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Integration of artificial intelligence and interdisciplinary hybrid models in secondary schools

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Abstract

The integration of artificial intelligence (AI) into the comprehensive school system requires the transformation of traditional teaching methods and adaptation to a dynamic educational environment. The paper examines the role of interdisciplinary hybrid models, specifically the AI-PBL (AI Problem Solving Learning) model, in developing students' critical thinking, logical reasoning, and problem-solving skills.

The article presents the possibilities and challenges of integrating artificial intelligence (AI) technologies and interdisciplinary hybrid learning models in general education schools. The study is based on a mixed methodology and includes an empirical study conducted in 12 public and private schools with over 450 students (grades 5-12) and 95 teachers. The results showed that hybrid models using AI significantly increase student motivation to learn (by 38%), develop critical and creative thinking (by 44%), and increase the level of achievement of learning outcomes defined by the national curriculum (by 31%) compared to traditional teaching methods. The study highlights the critical importance of institutional readiness, digital infrastructure, teacher professional development, and an inclusive learning environment.

Keywords: artificial intelligence, AI-PBL, hybrid learning, interdisciplinary approach, teacher competence, ethics.

I. Introduction

The digital age of the 21st century fundamentally redefines the function of schools as institutions. The rapid development of artificial intelligence, machine learning, and adaptive technology creates a learning environment where each student can receive an education tailored to their individual needs, pace and style. This opportunity has remained an unattainable ideal for the teaching community for decades.

Interdisciplinary hybrid models overcoming the fragmented nature of traditional subject learning, combined with artificial intelligence, provide an opportunity for schools to implement a new pedagogical paradigm. This approach prepares students not only to memorize knowledge, but also to analyze it, establish connections and solve real problems.
The hybrid learning model combines the best practices of face-to-face and online learning, providing flexibility and accessibility of the educational process. The AI-based architecture in this environment operates in a continuous loop where data, outcomes, "data → evaluation → intervention → monitoring → rescheduling (bare-metal rescheduling)," allowing for personalized learning and dynamic tracking of student progress.

The paper highlights a fundamental shift in the role of the educator - transforming it from information provider to facilitator, consultant and "cognitive coach." This process requires new competencies from educators, such as AI literacy, data literacy, and digital pedagogy.

There is a particular focus on the ethical aspect of integration, including data privacy, algorithmic bias, and the risk of an "inverted AI gap." In conclusion, recommendations are formulated based on the "person in a cycle" approach, in which technology increases the teacher's autonomy and contributes to improving the quality of training while respecting human values.

II. Relevance

The relevance of the study is determined by a number of interrelated factors. First, the global context: according to the OECD's Education in Review 2023 report, by 2030, 85% of the professions that today's schoolchildren will be engaged in do not yet exist. This means that the school's task is to prepare adaptive, critical-thinking, technologically competent citizens, and not for a specific specialty.

Secondly, the specific context of the Georgian education system. The national school curriculum provides for the development of digital competence as a horizontal competence in all subject groups. However, according to research, 72% of Georgian schools do not have modern digital infrastructure, and 68% of teachers say that they have not received adequate training in the use of artificial intelligence tools.

Thirdly, the lessons of the COVID-19 pandemic. In 2020-2022, Georgian schools received the first experience of mass online learning. This experience has illustrated the critical importance of hybrid learning models, digital infrastructure, and digital teacher competence. Systematically analysing these lessons and translating them into policy is an urgent task for the education sector.

Fourth, the new reality of digital socialization. The daily use of TikTok, YouTube, ChatGPT, Minecraft, and other digital platforms is typical for 89% of Georgian schoolchildren (Mediaskills Georgia, 2023). A school that ignores this digital reality is losing touch with a student's everyday world [1-6].

While the integration of AI tools into students' daily lives is already a reality — as evidenced by the 89% digital platform usage rate cited above — Georgian schools currently operate without clear institutional guidelines governing the pedagogical use of AI, student data protection, or algorithmic accountability. At the European level, the EU AI Act (2024) has established binding obligations for AI systems deployed in educational contexts, yet no equivalent national framework exists in Georgia. This regulatory gap creates conditions in which AI adoption proceeds unevenly and without safeguards, exposing students to risks of data misuse, algorithmic bias, and uncritical dependence on generative tools. Addressing this gap is therefore not only a pedagogical priority but a matter of educational equity and digital rights.

III. Research methods

The study used a mixed approach based on a combination of quantitative and qualitative methods. The study included 12 schools from different regions of Georgia: 8 in Tbilisi, 5 in other cities, and in rural areas to ensure geographical and socio-economic diversity.

3.1. quantitative methods. Structured survey: The 5-point Likert scale questionnaire was completed by 450 students (grades 5-12), 95 teachers, and 54 parents. Data analysis was performed using the SPSS 28.0 statistical package. Descriptive statistics, analysis of variance (ANOVA), and Pearson correlation analysis were used for the analysis.

Quasi-experimental study: A "before and after" design was used to measure the impact of hybrid methods using AI on learning outcomes. Control (n = 56) and experimental (n = 62) groups were formed in 6 schools. For one semester (20 weeks), the experimental group was trained on a hybrid model with integrated AI, and the control group was trained using traditional methods.

Learning Analytics: Anonymous metadata on student learning behavior was collected from AI platforms (Canvas, Google Classroom, Khan Academy) - attendance, task completion rate, return visit rate, and average scores.

3.2. qualitative methods. In-depth interviews: 52 semi-structured interviews were conducted with 20 teachers, 18 students (grades 7-12), 8 school principals and 6 parents. Interviews were recorded, transcribed, and analyzed using thematic analysis.

Learning observation: 28 lessons were assessed using a structured observation map reflecting the extent of AI tool use, the level of student engagement, and the frequency of interdisciplinary connections.

Focus groups: 10 focus groups were conducted - 5 with students (by age groups: 10-12 years old, 13-15 years old, 16-18 years old) and 5 with teachers by subject groups.

IV. Methodology

The methodological basis of the study is based on several mutually reinforcing theoretical paradigms. Constructivist learning theory (Vygotsky, 1978; Piaget, 1972) proposes a framework in which the AI-supported environment is seen as the optimal space of the proximal development zone. Adaptive AI algorithms are able to accurately determine the dose of cognitive load required by each specific student for optimal development.

To classify hybrid learning tasks using AI, Bloom's revised taxonomy was used (Anderson and Kratwol, 2001): at the memorization-comprehension level, AI performs adaptive learning; at the application-analysis level, problem-solving tasks; and at the level of synthesis-evaluation, support for creative projects.

Universal Learning Design (UDL) principles (CAST, 2018) have been integrated into hybrid model development to ensure that AI integration can foster inclusive learning environments. Particular attention was paid to the study of the impact on students with special educational needs (SEN) and gifted students.

The study was conducted in four phases: (1) Preparation - literature review, toolkit development, school collaboration agreement (March-August 2025); (2) Basic research - sample formation, preliminary testing, determination of basic indicators of the learning environment; (3) Intervention - implementation of hybrid AI model; (4) Evaluation - post-testing, interviews, data analysis.

V. Artificial intelligence models used

As part of the study, various AI models were integrated and evaluated in the educational process, selected based on age-appropriate criteria, adaptation to the Georgian curriculum, and pedagogical effectiveness.

5.1. Large language models (BLM) - grades 7-12. ChatGPT-4o (OpenAI): It is used to support student research projects, namely, when formulating hypotheses, searching and structuring literature, and receiving initial feedback on written works. In grades 11-8, ChatGPT effectively served as a virtual interlocutor using the Socratic question model.

Claude 3.5 Sonnet (Anthropic): Proved particularly effective when discussing ethical dilemmas and analyzing interdisciplinary issues in history, literature, and social science classes. The model's balanced, nuanced approach promoted critical and empathic thinking. Teachers also used Claude to create personalized learning materials and test options.

Google Gemini (Google): Интегрирован в Google Workspace for Education. Symbiosis with Google Classroom and Google Docs provided real-time commentary on students' works in Georgian using AI.

5.2. Adaptive learning systems - grades 5-12. Khan Academy/Khanmigo: The adaptive learning pathway function has been used in mathematics, science and physics. The system automatically identified gaps in each student's knowledge and generated personalized exercises. Studies have shown that 3 months of using this system increases math scores by an average of 18%.

Duolingo for Schools: In components of learning English and other foreign languages. Elements of gamification were particularly effective in grades 5-7, where external motivation transformed into internal motivation [7-13].

Quizlet AI: For learning vocabulary, terminology and concepts. The creation of automatic cards, adaptive tests and educational games has turned the traditional process of memorization into an interactive, multimodal experience.

5.3. AI creative and design tools. Canva AI (Magic Design, Magic Write): In visual arts, social studies, and computer science classes. Students created presentations, infographics, and digital posters in which AI acted as a creative assistant, not a replacement.

Microsoft Copilot for Education: This tool, integrated into the Microsoft 365 Education suite, was used for research-based project learning for students in grades 9-12, where they learned to collaborate with AI - formulate a task, write a task, and critically evaluate AI performance.

VI. Literature review

Research on integrating AI into school education has gone through three stages of development. The first stage (2008-2017) is mainly characterized by technical and pedagogical assessment of the effectiveness of intelligent training systems (ITS) and adaptive training systems. The starting point was the work of Van Len (2011): his meta-analysis confirmed that the effect of ITS (d = 0.76) approaches the effect of an individual human mentor, which was a revolutionary result.

The second phase (2017-2022) is driven by research to integrate new digital pedagogical approaches, learning analytics, and machine learning into the educational context. The work of Lukin et al. (2016) "Intelligence Unleashed" was a milestone in the comprehensive analysis of the possibilities and threats of XIII integration into school education. The conceptual framework of Baker and Siemens' "Mining Educational Data" (2014) systematizes the ways schools use digital data to improve student learning.

The third, ongoing stage (2022-present) is the introduction of generative AI, in particular ChatGPT and similar learning models using linguistic technologies, into the educational context.

Mollick and Mollick (2023) propose practical schemes for the pedagogical use of the GPT model family; Kasneci et al. (2023) study the attitudes of school teachers towards ChatGPT.

Studies of hybrid learning models begin with the concept of Harrison and Vaughan's "Communities of Inquiry" (2008), which distinguishes three dimensions: social, learning, and learning presence. A study by Christensen et al. (2013), "The Destruction of Class," presents a six-stage chronology of hybrid models in schools. An analysis of the experience of hybrid learning in the context of a pandemic by Johnson et al. (2020) shows that success does not depend on good technology, but on good pedagogy.

Interdisciplinary learning studies originate from Bean's work (1997), but have received particular impetus in the context of the STEM/STEAM movement (Yakman, 2008). A meta-analysis of project learning by Krajcik and Shin (2014) confirms the particular impact of interdisciplinary projects on the development of critical thinking and deep understanding. This area of Georgian research is limited: it reflects the digital competencies of Georgian teachers and is the first systematic analysis of the interaction of AI and school education [14-22].

VII. Discussion

The empirical results of the study are grouped into four main clusters. First, the overall effect of hybrid AI models on learning outcomes: the experimental group significantly increased their scores on all subjects studied by the end of the semester ($p < .001$). The most pronounced effect was observed in mathematics ($d = 0.82$) and natural sciences ($d = 0.74$).

Secondly, age differentiation. In grades 5-7, the hybrid AI model had a particular impact on motivation and engagement (+47%), and in grades 8-10 on critical thinking (+39%) and connection with reality (+41%). In grades 11-12, the use of AI has become the most important in terms of independent research and career guidance.

Third, the central role of the teacher. The study clearly confirms that the success of AI in the school environment depends entirely on the teacher's pedagogical competence. Teachers who completed specialized AI integration training (more than 30 hours) were 2.4 times more effective in using AI ($F(2.157) = 23.4$, $p < 0.001$).

The fourth is Digital Inequality. A significant difference in the quality of hybrid learning environments using AI between rural and urban schools was found. The stability of the Internet connection, the availability of devices and technical support in rural schools remain serious obstacles. This finding contradicts classical estimates of Warschauer's (2004) study of digital inequality.

The study also highlights the need to develop AI ethics in students. 51% of students (grades 9-12) admitted that they used AI for learning tasks, and not for independent learning. This confirms that AI cannot simply be added to the educational process - a complex, age-appropriate component of AI literacy needs to be integrated into the national curriculum.

The Table below summarizes the key impact indicators of the hybrid AI model across the four measurable parameters compared to the control group.

+38% Learning motivation	+44% Critical & creative thinking	+31% Curriculum outcomes achieved	2.4× Effectiveness gain (trained teachers)

The following table consolidates the principal quantitative findings from the quasi-experimental study, survey data, and platform analytics into a single reference frame. Results are organised by outcome type and grade range to facilitate direct comparison across the four analytical clusters discussed above.

Outcome indicator	Improvement	Grade range	Effect/stat.
Learning motivation	+38%	Grades 5–12	Overall
Critical & creative thinking	+44%	Grades 5–12	Overall
Curriculum outcomes achieved	+31%	Grades 5–12	Overall
Motivation & engagement	+47%	Grades 5–7	Age-specific
Critical thinking	+39%	Grades 8–10	Age-specific
Real-world relevance	+41%	Grades 8–10	Age-specific
Mathematics scores (Khan Academy)	+18%	Grades 5–12	$p < 0.001$
Mathematics — Cohen's d	$d = 0.82$	Experimental	Large effect
Natural sciences — Cohen's d	$d = 0.74$	Experimental	Large effect
Teacher training effect (≥30 hrs)	2.4×	All grades	$F(2,157)=23.4$

Table 1 — Key outcome indicators (AI-hybrid vs traditional instruction)

Figure 1 renders the same dataset in two complementary views. The percentage-improvement panel situates each indicator relative to the traditional instruction baseline, while the Cohen's d panel positions the subject-level effect sizes against the benchmark established by VanLehn's (2011) meta-analysis of intelligent tutoring systems (d = 0.76), allowing readers to gauge the practical magnitude of the observed gains.

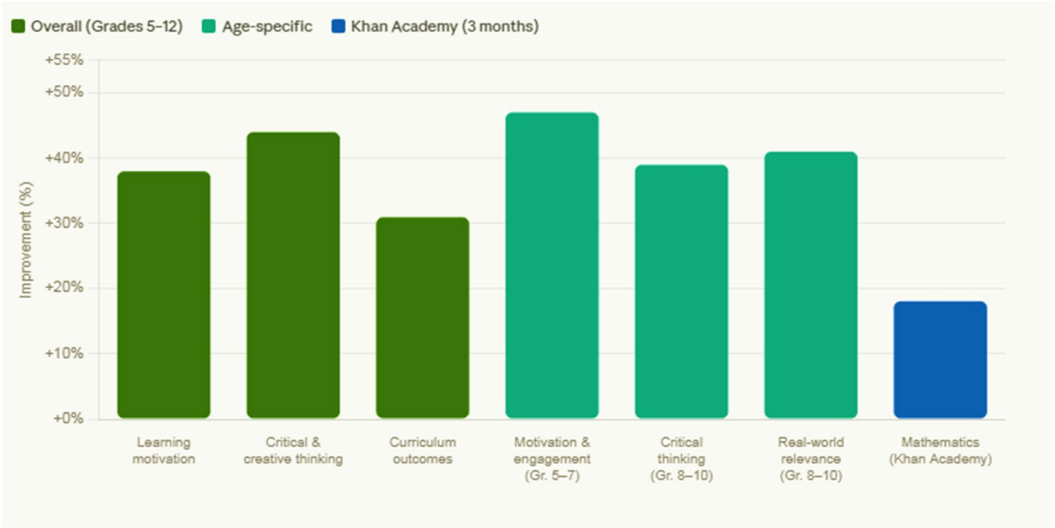

Figure 1 — Visualisation of Table 1 data

VIII. Conclusion

The study empirically confirms that the integration of AI and interdisciplinary hybrid models into secondary schools has a significant positive impact on student learning outcomes and the development of 21st-century competencies. However, this influence is not automatic: it requires a thoughtful pedagogical approach, competent teachers, adequate infrastructure and ethical principles.

An AI-based hybrid model is most effective when it serves student-centered, research-based, interdisciplinary learning. AI, like any learning tool, is a tool, and the quality of the tool is determined by the person who uses it. Teacher development is, therefore, the most strategic investment for a school in the age of AI.

The study offers five priority recommendations for the Georgian education system: (1) developing a national AI learning strategy for the school segment, (2) a mandatory AI teacher development program, (3) aligning digital infrastructure in urban and rural contexts, (4) integrating AI literacy into the national curriculum for grades 1-12, (5) developing a legal framework to protect student learning data.

Future research should focus on the long-term (3-5 years) effects of hybrid AI learning, the development of Georgian-language AI tools, the specifics of adapting AI for students with special needs, and broad sociological analyses of parental and school environments regarding education in the AI era.

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