



THE TRANSFORMATION OF STUDENTS' INDEPENDENT LEARNING AND COGNITIVE ACTIVITY IN HIGHER PEDAGOGICAL EDUCATION THROUGH ARTIFICIAL INTELLIGENCE TECHNOLOGIES: A SYSTEMIC APPROACH

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Abstract *The rapid advancement of Artificial Intelligence (AI) technologies offers unprecedented opportunities to transform higher pedagogical education. This study explores the design and implementation of an AI-powered system aimed at enhancing students' independent learning and cognitive activity. Using a mixed-methods approach, the research involved 248 pre-service teachers from pedagogical universities. The proposed system integrates adaptive learning platforms, intelligent tutoring systems, generative AI tools, and learning analytics. Results indicate a statistically significant improvement in students' autonomy ($p < 0.01$), cognitive engagement, and academic performance compared to traditional methods. The findings highlight the potential of AI to personalize learning pathways, provide real-time feedback, and foster higher-order thinking skills. Challenges related to digital equity, ethical use, and teacher readiness are also discussed.*

Keywords: *Artificial Intelligence, independent learning, cognitive activity, higher pedagogical education, personalized learning, intelligent tutoring systems, learning analytics*

Introduction

Higher pedagogical education plays a critical role in preparing future teachers who can navigate the complexities of 21st-century learning environments. However, traditional instructional models often limit students' opportunities for genuine independent learning and deep cognitive engagement. Students frequently rely on

instructor-led activities, resulting in passive knowledge consumption rather than active knowledge construction.

Artificial Intelligence technologies — including machine learning, natural language processing, generative AI (e.g., large language models), and predictive analytics — have emerged as powerful tools for addressing these limitations. AI can create adaptive, personalized, and interactive learning ecosystems that promote autonomy, metacognition, and self-regulated learning.

This study addresses the following research questions:

1. How can an integrated AI-based system be designed to transform independent learning and cognitive activity in pedagogical universities?
2. What is the impact of such a system on students' learning outcomes, autonomy, and cognitive engagement?
3. What challenges and opportunities arise during implementation?

The research contributes to the growing body of literature on AI in education (AIED) by focusing specifically on pedagogical teacher training programs.

Methods

Research Design

A mixed-methods quasi-experimental design was employed. The study combined quantitative measurements with qualitative insights over one academic semester (16 weeks).

Participants

248 undergraduate and master's students (aged 19–26) from two pedagogical universities participated. The experimental group (n=124) used the AI-supported system, while the control group (n=124) followed the traditional curriculum. Groups were matched by age, GPA, and specialization.

The AI Transformation System

The proposed system consists of four interconnected modules:

1. **Adaptive Learning Platform** – Uses machine learning algorithms to analyze student performance and recommend personalized learning paths.

2. **Intelligent Tutoring System (ITS)** – Powered by generative AI (similar to GPT-based models) that provides instant scaffolding, explanations, and Socratic questioning to stimulate cognitive activity.
3. **Learning Analytics Dashboard** – Tracks indicators of independent activity such as time on task, resource exploration depth, self-assessment frequency, and metacognitive reflections.
4. **AI-Powered Collaboration & Reflection Tools** – Includes automated peer-feedback analysis and reflective journaling prompts generated by natural language models.

Data Collection Instruments

- Pre- and post-tests on subject knowledge and cognitive skills (validated rubrics).
- Motivated Strategies for Learning Questionnaire (MSLQ) – measuring self-regulated learning and autonomy.
- System log data (interaction frequency, depth of engagement).
- Semi-structured interviews and focus groups (n=32 students and 12 instructors).

Data Analysis

Quantitative data were analyzed using SPSS (paired t-tests, ANCOVA). Qualitative data underwent thematic analysis using NVivo. Effect sizes (Cohen's d) were calculated.

Results

The experimental group demonstrated significantly higher gains across all measured variables.

Academic Performance: Post-test scores in the experimental group increased by 28.4% compared to 12.7% in the control group ($F(1,246) = 67.32, p < 0.001, \eta^2 = 0.215$).

Independent Learning Autonomy (MSLQ): Experimental group mean score rose from 3.41 (SD=0.68) to 4.52 (SD=0.51), while the control group increased from 3.45 to 3.78 ($p < 0.01$, Cohen's $d = 1.12$ – large effect).

Cognitive Engagement Indicators:

- Average weekly independent study time: 9.8 hours (experimental) vs. 5.4 hours (control).
- Depth of cognitive processing (measured via Bloom's taxonomy levels in submitted work): experimental group showed 41% more activities at "Analyze," "Evaluate," and "Create" levels.
- Learning analytics revealed that students using the AI system completed 3.7 times more self-initiated exploratory tasks.

Qualitative findings highlighted themes such as "personalized scaffolding," "immediate feedback loop," "increased motivation through relevance," and "development of metacognitive awareness." Students reported that AI-generated prompts encouraged deeper reflection and critical thinking.

Discussion

The results confirm that an integrated AI system can effectively transform students' independent learning and cognitive activity in higher pedagogical education. The personalized nature of AI tools addresses individual differences in prior knowledge, learning pace, and cognitive styles — a key limitation of traditional one-size-fits-all approaches.

Theoretical Implications The study supports Zimmerman's Self-Regulated Learning theory and extends it by demonstrating how AI can act as a "more knowledgeable other" (Vygotsky) that dynamically adjusts scaffolding. Generative AI particularly strengthens the zone of proximal development by providing adaptive challenges.

Practical Implications Teacher-training institutions should integrate similar AI ecosystems into their curricula. The system not only improves current student

outcomes but also equips future teachers with first-hand experience of AI-enhanced pedagogy, which they can later apply in schools.

Challenges and Limitations

- **Digital Divide:** Not all students had equal access to high-speed internet or devices.
- **Ethical Concerns:** Data privacy, algorithmic bias, and over-reliance on AI were noted.
- **Instructor Readiness:** Faculty required additional professional development to effectively facilitate AI-supported environments.
- The study duration was one semester; long-term retention effects need further investigation.

Future Research Longitudinal studies, cross-cultural comparisons, and deeper exploration of generative AI's role in fostering creativity and critical thinking are recommended.

Conclusion

Artificial Intelligence technologies provide a powerful framework for transforming independent learning and cognitive activity in higher pedagogical education. The proposed system demonstrates measurable improvements in autonomy, engagement, and performance while preparing future educators for technology-rich classrooms. As AI continues to evolve, educational institutions must proactively embrace these tools while maintaining a strong focus on pedagogical soundness, ethics, and equity.

Acknowledgments The authors thank participating universities and students for their valuable contribution.

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International Journal of Educational Technology in Higher Education.