hcmiu.edu.vn

ABSTRACT— This study explores how Artificial Intelligence (AI) supports personalized education and advances Sustainable Development Goals (SDGs), especially SDG4 on inclusive, quality learning. Through literature review, policy insights, and distinguished cases such as Duolingo and Squirrel AI, it highlights how adaptive algorithms, natural language processing, and generative AI improve engagement, retention, and accessibility. AI-driven platforms directly promote SDG4.7 and indirectly support SDG5, SDG8, and SDG10. This study advocates hybrid human-AI models, ethical governance, infrastructure investment, and local adaptation to maximize benefits, positioning AI as a transformative enabler for sustainable, equitable education globally.

Keywords— Artificial Intelligence (AI), adaptive learning, sustainable development

I. INTRODUCTION

In recent years, Artificial Intelligence (AI) emerged as a transformative force within global education systems, offering the potential perspective to enhance, quality and inclusivity for society as well as many generations. Recent studies have explored the huge contributions that AI bring, and spread in various industries including automobiles, hospitals, education, banking industry, customer services, etc. ([19]; [11]; [2]; [3]). Meanwhile, in accordance with Sustainable Development Goal 4 (SDG4), this issue states that inclusive and quality education are among the most prevalent globally which suitable for new educational era.

Additionally, education has been playing crucial role and acts as a main key to developing any society. It has undergone through technological progress, climate change as well as global warming [1]. Since we entered the post – COVID 19, adaptive learning and Artificial Intelligence (AI) have brought many significant advantages for users and society, shedding a crucial light in educational evolution ([23]; [22]). Recognizing this huge revolution, many scholars argue that generative AI and adaptive learning platforms will provide the most powerful tools to supercharge SDGs that include education, gender equality and social inclusion ([24]; [16]).

At the cornerstone of this potential lies personalized learning, enabled by Artificial Intelligence, that adapts content, pace and feedback to each learner's strengths as well as progress in real time. Specifically, adaptive learning research in educational settings has revealed positive outcomes in studies, with measurable improvements in engagement and understanding ([12]; [21]). Various platforms such as Duolingo, Dream Box Learning, Knewton Alta, etc exemplify this transition. By leveraging the proprietary Birdbrain AI engine alongside generative technologies such as GPT4, Duolingo represents as the dynamic crafts lessons, error specific feedback, pronunciation analysis, and repeat prompts that adjusts to personalization users' proficiency and retention patterns [9]. In accordance with [24], Duolingo's AI first strategy, scaling from a few million users to over 100 million active users by early 2025, this issue reflects a broader ambition to democratize learning thorough algorithm driven personalization.

Despite the growing body of research on AI applications and personalized learning, there remains a limited understanding of how these technologies specifically contribute to the achievement of sustainable education goals, particularly within the framework of SDG 4. Existing studies often focus on technological effectiveness or learning outcomes in isolation, rather than examining the intersection between AI-driven personalization and sustainable development in education. This gap highlights the need for further investigation into how AI-enabled personalized learning can support inclusive, equitable, and sustainable educational practices.

Therefore, this qualitative study aims to explore the role of Artificial Intelligence in enabling personalized learning and its contribution to sustainable education. Specifically, the study seeks to address the following research questions:

- How does Artificial Intelligence enable personalized learning?
- In what ways does it contribute to the achievement of Sustainable Development Goals in education?

II. THEORETICAL FRAMEWORK

A. CONSTRUCTIVIST LEARNING THEORY

Constructivism can be understood as a learning theory that emphasizes how individuals actively build their own understanding. Rather than simply absorbing information, learners develop meaning by connecting new ideas with what they already know and believe. In this sense, knowledge emerges through an ongoing interaction between prior experience and new concepts [20]. This perspective also reshapes the role of the teacher. Unlike behaviourist approaches that prioritize teacher led instruction, constructivism promotes a student centred environment. Here, the teacher acts more as a facilitator, guiding learners as they explore ideas, engage with content, and make sense of their experiences. The aim is to support students in becoming active participants in their own learning, helping them link existing knowledge with new insights in meaningful ways [11].

Generally, constructivism rests on the idea that learning is constructed by the learner. New knowledge does not appear in isolation; instead, it is built upon what the learner has already acquired [4]. Two key principles underpin this view. First off, learners rely on their prior knowledge as a foundation for developing new understanding. Even before formal schooling, individuals accumulate experiences and ideas that shape how they interpret new information. As they encounter new learning situations, they revise and expand their existing knowledge structures [22]. Secondly, learning is inherently active rather than passive. Learners do not simply receive information; they engage with it, reflect on it, and evaluate it in relation to what they already know. Throughout this process, they remain involved applying current understandings, identifying important elements in new experiences, and assessing how well new information aligns with prior knowledge. Based on this evaluation, learners adjust and refine their understanding, continuously reconstructing their knowledge over time [18].

B. PERSONALIZED EDUCATION

Personalized education refers to adjusting instructional content, delivery pace, and learning pathways to align with a learner's unique profile. As such, personalized education will raise motivation, improve retention and allow learners, especially learners at risk or with special demands, to reach their full potential ([8], [21], [17]). In short, personalized education comprises two main categories:

- tailoring learning to each student through their strengths, their capabilities, needs and interests
- offering students choices, voices and flexibility in order to adapt learning outcomes. In various way, schools become a place as democratic institutions [28].

Recently, many studies have aimed to explore the role of personalized education. For instance, [15] reflects how teachers bring lessons to transit from teacher – centered to student – centered, and then to more student learning process through flexible learning of process. In this stage, learners are encouraged to cover conversations, thoughtful discussions, presentations, research and writing. The more learners engage in the lessons, the more knowledge they can absorb as well as apply in practical issues.

Figure 1 below will illustrate the frequency of searching the terms of adaptive learning through 5 years, from August 2020 until April 2025. Based on figure 1, it is easy to capture that adaptive learning has significantly changed thorough years, and for the period 2025, this trend is witnessed as the awoken and demand for learners in the rotation of technology. Additionally, Figure 2 expresses that the regions that has demanding for searching this term “adaptive learning”, which is China and it seems that the whole globe aims to figure out what is it mean about adaptive learning, and how adaptive learning merge with AI. However, Africa and Antarctica are still lack of searching this term, referred to figure 2.



Figure 1. Dynamics of frequency of search of the terms of “adaptive learning” from 2020 to 2024. (Google Trends)



Figure 2. Searching areas of the terms of “adaptive learning” from 2020 to 2024. (Google Trends)

C. ARTIFICIAL INTELLIGENCE IN EDUCATION

Modern Artificial Intelligence (AI) systems are redesigning educational issues by combining adaptive learning technologies, natural language processing (NLP) and generative models into cohesive instructional frameworks. Acting as the core of these innovations, adaptive learning algorithms, which continuously analyze performance of students and meanwhile, modify instructional content in real time [7]. By dynamically responding to individual learners’ strengths and weaknesses, AI systems aim to promote more efficient mastery of subject issues as compared to static and one size fits all approaches [26].

Another important issue is Natural Language Processing, enabling AI systems to interpret and produce human-like languages. Following that, NLP facilitates context aware explanations, fosters the answering of open-ended questions and supports interactive dialogue between students and systems [24]. This capability is particularly significant for simulating the responsiveness of skilled tutors; hence it is expected to promote engagement and comprehension.

Building on these foundations, generative Artificial Intelligence models, in particular GPT4, Gerek, Gemini, etc., is expected to widen the instructional toolkit by generating personalized exercise, instant feedback and conversational learning scenarios [13]. These facilities can synthesize seamless and reasonable explanations, embed concepts within practical world contexts and furthermore adapt materials to interests of learners, therefore lead to higher motivation and retention rates.

Implementation platforms demonstrate how these technologies can operate on a scale. In particular, Squirrel AI, one of the leading examples in China region, has integrated adaptive algorithms, NLP and generative capabilities within a unified platform. Utilizing fine grained knowledge graphs and diagnostic assessments, it illustrates specific learning gaps and describes individual learning pathways across thousands of micro concepts in both mathematics and additional domains [6]. This platform approach ensures that students receive precisely targeted instructions, boosting mastery as well as enhancing long term results.

In a nutshell, current AI driven educational systems enhance adaptive learning, natural language processing, and generative capabilities into scalable platforms. This convergence enables highly personalized, data driven learning experiences that significantly enhance both educational quality and effectiveness for learners across globe.

D. SDG4 AND THE BROADER SDG AGENDA

In accordance with UNESCO (2017), Sustainable Development Goal 4, which is named SDG4, refers to envisioning inclusive, equitable and high-quality education for all populations, enhancing targets including universal literacy, lifelong learning opportunities and the integration of sustainability-oriented curricula.

Additionally, artificial intelligence (AI) offers significant potential to advance these purposes by enabling adaptive, accessible learning platforms that can personalize instruction and explore diverse learner demands [10]. Nonetheless, technological capability alone is insufficient. In order to bring meaningful impact, this issue requires a number of supportive policy frameworks, robust digital infrastructure, comprehensive teacher professional development and stringent ethical oversight (UNESCO, 2021). The huge impact of AI in education also broadens beyond SDG4, somehow intersect with SDG5 on gender equality, SDG8 on decent work and economic development, and finally, related to SDG10 on narrowing inequalities (ITU & UNESCO, 2022). Whenever utilizing thoughtfully and inclusively, AI enables to function as multidimensional enabler of procedure across number of Sustainable Development Goals, meanwhile foster both educational quality and social equity.

III. METHODOLOGY

This study employed a structured literature review approach to systematically identify and explore the existing research on the application of Artificial Intelligence (AI) in education, with specific attention to adaptive learning and its connections to the Sustainable Development Goals (SDGs). In order to assure comprehensive coverage, additional systematic strategy has been combined few of relevant keywords, such as “Artificial Intelligence in

education", "AI in education", "adaptive learning", "AI + adaptive learning + SDGs", and "adaptive learning with SDGs". These categories were applied to across titles, abstracts as well as keyword fields to capture a broad relevant body of literature. At the same time, this attempt has applied clearly defined inclusion criteria to assure the quality and relevance of the selected literature. Only publications written in English were included, and the primary analysis focused on peer reviewed journal articles and review papers. Furthermore, attempts were required to explicitly show applications of Artificial Intelligence in education and adaptive learning.

This study applied clearly defined inclusion criteria to ensure the quality and relevance of the selected literature. Only publications written in English were included, and the primary analysis focused on peer-reviewed journal articles and review papers. In addition, studies were required to explicitly address applications of Artificial Intelligence in education and/or adaptive learning. To complement these sources and capture recent developments in this rapidly evolving field, selected grey literature and pre-publication studies were also considered. These materials were obtained from reputable academic repositories, such as SSRN and other recognized scholarly platforms, and were used to provide additional context rather than forming the core analytical dataset.

Originally, this study covered about 3.500 records and there is a multi- stage screening process. Firstly, duplicate entries were identified and removed. The remaining records were then screened based on titles and abstracts to evaluate their relevance. Studies could not adapt the inclusion criteria, for instance, those outside the scope of AI in education were obmitted at this stage. Secondly, full text versions of the remaining studies were reviewed in detail to confirm their aligibility. Following this rigorous screening procedure, a number of 1.090 attempts were maintained for the final stage. It is illustrated in a PRISMA style flow diagram in figure 3, which outlines the stages of identification, screening, eligiblity assessment, and final inclusion. The final dataset covers a range of disciplines, including education, information systems, economics, and decision sciences. This diversity emphasizes the interdisciplinary nature of AI driven adaptive learning and underscores its broader relevance to advancing the Sustainable Development Goals.



Figure 3. Research Scanning (own elaboration)

III. DISCUSSIONS ABOUT ADAPTIVE LEARNING INTEGRATED ARTIFICIAL INTELLIGENCE WITH SUSTAINABLE DEVELOPMENT GOALS

A. INTERPRETATION OF DISTINGUISHED CASE STUDIES IN RELATION TO EXISTING RESEARCH

The case studies of Duolingo and Squirrel AI provide empirical illustrations of how AI-driven personalization aligns with and extends established research on adaptive learning and intelligent tutoring systems. Rather than functioning solely as technological tools, these platforms demonstrate how real-time data analytics and learner modeling operationalize theories of individualized instruction and mastery-based learning ([30]; [29]).

In the case of Duolingo, the integration of adaptive algorithms, gamification, and generative AI reflects prior findings that adaptive feedback and incremental task difficulty significantly enhance learner engagement and retention. Existing studies in educational technology have emphasized the role of continuous formative assessment in promoting learner autonomy and motivation. The Birdbrain model supports this theoretical perspective by dynamically predicting learner success probabilities and adjusting task difficulty accordingly. The incorporation of GPT-4-based conversational practice further extends earlier adaptive learning models by enabling authentic interaction, suggesting that generative AI may transform personalization from content adaptation to interactive knowledge construction.

Similarly, Squirrel AI exemplifies the evolution of precision learning through fine-grained knowledge graphs. Previous research on cognitive diagnostic assessment has highlighted the effectiveness of identifying micro-level learning gaps to enhance remediation strategies. The ultra-detailed knowledge mapping used by Squirrel AI demonstrates how theoretical models of hierarchical knowledge structures can be implemented at large scale. This indicates that AI-powered personalization is not only feasible for individual learners but also scalable across millions of users, thereby validating predictions made in earlier adaptive learning research regarding scalability and efficiency ([6]; [5]).

B. INTEGRATING EMERGING ACADEMIC TRENDS WITH PERSONALIZED LEARNING THEORY

Emerging educational frameworks increasingly combine generative AI with adaptive learning to develop warmth, closeness and more human systems that continuously adjust instructional content and feedback in order to response to learner performance. These integrative models aim to leverage real time analytics in order to align difficulty, modality as well as pacing with individual demands, therefore enhancing personalization without removing the educator's oversight [10]. A distinguished illustration is the Artificial Intelligence – Enabled Intelligent Assistant (AIIA), which conducts tailored quizzes, flashcards, and interactive tutoring sessions which based on detailed learner profiles [24]. By delivering targeted micro learning resources and immediate feedback, AIIA remarkably reduces extraneous cognitive load while boosting engagement and satisfaction in higher education perspectives. Meanwhile, [25] also shows that learners are more likely to gain greater independence and retain more content whenever utilizing these systems as compared with traditional and non-adaptive learning systems. Therefore, innovations highlight the maturation of next generation AI tutors, scalable deeply and meanwhile easily supporting millions of learners while respecting the pedagogical nuances of formal education. This sheds huge value for future adaptive generative AI platforms, acting as collaborative partners for educators.

C. IMPLICATIONS FOR SUSTAINABLE DEVELOPMENT AND EDUCATIONAL POLICY

With respect to direct impact of AI to sustainable development, AI powered platforms such as Duolingo and Squirrel AI can enhance accessibility by providing affordable, scalable learning. By adjusting to each individual skill level, these platforms can deliver content which is suitable for each learner, promoting both effectiveness and inclusivity [27]. As a result, these AI driven platforms directly enhance Sustainable Development Goal 4.7, which is expected to ensure that all learners acquire the knowledge and necessary skills for sustainable development, including themes, in particular gender equality and global citizenship [14].

Regarding theoretical perspective, these results could enhance the broader discourse on digital equity by expressing how personalized learning technologies can function as mechanisms for decreasing educational disparities. By traditionally risen from socio economic inequalities. This issue supports thereotical models linking adaptive instruction with improved learning equity and long-term knowledge retention.

From a policy perspective, the adoption of AI-driven personalized learning systems has significant implications for national education strategies. Governments and educational institutions may consider integrating adaptive learning technologies into public education systems to enhance accessibility for learners in rural or underserved regions. Such integration aligns with Sustainable Development Goals related to gender equality (SDG 5), reduced inequalities (SDG 10), and decent work (SDG 8), as lifelong learning opportunities enable individuals to develop digital competencies necessary for modern labor markets [14].

Nonetheless, policymakers must also represent potential risks associated with AI implementation, including data privacy concerns, algorithmic bias, and unequal technological access. Meanwhile, the need to establish regulatory frameworks that ensure transparency, accountability, and equitable access will be essential for maximizing the societal benefits of AI-enhanced education.

D. CHALLENGES THAT AI DRIVEN SYSTEMS BRING

Recent studies have shown that AI driven has brought huge value for users in various industries, spanning from education, banking, customer service, clinics to hospitability, etc. Yet AI driven platforms constitute a number of barriers that need to be considered. These challenges can be broadly categorized into ethical, technological, and

social dimensions. From an ethical perspective, recent studies have discussed the misleading and privacy issues that AI is related to. AI driven learning platforms depend on various data collection, constitute everything since user interaction to assessment outcomes and behavioral patterns. While these datasets enhance precise personalization, they also raise awarenesses about surveillance, informed consent and secure data. If these AI systems could not provide any robust safeguards, these facilities could empower learners risk and then erode users' trusts.

From a technological standpoint, the design of AI systems may inadvertently encourage passive learning behaviors. Generative AI platforms often provide instant feedback and ready-made solutions, which can reduce learners' incentives to engage in critical thinking or deep learning processes. As a consequence, learners may become passive recipients of information rather than active constructors of knowledge.

With respect to social perspective, digital inequality remains a significant barrier. There is a persistent gap between urban and rural communities, particularly in regions where learners lack access to digital devices, stable internet connectivity, or adequate digital literacy skills. This disparity risks exacerbating existing educational inequalities and limiting the inclusive potential of AI in education.

Generally, organizing these challenges into clear categories not only enhances conceptual clarity but also emphasizes the multifaceted risks associated with the integration of AI in educational contexts.

IV. CONCLUSIONS AND IMPLICATIONS

Based on challenges that are discussed above, it is important to develop suitable strategies. First, AI platforms should be seen as a tool to augment and not aim to replace fully as expertise of educators. It is very important that traditional teachers can bring lessons, contextualizing content, as well as fostering reflection, where the tasks that go beyond the scope of algorithms. It should be balanced between human judgement and empathy with AI adaptive efficiency. Secondly, it is suggested that it is a must for transparent governance policies for users. Ethical frameworks must state clearly to define how well data is collected, stored and utilized. In case the developers violate, it should have some warning, postponing, suspending or in charge of compensation for users. Thirdly, investment in infrastructure and digital literacy is non-negotiable. Following that, governments, NGOs, as well as private stakeholders should prioritize expanding accessing internet, provide devices and offer training to both learners and educators. Lastly, it is appropriate to cooperate between AI systems with input of local educators and learners to ensure local norms, languages and curricula. So that cooperation not only improves relevance but also boosts ownership and trust within communities.

Overall, the findings emphasize that AI-driven personalized education has moved from conceptual promise to practical application, enabling adaptive learning that addresses diverse learner needs at scale. This study contributes to the literature by synthesizing the relationship between AI-powered personalization and sustainable development goals, particularly SDG 4, and by proposing an integrated framework that combines technological innovation with human-centered educational practices. The results underscore that the effectiveness of AI in education depends not only on technological capability but also on supportive policy environments, ethical design, and collaborative implementation.

Despite these contributions, this study has several limitations. First, the analysis relies primarily on conceptual synthesis and selected case examples, which may limit the generalizability of the findings across different educational contexts. Secondly, variations in technological readiness and socio-economic conditions across regions were not examined in depth. The future study should therefore conduct empirical studies across diverse educational systems to evaluate the long-term effectiveness of AI-driven personalized learning. Additionally, further investigation into emerging technologies, such as the integration of AI with immersive tools like virtual reality (VR) and augmented reality (AR), may provide valuable insights into enhancing experiential and context-rich learning environments aligned with sustainable development outcomes.

Generally, the responsible integration of AI into education has the potential to transform learning systems into more inclusive, adaptive, and sustainable environments. By aligning technological innovation with ethical governance, educator involvement, and equitable infrastructure development, AI-driven personalized education can play a significant role in advancing inclusive, quality, and lifelong learning opportunities, thereby supporting the broader ambitions of SDG 4.

V. STATEMENTS AND DECLATIONS

Acknowledgments:

We are extremely grateful to all reviewers for their insightful and constructive feedback, which helped us enhance this paper.

Fundings:

This research paper did not receive any financial aid from any source.

Availability of data and materials:

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable.

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AI CÁ NHÂN HÓA GIÁO DỤC NHƯ THỂ NÀO ĐỂ GÓP PHẦN ĐẠT ĐƯỢC CÁC MỤC TIÊU PHÁT TRIỂN BỀN VỮNG

Đặng Thị Thu Hằng, Đinh Ngọc Long

TÓM TẮT— Nghiên cứu phân tích vai trò của Trí tuệ nhân tạo (AI) trong cá nhân hóa giáo dục và thúc đẩy các Mục tiêu Phát triển Bền vững (SDGs), đặc biệt là SDG 4 về giáo dục có chất lượng, công bằng và toàn diện. Dựa trên tổng quan tài liệu, phân tích chính sách và các trường hợp điển hình như Duolingo và Squirrel AI, nghiên cứu cho thấy các công nghệ như thuật toán thích ứng, xử lý ngôn ngữ tự nhiên và AI tạo sinh có thể nâng cao sự tham gia, khả năng ghi nhớ và khả năng tiếp cận giáo dục của người học. Các nền tảng giáo dục ứng dụng AI trực tiếp hỗ trợ SDG 4.7, đồng thời góp phần thực hiện SDG 5, SDG 8 và SDG 10. Nghiên cứu đề xuất mô hình kết hợp con người–AI, quản trị AI có đạo đức, đầu tư cơ sở hạ tầng và thích ứng với bối cảnh địa phương nhằm phát huy vai trò của AI trong xây dựng nền giáo dục bền vững và công bằng.

Từ Khóa— Trí tuệ nhân tạo (AI), học tập thích ứng, phát triển bền vững



Đặng Thị Thu Hằng:

- Tốt nghiệp Tiến sĩ trường Đại học UCSI – 2025.
- Giảng viên, Trường Đại học Ngoại ngữ - Tin học Thành phố Hồ Chí Minh
- Lĩnh vực quan tâm: Cấu trúc vốn, ESG, tài chính hành vi, thị trường chứng khoán, tâm lý trong kinh doanh
- Điện thoại: 0937170950



Đinh Ngọc Long:

- Tốt nghiệp Thạc sĩ Thương Mại – Tài Chính tại trường Đại học Macquarie, Úc. Hiện đang là Nghiên Cứu Sinh trường Đại học Tomasbata tại Zlin, Cộng hòa Séc
- Tóm tắt công việc hiện tại: Giảng viên khoa Quản trị kinh doanh, Đại học quốc tế, Đại học Quốc gia TPHCM
- Lĩnh vực quan tâm: Khởi nghiệp, giáo dục khởi nghiệp, đổi mới sáng tạo. - Điện thoại: 0906391611