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AI-ENHANCED PERSONALIZED LEARNING AND ACADEMIC PERFORMANCE: INVESTIGATING DIGITAL EQUITY, COGNITIVE ENGAGEMENT, AND LEARNING OUTCOMES IN PAKISTAN'S HIGHER EDUCATION SYSTEM

Muhammad Irfan[*1], Dr. Mahboob Ullah[2], Khalid Bilal[3]

*[*1]PhD education scholar Education GCU faisalabad*
[2]Associate Professor, Department of Management Sciences, Abasyn University, Peshawar, Pakistan
[3]Department of Management Sciences, Abasyn University, Peshawar, Pakistan

[*1]muhammadirfansial86@gmail.com,
[2]mahboob.ullah@abasyn.edu.pk,
[3]khalid.bilal@abasyn.edu.pk

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Abstract

Artificial intelligence (AI) is increasingly transforming higher education through personalized content, adaptive feedback, intelligent tutoring, and generative AI. However, its educational value may depend on students' cognitive engagement and their ability to access and use digital technologies equitably. This study examines the relationship between AI-enhanced personalized learning and academic performance in Pakistan's higher education system, focusing on cognitive engagement as a mediator and digital equity as a moderator. A quantitative, cross-sectional explanatory design is proposed, using a structured questionnaire to assess AI-enhanced personalized learning, cognitive engagement, digital equity, and academic performance/learning outcomes among university students with experience of AI-supported learning. The proposed analysis includes descriptive statistics, reliability and validity assessment, correlation analysis, and structural equation modelling for direct, mediation, and moderation effects. The study contributes an integrated perspective by linking AI personalization with learner cognition and digital access conditions in the Pakistani context. Because no raw dataset or statistical output was supplied in the source paper, no empirical coefficients or significance claims are reported here.

Keywords: *Artificial intelligence; personalized learning; cognitive engagement; digital equity; academic performance; higher education; Pakistan*

Introduction

Artificial intelligence has moved beyond a technical support role and become an important component of higher education. Machine learning, learning analytics, intelligent tutoring systems, and generative AI can provide adaptive content, individualized explanations, feedback, and learning support. Personalized adaptive learning has generally shown positive associations with academic performance and engagement, although outcomes vary with implementation, infrastructure, pedagogy, and learner characteristics (du Plooy et al., 2024; Mustafa et al., 2024).

Generative AI further expands personalization by enabling interactive explanations, examples, feedback, and problem-solving support. However, AI does not automatically improve learning. Cognitive engagement—students' mental effort, critical thinking, strategic processing, reflection, and self-regulation—may determine whether AI functions as a learning scaffold or substitutes for independent thinking. Concerns about over-reliance and cognitive offloading therefore remain important (Lo, 2023; Kasneci et al., 2023).

Digital equity is another critical condition. Effective AI-supported learning requires suitable devices, reliable connectivity, affordability, digital and AI literacy, and technical support. Pakistani students experience differences in digital access and technological capability, particularly across socioeconomic and geographical groups (Amjad et al., 2024). Thus, AI may reduce educational inequalities through scalable personalized support, but it may also reproduce them if digitally advantaged students benefit more.

The present study integrates these issues by examining AI-enhanced personalized learning as the independent variable, cognitive engagement as a mediator, digital equity as a moderator, and academic performance/learning outcomes as the dependent variable. This framework moves beyond a simple technology–performance relationship and focuses on the mechanisms and

conditions through which AI-supported learning may produce educational benefits.

2. Problem Statement

Although AI-supported personalized learning has demonstrated educational potential, evidence remains insufficient regarding how and under what conditions it improves learning. Existing research often emphasizes AI adoption, perceptions, or direct academic outcomes without adequately explaining the cognitive processes involved. Students may use AI to obtain individualized explanations and feedback, but they may also rely on AI-generated answers without critical evaluation.

A second concern is digital inequity. Equal availability of an AI platform does not guarantee equal capacity to use it. Differences in devices, internet connectivity, affordability, digital competence, and technical support can create unequal educational benefits. Pakistani research has documented such disparities, while existing studies have generally examined AI use, ChatGPT, digital access, or learning outcomes separately.

Accordingly, the central problem is the limited empirical understanding of how AI-enhanced personalized learning affects academic performance in Pakistan's higher education system through cognitive engagement and under conditions of unequal digital access.

3. Research Questions

1. To what extent does AI-enhanced personalized learning influence academic performance?
2. What is the relationship between AI-enhanced personalized learning and cognitive engagement?
3. To what extent does cognitive engagement influence academic performance and learning outcomes?
4. Does cognitive engagement mediate the relationship between AI-enhanced personalized learning and academic performance?
5. To what extent does digital equity influence effective use of AI-enhanced personalized learning?
6. Does digital equity moderate the relationship between AI-enhanced personalized learning and learning outcomes?
7. Do AI-enhanced personalized learning, cognitive engagement, and digital equity jointly explain variation in academic performance?

4. Research Objectives

The study aims to:

1. Examine the effect of AI-enhanced personalized learning on academic performance.
2. Determine the relationship between AI-enhanced personalized learning and cognitive engagement.
3. Assess the effect of cognitive engagement on academic performance and learning outcomes.
4. Test the mediating role of cognitive engagement.
5. Evaluate the role of digital equity in effective AI-supported learning.
6. Test the moderating role of digital equity.
7. Empirically examine an integrated model of AI personalization, cognitive engagement, digital equity, and learning outcomes.

5. Significance of the Study

The study contributes theoretically by integrating technological, cognitive, and equity dimensions into one model. Practically, it can guide universities in selecting AI tools, designing adaptive

learning activities, strengthening AI literacy, and developing appropriate faculty support. From an equity perspective, it can identify barriers related to devices, connectivity, affordability, digital competence, and technical assistance. At the policy level, the study can inform AI literacy, infrastructure, assessment redesign, data protection, academic integrity, and equitable access. Overall, it supports a human-centred approach in which AI complements rather than replaces teachers and students' cognitive effort.

6. Literature Review

AI-enhanced personalized learning uses intelligent technologies to adjust learning content, pace, difficulty, feedback, and support according to learner needs. A systematic review reported improvements in academic performance in a majority of studies and improvements in engagement in a substantial proportion, although implementation conditions affect outcomes (du Plooy et al., 2024). Broader reviews similarly identify substantial potential for AI in higher education while emphasizing ethical, pedagogical, and methodological challenges (Bond et al., 2024; Castillo-Martínez et al., 2024).

The relationship between AI personalization and academic performance can be explained through adaptive feedback, individualized content, identification of knowledge gaps, and appropriately challenging learning tasks. However, the effect is unlikely to be uniform. AI can facilitate deeper learning when used for scaffolding and feedback, but passive consumption or unrestricted answer generation may reduce cognitive effort.

Cognitive engagement is therefore central to the proposed model. It involves concentration, deep processing, critical evaluation, problem solving, reflection, and persistence. Generative AI can strengthen these processes by supporting explanations and feedback, but it can also encourage cognitive offloading. Research on ChatGPT highlights both educational opportunities and risks of over-reliance and reduced critical thinking (Lo, 2023; Kasneci et al., 2023). The quality of interaction with AI may therefore matter more than simple frequency of use.

Self-regulated learning is closely related to this process. AI can support goal setting, monitoring, feedback, and reflection, while students remain responsible for evaluating and applying information. Recent work on GenAI and self-regulated learning further supports the importance of learner regulation in AI-mediated environments (Lim & Bannert, 2026).

Digital equity extends beyond internet access to include devices, affordability, digital literacy, AI literacy, accessibility, and technical support. Evidence from Pakistani higher education indicates substantial disparities in digital access, particularly among disadvantaged and remote students (Amjad et al., 2024). Consequently, digital equity may strengthen or weaken the educational benefits of AI personalization. Students with stable connectivity, suitable devices, and stronger digital capabilities may be better positioned to convert AI access into meaningful learning outcomes.

Overall, the literature indicates three principal gaps: a construct-integration gap because AI personalization, engagement, equity, and outcomes are often studied separately; a mechanism gap concerning the mediating role of cognitive engagement; and a contextual gap because integrated evidence from Pakistan remains limited. The proposed study addresses these gaps through a single explanatory model.

7. Theoretical Framework

The study is primarily grounded in Self-Regulated Learning (SRL) Theory. SRL explains learning as an active process involving planning, performance, monitoring, and self-reflection. AI-enhanced personalization can support the forethought phase through individualized learning plans and identification of learning needs; the performance phase through adaptive tasks, feedback, and

explanations; and the self-reflection phase through performance analytics and formative feedback.

The theory also explains possible negative outcomes. When students use AI as a substitute for planning, reasoning, and evaluation, self-regulatory activity may decline. Digital equity is incorporated as a contextual condition because students require adequate technological resources and competencies to benefit from AI-supported self-regulation.

Conceptually, the model is:

AI-enhanced personalized learning → Cognitive engagement → Academic performance/learning outcomes,

with digital equity moderating the effectiveness of AI-enhanced personalized learning.

8. Hypotheses

H1: AI-enhanced personalized learning positively affects cognitive engagement.

H2: AI-enhanced personalized learning positively affects academic performance and learning outcomes.

H3: Cognitive engagement positively affects academic performance and learning outcomes.

H4: Cognitive engagement mediates the relationship between AI-enhanced personalized learning and academic performance.

H5: Digital equity positively affects effective engagement with AI-enhanced personalized learning.

H6: Digital equity positively moderates the relationship between AI-enhanced personalized learning and academic performance/learning outcomes.

H7: AI-enhanced personalized learning, cognitive engagement, and digital equity jointly explain significant variation in academic performance and learning outcomes.

9. Methodology

Research Design. A quantitative, cross-sectional explanatory design is proposed to test the relationships among AI-enhanced personalized learning, cognitive engagement, digital equity, and academic performance.

Population and Sampling. The population comprises students enrolled in recognized higher education institutions in Pakistan who have used or encountered AI-supported educational technologies. A multistage approach is proposed, with institutions grouped by sector and geographical context, followed by selection of relevant departments and eligible students. Proportionate stratification may be used where appropriate to improve representation.

Data Collection. Data are to be collected through a structured self-administered questionnaire. Participants should receive information about the study purpose, voluntary participation, confidentiality, and their right to withdraw. Online administration may be supplemented by researcher-assisted or physical administration where necessary, particularly because digital equity is a central study variable.

Instrument. The questionnaire contains demographic information and measures of four principal constructs. AI-enhanced personalized learning covers individualized content, adaptive pace, recommendations, explanations, feedback, assessment, identification of learning needs, and academic assistance. Cognitive engagement covers concentration, critical evaluation, deep understanding, strategic learning, problem solving, reflection, independent thinking, and persistence. Digital equity covers devices, connectivity, affordability, electricity, access to AI platforms, digital/AI literacy, technical support, accessibility, and equality of opportunity. Academic performance/learning outcomes may be measured through reported achievement and,

where ethically and practically available, objective indicators such as GPA or course grades.
Measurement. A five-point Likert scale is proposed. Items should be adapted from established literature and reviewed by experts for content validity. A pilot test should assess clarity, terminology, completion time, response variability, and reliability. Cronbach's alpha and composite reliability should be assessed, with convergent validity examined through factor loadings and AVE and discriminant validity through Fornell–Larcker and/or HTMT criteria.
Data Analysis. Data should be screened for missing responses, outliers, patterned responses, and other quality problems. Descriptive statistics and correlations should be reported first. Structural equation modelling can then test direct effects, mediation through cognitive engagement, and moderation by digital equity. Bootstrapping should be used for indirect effects, and interaction terms should be used for moderation. Because the source paper contains no raw dataset or statistical output, numerical results, p-values, coefficients, and hypothesis decisions must be inserted only after analysis of the actual data.
Ethics. Participation should be voluntary and based on informed consent. Anonymity, confidentiality, secure data handling, responsible AI use, privacy, and academic integrity should be maintained throughout the research process.

10. Data Analysis and Results Framework

The analysis should begin with descriptive statistics for the four main constructs, followed by reliability and validity assessment. Correlation analysis should establish the direction and strength of bivariate relationships. Structural equation modelling should then test H1–H3 and H5, while bootstrapping should test H4 and an interaction term should test H6. R^2 and relevant effect-size measures should be reported to assess explanatory power.
The original paper contains placeholders rather than actual statistical output. Therefore, the present shortened version does not report fabricated findings. Once the dataset is available, tables should present N, means, standard deviations, reliability coefficients, AVE, discriminant validity, path coefficients, confidence intervals, p-values, R^2, and hypothesis decisions. Interpretation should be based on effect sizes, confidence intervals, and substantive significance as well as statistical significance.

11. Discussion

The proposed framework suggests that AI-enhanced personalized learning may improve academic outcomes through individualized explanations, adaptive tasks, feedback, and learning support. These functions can strengthen cognitive engagement when students actively evaluate, apply, and reflect on AI-generated information. This interpretation is consistent with evidence that personalized adaptive learning can improve performance and engagement (du Plooy et al., 2024).
Cognitive engagement is especially important because generative AI can either support or replace independent reasoning. AI is more educationally valuable when used as a cognitive scaffold—for example, through guided questioning, progressive hints, feedback, and error diagnosis—rather than unrestricted answer generation. This perspective is consistent with concerns about over-reliance and reduced critical thinking in the AI-in-education literature (Kasneci et al., 2023; Lo, 2023).
The proposed mediation relationship would indicate that AI personalization affects outcomes partly through students' cognitive engagement, extending research beyond a simple technology–performance association. Digital equity adds a contextual dimension: students with reliable connectivity, appropriate devices, and stronger digital competencies may obtain greater benefits from AI-supported learning. This is particularly important in Pakistan, where digital-access disparities have been documented (Amjad et al., 2024).

Accordingly, AI should be understood as a complement to teachers and learners rather than a replacement for human instruction or cognitive effort. Its effectiveness depends on pedagogical design, student agency, digital capability, and institutional support.

12. Conclusion

AI-enhanced personalized learning offers significant potential for improving higher education by providing adaptive content, individualized feedback, and learner-specific academic support. However, its effectiveness should not be understood as an automatic consequence of AI access. Cognitive engagement is likely to be an important mechanism through which personalization translates into learning outcomes, while digital equity may determine who can benefit most effectively.

For Pakistan's higher education system, sustainable AI integration therefore requires a combination of intelligent technologies, active student engagement, AI and digital literacy, faculty support, institutional governance, and equitable technological access. A human-centred approach is essential to ensure that AI enhances educational quality without widening existing inequalities.

13. Implications

The study extends SRL theory by positioning AI as an external scaffold for planning, monitoring, feedback, and reflection, while recognizing cognitive engagement as a key learning mechanism and digital equity as a contextual condition.

For universities, AI platforms should be evaluated for adaptive learning quality, formative feedback, accessibility, privacy, and capacity to promote meaningful cognitive activity. Faculty development should address AI-assisted pedagogy, verification of AI outputs, assessment redesign, and prevention of inappropriate cognitive offloading. Students should receive training in prompt design, source verification, hallucination detection, privacy, and responsible academic use.

At policy level, AI strategies should prioritize affordable broadband, institutional infrastructure, suitable student devices, AI/digital literacy, teacher development, accessibility, data protection, transparent governance, and equitable access for disadvantaged and rural communities.

14. Recommendations

1. Develop institution-wide AI personalization strategies linked to clear pedagogical objectives.
2. Design AI systems around questioning, guided problem solving, feedback, reflection, and progressive scaffolding.
3. Integrate AI-literacy training into university curricula.
4. Provide continuous faculty development in AI-enhanced pedagogy and assessment.
5. Reduce digital inequalities through subsidized connectivity, device-loan schemes, campus facilities, and technical support.
6. Redesign assessments to emphasize reasoning, application, reflection, oral explanation, and process-based evidence.
7. Establish policies for privacy, data security, algorithmic transparency, accessibility, and academic integrity.
8. Evaluate AI interventions using measurable learning outcomes rather than satisfaction or adoption alone.
9. Monitor differences in AI benefits across socioeconomic, geographical, disciplinary, and digital-competence groups.
10. Maintain teacher–AI complementarity, preserving educators' roles in mentoring, judgment, social learning, and academic development.

15. Limitations and Future Research

The cross-sectional design limits causal inference, while self-reported measures may introduce response bias. The focus on Pakistani higher education also limits generalizability to other countries and educational levels. Future studies should incorporate objective indicators such as course grades, learning-platform logs, and AI interaction records. Longitudinal and experimental designs are needed to examine persistence and causality.

Future research should also distinguish among generative AI, intelligent tutoring systems, adaptive platforms, automated feedback, and learning analytics rather than treating all AI use as one category. Additional mediators such as self-regulated learning, motivation, self-efficacy, metacognition, critical thinking, and cognitive load could be examined. Digital equity research should also consider algorithmic fairness, accessibility, language, disability, socioeconomic inequality, and AI literacy. Mixed-method and comparative research could further explain how and why AI personalization produces different outcomes across learners and institutions.

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