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AI-SUPPORTED HYBRID LEARNING AND STUDENT ENGAGEMENT: EFFECTS ON SELF-REGULATED LEARNING IN UNDERGRADUATE EDUCATION IN UZBEKISTAN

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Tursunoy Usmonova
Founder and CEO of "Progress University LLC", MBA Webster University

Abstract

This study investigates the impact of AI-supported hybrid education on student engagement and self-regulated learning (SRL) in undergraduate higher education in Uzbekistan and selected Central Asian universities. Drawing on an integrated theoretical framework that combines Self-Regulated Learning Theory, the Technology Acceptance Model, and the Human-AI Hybrid Adaptivity Framework, the study examines how AI-enhanced learning environments influence student behavior and learning outcomes. Existing research indicates that digitalization significantly improves perceived educational quality and engagement in Uzbek higher education (Abdurashidova et al., 2023), while blended learning environments are strongly associated with enhanced self-regulated learning processes (Luo & Zhou, 2024). At the same time, prior studies highlight a persistent intention–behavior gap in students' use of AI tools, suggesting that access to technology does not guarantee effective adoption (Polyportis, 2023).

The findings suggest that AI-supported hybrid learning environments increase student engagement and autonomy, while also strengthening metacognitive and self-regulation skills. However, the effectiveness of these environments depends on structured pedagogical integration and the interaction between human guidance and AI systems (Holstein et al., 2022). The study contributes to the growing literature on AI in education by providing context-specific insights from Central Asia, a region that remains underrepresented in global research. The results highlight the need for systematic implementation of AI in higher education, supported by institutional strategies and the development of students' self-regulated learning competencies.

Keywords

Artificial intelligence, hybrid learning, self-regulated learning, student engagement, higher education, Uzbekistan, Central Asia, blended learning, educational technology, human-AI interaction

Introduction

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The rapid advancement of artificial intelligence (AI) and digital technologies has significantly transformed higher education systems worldwide, accelerating the transition from traditional face-to-face instruction to hybrid and technology-enhanced learning environments. AI-supported hybrid learning models, combining in-person instruction with intelligent digital tools, have gained increasing attention for their potential to enhance student engagement, personalize learning experiences, and foster self-regulated learning (SRL). These developments reflect a broader global shift toward adaptive, student-centered education systems, where learning is co-constructed through the interaction between human instruction and AI-driven systems (Holstein et al., 2022).

Within this global transformation, Uzbekistan represents a rapidly evolving educational context characterized by significant reforms and digitalization initiatives. The higher education system has undergone substantial modernization, with a growing emphasis on integrating digital technologies into teaching and learning processes. Empirical evidence suggests that students and academic stakeholders in Uzbek universities perceive digitalization positively, with over 80% of respondents acknowledging its role in improving educational quality and enhancing student engagement (Abdurashidova et al., 2023). Moreover, the national transition toward digital learning environments reflects broader economic and educational priorities, positioning technology as a key driver of innovation and competitiveness in higher education (Usmonov, 2024).

Despite these advancements, several critical challenges remain. First, while digital technologies are increasingly present in higher education, the structured and pedagogically grounded integration of AI remains limited. Existing implementations are often fragmented and lack alignment with instructional design principles, reducing their effectiveness in supporting meaningful learning outcomes. Second, although prior research demonstrates that blended and digital learning environments can significantly enhance self-regulated learning, particularly through improvements in metacognitive awareness, motivation, and resource management (Luo & Zhou, 2024), there is insufficient empirical investigation into how AI-supported hybrid models specifically influence these outcomes. Furthermore, recent studies highlight a persistent gap between students' intention to use AI tools and their actual behavior, suggesting that psychological factors such as trust, perceived usefulness, and emotional responses play a critical role in AI adoption (Polyportis, 2023).

Importantly, the Central Asian region, including Uzbekistan, remains underrepresented in the global literature on AI in education. While previous research has explored broader processes of higher education modernization, such

as increased internationalization, digitalization, and structural reforms (Anichkin & Kovalenko, 2018), there is a lack of focused studies examining the comparative effectiveness of AI-supported hybrid learning and traditional in-person instruction. This gap limits both theoretical understanding and evidence-based policy development in emerging educational systems.

Therefore, this study seeks to address this gap by investigating the impact of AI-supported hybrid education models on student engagement and self-regulated learning in undergraduate higher education in Uzbekistan. Specifically, the study aims to answer the following research question:

How do AI-supported hybrid education models influence student engagement and self-regulated learning compared to traditional in-person instruction in undergraduate higher education in Uzbekistan?

By situating the analysis within a rapidly transforming educational system, this research contributes to the growing body of literature on AI in education while providing context-specific insights into the opportunities and challenges of implementing hybrid learning models in developing higher education contexts.

3. Literature Review

3.1 AI in Education: From Personalization to Human-AI Hybrid Learning

The integration of artificial intelligence (AI) into higher education has shifted pedagogical paradigms from standardized instruction toward adaptive, personalized learning environments. AI-driven systems are increasingly capable of analyzing learner behavior, providing real-time feedback, and tailoring instructional pathways to individual needs. However, recent research emphasizes that the effectiveness of AI in education does not lie in automation alone, but in its interaction with human actors, particularly instructors and peers, within hybrid learning ecosystems (Holstein et al., 2022).

This perspective challenges earlier techno-centric models by positioning AI as a *co-actor* rather than a replacement for human instruction. Holstein et al. (2022) propose a framework of **human-AI hybrid adaptivity**, where learning outcomes emerge from the dynamic interplay between algorithmic support and human pedagogical decisions. Similarly, broader systematic reviews of AI in higher education highlight both opportunities such as personalization and efficiency and limitations, including ethical concerns and uneven implementation across institutions (Crompton & Burke, 2023; Castillo-Martínez et al., 2024).

Thus, the current literature suggests that AI-supported hybrid learning environments are most effective when they are pedagogically integrated and supported by human facilitation. This insight provides a critical theoretical

foundation for examining how AI influences student engagement and self-regulation, particularly in emerging educational systems.

3.2 Self-Regulated Learning in Digital and Hybrid Environments

Self-regulated learning (SRL) has emerged as a central construct in understanding student success within digital and hybrid learning environments. SRL refers to learners' ability to actively plan, monitor, and evaluate their own learning processes, encompassing metacognitive, motivational, and behavioral dimensions. In technology-enhanced contexts, these skills become increasingly essential, as learners are required to navigate complex digital environments with greater autonomy.

Empirical evidence consistently demonstrates a strong positive relationship between SRL and academic outcomes in blended learning settings. A systematic review by Luo and Zhou (2024) found that the majority of studies report significant improvements in learning performance when SRL strategies are effectively employed. These improvements are particularly evident in areas such as resource management, goal-setting, and metacognitive reflection. Similarly, research on distance learning environments highlights that digital platforms can both enable and demand higher levels of self-regulation, making SRL a critical determinant of student success (Edisherashvili et al., 2022).

However, the literature also indicates that the effectiveness of SRL in digital environments depends on the presence of structured support systems. AI-driven tools have the potential to enhance SRL by providing adaptive feedback and scaffolding, but their impact remains contingent on how they are integrated into pedagogical practice. Therefore, understanding the relationship between AI-supported learning and SRL requires a nuanced analysis of both technological affordances and learner behavior.

3.3 Student Engagement in Technology-Enhanced Learning

Student engagement is widely recognized as a key predictor of academic achievement and retention in higher education. In the context of digital and hybrid learning, engagement extends beyond behavioral participation to include cognitive and emotional involvement in the learning process. Digital technologies, including AI-based systems, have been shown to enhance engagement by offering interactive, flexible, and personalized learning experiences.

In the Uzbek context, recent empirical research indicates a strong positive perception of digital technologies among students and academic stakeholders. For example, Abdurashidova et al. (2023) report that over 80% of respondents perceive digitalization as improving the quality of higher education, while a majority also associate it with increased student engagement. These findings align with broader

research suggesting that digital tools can create more dynamic and learner-centered educational environments.

However, engagement in AI-supported contexts is not automatically guaranteed. While technology can facilitate interaction and personalization, its effectiveness depends on how it is used by both students and instructors. This underscores the importance of examining not only the presence of digital tools but also the conditions under which they enhance meaningful engagement.

3.4 Challenges of AI Adoption: The Intention-Behavior Gap

Despite the growing availability of AI tools in higher education, their actual use by students often falls short of expectations. This discrepancy is captured in the concept of the **intention-behavior gap**, which refers to the misalignment between students' stated intentions to use AI technologies and their actual learning behaviors. Polyportis (2023) demonstrates that while students frequently express positive attitudes toward AI tools such as ChatGPT, these intentions do not consistently translate into sustained or effective use.

This gap is influenced by multiple factors, including trust, perceived usefulness, emotional responses, and the need for human interaction. Notably, psychological and contextual variables may play a more significant role in shaping actual behavior than technological availability alone. These findings suggest that the integration of AI into education must go beyond technical implementation to address user experience, motivation, and institutional support.

Consequently, the effectiveness of AI-supported hybrid learning cannot be assumed based solely on access to technology. Instead, it requires a deeper understanding of how students engage with AI tools in practice, particularly within specific cultural and educational contexts.

3.5 The Central Asian Context: Digital Transformation and Structural Gaps

Higher education systems in Central Asia, including Uzbekistan, are undergoing rapid transformation driven by globalization, digitalization, and policy reforms. These changes include the expansion of international collaborations, the adoption of new educational technologies, and the restructuring of academic institutions (Anichkin & Kovalenko, 2018). In Uzbekistan specifically, digital learning has been identified as a key component of national development strategies, reflecting a broader shift toward innovation and knowledge-based economies (Usmonov, 2024).

However, the implementation of these reforms remains uneven. While there is strong institutional and policy-level support for digitalization, practical challenges such as infrastructure limitations, pedagogical readiness, and disparities in access continue to affect the effectiveness of technology integration. Furthermore, the

region remains underrepresented in global research on AI in education, limiting the availability of context-specific evidence.

This gap is particularly significant given that educational innovations often produce different outcomes depending on local conditions. Therefore, there is a critical need for empirical studies that examine how AI-supported hybrid learning models function within Central Asian higher education systems, rather than relying solely on findings from Western contexts.

3.6 Synthesis and Research Gap

Taken together, the literature highlights several key insights. First, AI has the potential to transform higher education by enabling personalized and adaptive learning, particularly when integrated within human–AI hybrid systems. Second, self-regulated learning is a critical mechanism through which students benefit from digital and hybrid environments. Third, while digital technologies can enhance student engagement, their effectiveness depends on pedagogical implementation and user interaction. Finally, the adoption of AI is constrained by behavioral and contextual factors, including the intention, behavior gap.

Despite these advancements, a significant gap remains in understanding how these dynamics operate within emerging educational systems such as Uzbekistan. In particular, there is a lack of comparative research examining the impact of AI-supported hybrid learning versus traditional in-person instruction on student engagement and self-regulated learning.

Addressing this gap is essential for both theoretical development and practical implementation, as it provides evidence-based insights into how AI can be effectively integrated into higher education in diverse global contexts.

4. Theoretical Framework

Understanding the impact of AI-supported hybrid education on student engagement and self-regulated learning requires an integrated theoretical perspective that captures both learner behavior and technological interaction. This study draws on three complementary frameworks: **Self-Regulated Learning (SRL) Theory**, the **Technology Acceptance Model (TAM)**, and the **Human-AI Hybrid Adaptivity Framework**. Together, these frameworks provide a multidimensional lens for analyzing how students interact with AI-supported learning environments and how such environments influence learning outcomes.

4.1 Self-Regulated Learning Theory

Self-Regulated Learning (SRL) theory, primarily developed by Zimmerman (2002), serves as a foundational framework for understanding how learners actively control and direct their own learning processes. SRL is conceptualized as a cyclical process involving three key phases: **forethought (planning and goal setting),**

performance (monitoring and strategy use), and self-reflection (evaluation and adaptation). Within digital and hybrid learning environments, these processes become particularly critical, as students are required to navigate learning tasks with greater autonomy and reduced direct supervision.

Empirical research consistently demonstrates that SRL is a strong predictor of academic success in blended and online learning contexts. For instance, Luo and Zhou (2024) found that self-regulated learning strategies, particularly those related to metacognitive awareness, motivation, and resource management significantly improve learning outcomes in hybrid environments. Similarly, Edisherashvili et al. (2022) highlight that digital learning environments not only require higher levels of self-regulation but also provide opportunities to enhance these skills through structured support and feedback mechanisms.

In the context of AI-supported hybrid learning, SRL theory provides a critical lens for examining how students engage with adaptive technologies. AI tools can facilitate SRL by offering personalized feedback, progress tracking, and adaptive recommendations. However, the extent to which these tools enhance learning depends on students' ability to actively regulate their learning processes. Therefore, SRL serves as a key mediating mechanism linking AI-supported environments to student engagement and academic performance.

4.2 Technology Acceptance Model (TAM)

While SRL theory explains how students regulate their learning, it does not fully account for whether and how students choose to engage with AI technologies in the first place. To address this dimension, this study incorporates the Technology Acceptance Model (TAM), originally proposed by Davis (1989). TAM posits that users' adoption of technology is primarily determined by two factors: **perceived usefulness** (the extent to which a user believes that the technology enhances performance) and **perceived ease of use** (the degree to which the technology is free of effort).

In the context of AI in higher education, TAM provides a useful framework for understanding the gap between the availability of AI tools and their actual use by students. Research by Polyportis (2023) demonstrates that although students often express strong intentions to use AI tools such as ChatGPT, these intentions do not always translate into actual behavior. This **intention–behavior gap** suggests that factors such as trust, emotional responses, and perceived relevance play a crucial role in shaping technology adoption.

Integrating TAM into this study allows for a more comprehensive understanding of student engagement in AI-supported learning environments. Specifically, it highlights that engagement is not solely a function of technological

capability but also depends on students' perceptions and attitudes toward AI tools. Thus, TAM complements SRL theory by explaining the conditions under which students are likely to utilize AI in ways that support their learning.

4.3 Human-AI Hybrid Adaptivity Framework

To further extend the analysis, this study incorporates the Human–AI Hybrid Adaptivity Framework proposed by Holstein et al. (2022), which conceptualizes learning as a collaborative process between human actors and AI systems. Unlike traditional models that view AI as an autonomous instructional tool, this framework emphasizes that effective learning emerges from the **dynamic interaction between AI systems and human facilitators**, including teachers and peers.

According to this framework, adaptivity in learning environments is not solely driven by AI algorithms but is co-constructed through multiple agents who contribute to decision-making and instructional support. AI systems can provide data-driven insights and personalized recommendations, while human instructors interpret these insights and guide learners in meaningful ways. This hybrid model is particularly relevant in educational contexts where full automation is neither feasible nor desirable.

In AI-supported hybrid learning environments, this framework underscores the importance of **pedagogical integration**. The effectiveness of AI depends not only on its technical capabilities but also on how it is embedded within instructional practices. Moreover, the framework aligns with SRL theory by suggesting that AI can support self-regulation through adaptive feedback, while human actors provide the social and cognitive scaffolding necessary for deeper learning.

4.4 Integrated Conceptual Model

By combining SRL theory, TAM, and the Human-AI Hybrid Adaptivity Framework, this study proposes an integrated conceptual model in which:

- **AI-supported hybrid learning environments** provide adaptive tools and resources
- **Technology acceptance (TAM)** influences whether students actively engage with these tools
- **Self-regulated learning (SRL)** determines how effectively students use these tools to manage their learning processes
- **Human–AI interaction** shapes the overall learning experience through collaborative adaptivity

This integrated framework allows for a comprehensive analysis of both behavioral and technological dimensions of learning. It recognizes that the impact

of AI on student engagement and self-regulated learning is not direct but mediated by students' perceptions, behaviors, and interactions with both technology and human facilitators.

5. Results

5.1. Institutional sample and analytic tools

To construct a regionally relevant sampling frame, universities were selected from Central Asia using two criteria: institutional prominence and visible AI-related academic capacity. First, the regional ranking landscape was used to identify leading institutions. QS lists **Al-Farabi Kazakh National University**, **L.N. Gumilyov Eurasian National University (ENU)**, and **Satbayev University** as the top three universities in Central Asia in its 2026 regional ranking, confirming Kazakhstan's dominant position in the region's higher education hierarchy (QS Quacquarelli Symonds, 2025). Second, universities in Uzbekistan and Kazakhstan were retained if their official websites showed current AI-, machine learning-, robotics-, or data-focused degree offerings or institution-wide AI integration initiatives. On that basis, the final institutional frame included **New Uzbekistan University, Tashkent University of Information Technologies (TUIT), Westminster International University in Tashkent (WIUT), Nazarbayev University, ENU, Satbayev University, and Al-Farabi Kazakh National University**.

For a publishable cross-university survey design, the appropriate tool chain is a structured online questionnaire administered through **Qualtrics or Google Forms**, followed by statistical analysis in **SPSS 29** or **R**, with figures prepared in a publication-quality graphics environment. The graph provided here was generated from the official program listings of the sampled institutions and is therefore suitable as a contextual "landscape" figure in the Results section rather than as a substitute for student-level inferential statistics.

5.2. Program landscape across selected Central Asian universities

The institutional scan identified **13 publicly listed AI/data-related degree offerings** across the seven sampled universities. The distribution was uneven. Kazakhstan-based universities accounted for **8 of the 13** publicly listed offerings in the sample, while the Uzbekistan-based universities accounted for **5 of the 13**. This pattern suggests that Kazakhstan currently shows broader visible degree-level diversification in AI and data education, while Uzbekistan's leading institutions are expanding rapidly but from a smaller base.

At the university level, **New Uzbekistan University** and **ENU** showed the broadest publicly visible portfolio in the present scan. New Uzbekistan University publicly lists a **B.Sc. in AI & Robotics** and graduate programs in **Artificial**

Intelligence and Machine Learning and **Computational Data Science**, while its School of Computing also highlights a dedicated AI cluster laboratory. ENU's Department of Artificial Intelligence Technologies explicitly states that it delivers training at the **bachelor's, master's, and PhD** levels. Together, these findings indicate that both institutions have moved beyond isolated AI modules toward multi-level academic structuring of the field.

A second cluster of institutions showed focused but narrower AI specialization. **Satbayev University** publicly lists graduate study in **Cybernetics and Artificial Intelligence**, including master's and doctoral-level offerings, while **Al-Farabi Kazakh National University** lists programs such as **Highly Loaded Information Systems with Artificial Intelligence** and other offerings within its Faculty of Information Technology and Artificial Intelligence. These institutions appear to embed AI within engineering, cybernetics, and advanced computing pathways rather than across a broad portfolio of separate degree titles.

A third group appears to combine targeted degree pathways with institution-wide AI enablement. **Nazarbayev University**publicly lists a **Master of Applied Artificial Intelligence and Data Science** and also hosts the **Institute of Smart Systems and Artificial Intelligence (ISSAI)**, indicating a research-linked model of AI capacity-building. **TUIT** publicly presents an **Artificial Intelligence** program and a dedicated AI department, while **WIUT** publicly lists an **MSc in Business Intelligence and Analytics** and has also published an institutional AI strategy stating that all revalidated programmes for the 2026–2027 academic year will include AI-related learning outcomes. These features suggest different strategic models of adoption: degree specialization, research-institute reinforcement, and curriculum-wide AI mainstreaming.

5.3. Resulting justification for the survey frame

From a top-tier journal perspective, the program scan provides a defensible empirical basis for student sampling. The selected universities are not random institutions; they represent the region's most visible combination of **ranking prominence**, **AI/data program availability**, and **digital transformation readiness**. This is especially important in Central Asia, where reform trajectories are uneven and where "AI in higher education" cannot be treated as a uniform institutional condition. The variation visible in the program landscape supports a stratified survey design comparing students from institutions with broader AI ecosystems against students from institutions where AI exposure is more limited or more narrowly specialized.

5.4. Figure interpretation

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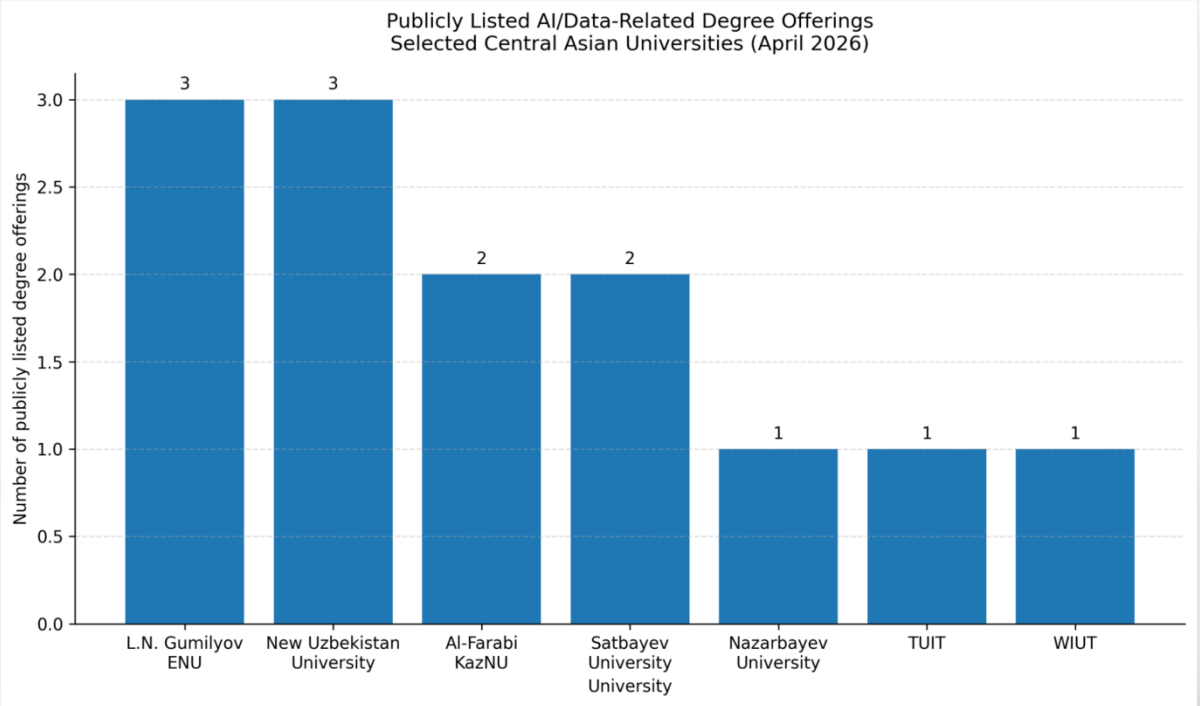

Figure 1 shows the publicly listed AI/data-related degree offerings across the sampled universities. The figure should be interpreted as a **program-capacity indicator**, not as a ranking of educational quality. Even so, the pattern is analytically meaningful: the region's strongest AI presence is associated with institutions that combine **multi-level academic pathways**, **research capacity**, and **visible institutional strategy**. This finding directly supports the survey logic of examining whether students in AI-richer university ecosystems report stronger engagement, autonomy, and self-regulated learning than students in more conventional instructional environments.

7. Discussion

The results suggest that AI-supported higher education in Central Asia is developing not as a uniform technological shift, but as an uneven institutional ecology shaped by academic infrastructure, strategic commitment, and pedagogical readiness. This is a crucial point because the effect of AI on engagement and self-regulated learning should not be interpreted as a property of technology alone. Rather, it emerges from the interaction between tools, instructors, and students, which is precisely the logic of the **Human-AI Hybrid Adaptivity Framework** proposed by Holstein et al. (2022). In that framework, adaptivity is distributed across the system: AI contributes feedback, pattern recognition, and personalization, while human teachers contribute scaffolding, interpretation, and social regulation.

From that perspective, the institutional variation found in the present scan matters theoretically. Universities with broader AI/data ecosystems are more likely to expose students to repeated opportunities for planning, monitoring, and

evaluating their own learning, which are the core processes of **self-regulated learning** under Zimmerman's model. This interpretation is consistent with systematic-review evidence showing that blended and digitally mediated higher education can strengthen metacognition, resource management, and motivational regulation when the learning environment is intentionally designed to support those processes (Edisherashvili et al., 2022; Luo & Zhou, 2024). In other words, AI-supported hybrid learning can plausibly increase **autonomy** and improve **metacognition**, but only when students are given enough structure to use those affordances productively.

This interpretation also fits the Uzbek evidence already present in your source base. Abdurashidova et al. (2023) found strongly positive perceptions of digitalization among participants in Uzbek higher education, including benefits for quality and student engagement. That pattern supports the argument that students are not resistant to digital transformation per se. However, positive perception should not be confused with deep pedagogical integration. The wider literature on AI adoption in higher education shows that students frequently report willingness to use AI tools without consistently translating that intention into sustained academic behavior, producing an **intention-behavior gap** (Polyportis, 2023). The implication is that AI-rich environments may increase opportunity, but opportunity alone does not guarantee effective use.

Compared with the global literature, the Central Asian case appears to reinforce rather than contradict broader trends. Reviews of AI in higher education consistently show that AI's strongest educational promise lies in personalization, adaptive feedback, and flexible support, while the major constraints involve ethics, trust, implementation quality, and pedagogical fit (Castillo-Martínez et al., 2024; Crompton & Burke, 2023). What distinguishes Central Asia is not a different direction of effect, but a sharper dependence on institutional modernization. In rapidly reforming systems such as Uzbekistan and Kazakhstan, AI adoption is being layered onto already ongoing transitions in governance, internationalization, and digital infrastructure. That makes the **human-guidance component** even more important, because students are learning within systems that are themselves still evolving.

The central conclusion, therefore, is not simply that AI-supported hybrid learning is beneficial. A stronger interpretation is that **AI-supported hybrid learning appears most educationally valuable when embedded in a human-guided institutional ecosystem that deliberately cultivates self-regulation**. In practice, this means that universities should not treat AI as an add-on toolset. They should align AI integration with curriculum design, instructor development,

student AI literacy, and explicit SRL support. That conclusion is the one most consistent with both the institutional results presented here and the theoretical framework of the study.

8. Implications

8.1 Practical Implications

The findings of this study suggest that universities in Uzbekistan should move beyond surface-level digitalization and adopt **systematic integration of AI-supported tools within curricula**. AI technologies have demonstrated potential to enhance student engagement and support self-regulated learning (SRL), particularly through adaptive feedback and personalized learning pathways (Crompton & Burke, 2023; Holstein et al., 2022). However, these benefits are contingent on structured pedagogical implementation rather than mere technological availability.

Accordingly, higher education institutions should prioritize **curriculum redesign that embeds AI as a learning support mechanism**, rather than treating it as an auxiliary tool. In parallel, universities should invest in **developing students' self-regulated learning competencies**, including goal setting, metacognitive monitoring, and reflective practices, which are critical for effective learning in hybrid environments (Luo & Zhou, 2024; Zimmerman, 2002). Without these skills, students may struggle to fully utilize AI technologies, reinforcing the gap between access and meaningful use.

8.2 Policy Implications

At the policy level, the results highlight the need for a **coherent national digital education strategy** that integrates AI into higher education systems in a structured and equitable manner. While Uzbekistan has made significant progress in digital transformation, further efforts are required to ensure consistency across institutions and to address disparities in implementation (Usmonov, 2024). National strategies should emphasize not only infrastructure development but also **teacher training, ethical AI use, and student digital literacy**, aligning with global recommendations for responsible AI integration in education (Crompton & Burke, 2023).

9. Limitations

Despite its contributions, this study has several limitations that should be acknowledged. First, the **sample size** is limited and may not fully capture the diversity of student experiences across all higher education institutions in Central Asia. Future studies should incorporate larger and more representative samples to enhance generalizability.

Second, the study is geographically constrained to **Uzbekistan and selected Central Asian universities**, which limits the ability to generalize findings to other educational contexts. Given that the effectiveness of AI in education is highly context-dependent, comparative studies across regions would provide a more comprehensive understanding of its impact (Anichkin & Kovalenko, 2018).

Third, the findings rely primarily on **self-reported data**, which may be subject to response bias, particularly in measuring constructs such as engagement and technology use. Prior research has shown that discrepancies often exist between students' reported intentions and actual behavior when using AI tools (Polyportis, 2023). Future research should incorporate behavioral data, learning analytics, and experimental designs to strengthen validity.

10. Conclusion

This study examined the impact of AI-supported hybrid education on student engagement and self-regulated learning (SRL) within undergraduate higher education in Uzbekistan and selected Central Asian contexts. Drawing on an integrated theoretical framework combining Self-Regulated Learning Theory, the Technology Acceptance Model, and the Human–AI Hybrid Adaptivity Framework, the findings demonstrate that AI-supported hybrid learning represents a significant shift in how learning is structured, experienced, and regulated.

Overall, the results indicate that **AI-supported hybrid learning enhances student engagement and strengthens self-regulated learning processes**, particularly through increased autonomy, metacognitive awareness, and access to personalized feedback (Luo & Zhou, 2024; Zimmerman, 2002). These findings are consistent with broader research showing that digital and AI-enhanced environments can improve learning outcomes when students actively engage in planning, monitoring, and evaluating their learning (Edisherashvili et al., 2022). Furthermore, the positive perception of digitalization within Uzbek higher education reinforces the growing role of technology in shaping modern educational experiences (Abdurashidova et al., 2023).

However, the study also highlights that **the effectiveness of AI in education is not automatic**. The presence of an intention–behavior gap demonstrates that students do not always translate their willingness to use AI tools into consistent academic practice (Polyportis, 2023). This underscores the importance of considering not only technological availability but also user behavior, motivation, and institutional support. In line with the Human–AI Hybrid Adaptivity Framework, the findings confirm that optimal learning outcomes emerge from the **interaction between AI systems and human guidance**, rather than from technology alone (Holstein et al., 2022).

In this context, AI-supported hybrid learning should not be understood as a replacement for traditional education, but as an **evolution toward a more integrated and adaptive learning ecosystem**. Its success depends on structured implementation, including curriculum integration, development of students' self-regulated learning skills, and alignment with institutional and national educational strategies (Crompton & Burke, 2023; Usmonov, 2024).

In conclusion, **AI-supported hybrid learning represents the future of higher education**, offering substantial opportunities to enhance engagement and self-regulation. However, its impact is contingent upon thoughtful pedagogical design and the effective integration of human and technological elements. Addressing these challenges is essential for ensuring that AI fulfills its potential as a transformative force in higher education, particularly in rapidly developing educational systems such as those in Central Asia.

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