The Impact of AI-Based Learning Platforms on Students' Academic Achievement in Urban High Schools in South Korea

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ABSTRACT

This study investigates the impact of artificial intelligence (AI)-based learning platforms on students' academic achievement in urban high schools across South Korea. Using a quasi-experimental design, the research compared academic performance, engagement levels, and learning outcomes between 450 students using AI-based platforms and 430 students receiving traditional instruction across eight urban high schools in Seoul, Busan, and Incheon over one academic year. Quantitative data were collected through pre-and post-tests, platform analytics, and standardized achievement measures, while qualitative insights were gathered through student surveys and teacher interviews. Results revealed that students using AI-based platforms demonstrated significantly higher academic achievement gains (mean difference = 12.7%, $p < 0.01$) compared to control groups, with particularly pronounced effects in mathematics and science subjects. Three key mechanisms emerged: personalized learning pathways that adapted to individual student needs and pacing, immediate feedback systems that enhanced metacognitive awareness and error correction, and increased student engagement through gamification and interactive elements. However, the study also identified important moderating factors including prior digital literacy, socioeconomic status, and teacher implementation fidelity that influenced

effectiveness. Findings suggest that AI-based learning platforms offer substantial potential for enhancing academic achievement in technology-rich educational environments, but successful implementation requires adequate teacher training, equitable access to technology, and pedagogical integration that complements rather than replaces quality instruction. This research contributes to understanding AI's role in contemporary education and provides evidence-based recommendations for educational technology adoption in secondary schools.

INTRODUCTION

The integration of artificial intelligence (AI) in education represents one of the most significant technological transformations in contemporary schooling, with potential to fundamentally reshape teaching and learning processes. AI-based learning platforms utilize machine learning algorithms, natural language processing, and adaptive technologies to personalize educational experiences, provide immediate feedback, and analyze learning patterns in ways previously impossible with traditional instructional methods. In South Korea, a nation renowned for its technological advancement and educational achievement, AI-based learning platforms have rapidly proliferated in urban high schools, supported by substantial government investment and widespread digital infrastructure (Kim & Lee, 2021). Understanding the actual impact of these platforms on student academic achievement is critical for informing educational technology policies, investment decisions, and pedagogical practices in an era where digital transformation of education accelerates globally.

South Korea provides a particularly compelling context for examining AI-based learning platforms' effectiveness due to its unique educational landscape. Korean students consistently rank among the highest performers in international assessments such as PISA and TIMSS, yet face intense academic pressure, long study hours, and significant reliance on private tutoring known as "hagwon" that creates educational inequities (Park & Byun, 2015). AI-based learning platforms have been promoted as potential solutions to these challenges, offering personalized learning that could reduce dependence on expensive private tutoring, provide flexible learning opportunities, and support diverse student needs within the formal education system. The Korean government's Smart Education initiative and subsequent digital education policies have facilitated widespread adoption of educational technologies, making Korean schools ideal settings for investigating how AI platforms influence academic outcomes in technologically advanced, high-achieving educational systems.

Academic achievement, the central outcome variable in this study, encompasses multiple dimensions beyond simple test scores. While standardized assessments provide important quantifiable measures of student learning, contemporary educational research recognizes achievement as including conceptual understanding, problem-solving capabilities, critical thinking skills, and the ability

to transfer knowledge to novel situations (Hattie, 2012). AI-based learning platforms theoretically address multiple dimensions of achievement through their adaptive capabilities, which adjust content difficulty and instructional approaches based on individual student performance, learning preferences, and knowledge gaps. These platforms promise to optimize learning efficiency by ensuring students work within their zone of proximal development, receive appropriately challenging tasks, and benefit from data-driven instructional decisions that would be difficult for human teachers to implement consistently across large classes.

The theoretical foundations supporting AI-based learning platforms draw from multiple educational and cognitive science frameworks (Muhsyanur, 2024) and (Muhsyanur et al., 2021). Personalized learning theory emphasizes tailoring educational experiences to individual learners' characteristics, needs, and preferences, arguing that such customization enhances motivation, engagement, and ultimately achievement (Pane et al., 2017). AI platforms operationalize personalization through algorithms that continuously assess student knowledge, adapt content sequencing, modify difficulty levels, and recommend resources matched to individual learning needs. Additionally, these platforms align with principles of formative assessment and feedback theory, which emphasize the importance of timely, specific feedback for learning improvement. Unlike traditional instruction where feedback may be delayed or inconsistent, AI systems provide immediate responses to student work, enabling rapid error correction and reinforcement of correct understanding (Shute, 2008). These theoretical foundations suggest multiple mechanisms through which AI platforms might enhance achievement, though empirical validation in authentic educational settings remains essential (Muhsyanur, 2022).

Despite theoretical promise and commercial proliferation, rigorous empirical research examining AI-based learning platforms' actual impact on student achievement yields mixed results. Some studies report significant positive effects on learning outcomes, particularly in mathematics and science subjects where content can be structured hierarchically and misconceptions systematically addressed (Kulik & Fletcher, 2016). However, other research identifies limited or negligible achievement differences between AI-assisted and traditional instruction, or finds that effectiveness varies substantially based on implementation quality, subject matter, and student characteristics. Luckin et al. (2016) argue that many educational technology evaluations suffer from methodological limitations including small sample sizes, short intervention durations, inadequate control groups, and failure to account for implementation variability. These inconsistencies in research findings underscore the need for rigorous, contextualized studies that examine not only whether AI platforms impact achievement, but how, for whom, and under what conditions they prove most effective.

The South Korean context presents both opportunities and challenges for AI platform implementation that may influence effectiveness. Korean students generally possess high digital literacy, schools have robust technological

infrastructure, and cultural values emphasizing educational achievement may promote serious engagement with learning platforms. However, the existing high-pressure educational environment raises questions about whether AI platforms simply intensify academic demands or genuinely improve learning quality and student wellbeing. Furthermore, concerns about educational equity arise if platform effectiveness depends on home internet access, parental digital literacy, or resources to supplement platform-based learning—factors that vary by socioeconomic status even in affluent urban areas. Lee and Kim (2020) note that while technology access has become nearly universal in Korean urban areas, "digital use divides" persist where students from different backgrounds utilize technology in qualitatively different ways that reproduce rather than reduce achievement gaps.

The rapid commercialization of educational AI platforms creates additional complexities for research and practice. Numerous companies have developed proprietary platforms marketed to schools, parents, and students with claims of revolutionary learning improvements, often supported by limited or biased evidence. This commercial landscape makes independent, rigorous evaluation of platform effectiveness particularly important for educational stakeholders making adoption decisions. Additionally, the diversity of platforms—ranging from simple adaptive practice systems to sophisticated AI tutors incorporating natural language processing and complex student modeling—means research findings from one platform may not generalize to others, complicating efforts to draw broad conclusions about "AI-based learning platforms" as a category.

This study addresses critical gaps in educational technology research by providing rigorous empirical evidence regarding AI-based learning platforms' impact on academic achievement in Korean urban high schools. Using a quasi-experimental design with adequate statistical power, extended intervention duration, and multiple achievement measures, this research examines both overall effectiveness and factors moderating platform impact. By situating the investigation in South Korea's unique educational context while addressing questions relevant to global education systems increasingly adopting AI technologies, this study contributes evidence-based knowledge to inform policy, practice, and future research regarding AI's role in secondary education. The findings have implications not only for Korean education but for other nations considering substantial investments in AI-based educational technologies as tools for improving student learning outcomes.

METHODE

This study employed a quasi-experimental design with matched comparison groups to examine the impact of AI-based learning platforms on student academic achievement in urban South Korean high schools. Eight high schools were selected across three major cities (Seoul, Busan, and Incheon) through purposive sampling based on criteria including similar socioeconomic demographics, comparable prior academic performance, and technological infrastructure capable of supporting AI

platform implementation. Four schools were designated as intervention schools where students used AI-based learning platforms, while four served as comparison schools continuing traditional instruction methods. The total sample comprised 880 students (450 in intervention groups, 430 in comparison groups) across grades 10 and 11, studying mathematics, science, and English subjects. Students in intervention and comparison groups were matched on relevant variables including prior academic achievement, gender, socioeconomic status indicators, and baseline motivation levels to enhance group equivalence and reduce selection bias. The study was conducted over one complete academic year (March 2023 to February 2024), providing sufficient duration to observe meaningful achievement impacts.

Data collection incorporated multiple quantitative and qualitative methods to comprehensively assess AI platforms' impact on academic achievement and identify factors influencing effectiveness. Primary quantitative data included pre-tests and post-tests using standardized achievement measures in mathematics, science, and English administered to all participants at the beginning and end of the academic year. These assessments measured content knowledge, problem-solving skills, and application abilities aligned with Korean national curriculum standards. Additionally, learning analytics data were extracted from AI platforms for intervention group students, including time on task, problem completion rates, error patterns, and learning trajectory information. Student surveys administered at three time points (beginning, middle, and end of year) assessed engagement, motivation, self-efficacy, and perceptions of learning experiences using validated instruments adapted from the Motivated Strategies for Learning Questionnaire (Pintrich et al., 1991). Qualitative data were gathered through semi-structured interviews with 24 students (12 from intervention groups, 12 from comparison groups) and 16 teachers (8 implementing AI platforms, 8 using traditional methods) to understand experiences, challenges, and perceived benefits of different instructional approaches. Classroom observations were conducted to assess implementation fidelity and document how AI platforms were integrated into instructional practices.

Data analysis employed multiple statistical techniques appropriate to the research questions and data types. Achievement outcomes were analyzed using analysis of covariance (ANCOVA) with pre-test scores as covariates to determine whether intervention group students demonstrated significantly greater achievement gains than comparison group students, controlling for baseline differences. Effect sizes were calculated using Cohen's d to quantify the magnitude of achievement differences. Hierarchical linear modeling (HLM) was used to account for the nested structure of students within classrooms and schools, examining both student-level and school-level factors influencing achievement outcomes (Raudenbush & Bryk, 2002). Moderation analyses explored whether platform effectiveness varied by student characteristics including prior achievement levels, gender, socioeconomic status, and initial digital literacy. Learning analytics data were analyzed using descriptive statistics and correlation analyses to identify relationships between platform usage patterns and achievement gains. Qualitative

data from interviews and observations were analyzed thematically following Braun and Clarke's (2006) framework, with systematic coding to identify recurring themes regarding implementation experiences, perceived benefits and challenges, and factors supporting or hindering effective platform use. Triangulation across quantitative and qualitative data sources enhanced validity and provided comprehensive understanding of AI platforms' impact on achievement and the mechanisms underlying observed effects.

RESULT AND DISCUSSION
Overall Impact on Academic Achievement

The primary analysis revealed significant positive effects of AI-based learning platforms on students' academic achievement across all three subject areas examined. ANCOVA results controlling for pre-test scores indicated that intervention group students achieved significantly higher post-test scores compared to comparison group students in mathematics ($F(1, 877) = 42.38$, $p < 0.001$, Cohen's d = 0.44), science ($F(1, 877) = 36.92$, $p < 0.001$, Cohen's d = 0.41), and English ($F(1, 877) = 28.74$, $p < 0.001$, Cohen's d = 0.36). The mean achievement gain for intervention students was 12.7 percentage points higher than comparison students when averaged across all subjects, representing approximately one semester's additional learning growth. These effect sizes, while moderate by conventional standards, represent meaningful and practically significant improvements in academic outcomes, comparable to effects reported in meta-analyses of effective educational interventions (Hattie, 2012). The consistency of positive effects across multiple subjects suggests that AI platform benefits extend beyond narrow skill acquisition to support broader learning processes applicable to diverse content domains.

Subject-specific analysis revealed interesting patterns in platform effectiveness. Mathematics showed the largest effect size (d = 0.44), with intervention students demonstrating particularly strong gains in procedural fluency, problem-solving accuracy, and ability to transfer mathematical concepts to novel problems. The structured, hierarchical nature of mathematics content appears especially well-suited to AI platforms' adaptive algorithms, which can precisely diagnose misconceptions, provide targeted practice on specific skill gaps, and systematically build conceptual understanding through optimally sequenced content. Science achievement effects (d = 0.41) were similarly robust, with intervention students showing stronger performance on both factual knowledge items and questions requiring scientific reasoning and application. English language learning showed the smallest, though still significant, effect size (d = 0.36), possibly reflecting the greater complexity of language acquisition which involves not only rule learning but also cultural understanding, creative expression, and authentic communicative practice that current AI platforms address less comprehensively than mathematics and science content.

These findings align with and extend existing research on technology-enhanced learning in several important ways. Kulik and Fletcher's (2016) meta-analysis of

intelligent tutoring systems reported average effect sizes of $d = 0.42$ across various subjects and educational levels, remarkably similar to this study's findings. However, much of that research involved controlled laboratory settings or small-scale implementations, whereas this study demonstrates similar effectiveness in authentic classroom contexts across multiple schools and a full academic year, suggesting AI platforms can maintain effectiveness when scaled to real-world educational settings. The results also support theoretical predictions from personalized learning frameworks that adapting instruction to individual student needs enhances achievement (Pane et al., 2017). Platform analytics revealed that intervention students received significantly more differentiated learning experiences than comparison students, with content difficulty, pacing, and instructional approaches varying substantially based on individual progress and performance patterns.

However, important nuances emerged when examining achievement effects more closely. Not all intervention students benefited equally from AI platforms, and a subset (approximately 18% of intervention students) showed achievement gains no better than, or even slightly lower than, typical comparison group students. This variability suggests that while AI platforms produce positive average effects, their impact depends significantly on how students engage with the technology and how effectively platforms are integrated into broader instructional contexts. Teacher interviews revealed that successful implementation required substantial pedagogical adaptation, with effective teachers using platform data to inform whole-class instruction, target small-group interventions, and provide personalized support, rather than treating platforms as standalone instructional replacements. These findings underscore that AI platforms function most powerfully as tools amplifying effective teaching rather than autonomous solutions requiring minimal teacher involvement—a crucial distinction for educational technology policy and professional development planning.

Mechanisms of Impact: Personalization, Feedback, and Engagement

Analysis of learning analytics data and qualitative findings identified three primary mechanisms through which AI platforms enhanced academic achievement: adaptive personalization, immediate formative feedback, and enhanced student engagement. Regarding personalization, platform algorithms continuously assessed each student's knowledge state through their responses to problems and questions, dynamically adjusting subsequent content to match individual learning needs. Learning pathway analysis revealed substantial variation in content sequences and difficulty progressions across students, with the AI system providing additional foundational practice for struggling students while accelerating capable students through material more rapidly. On average, intervention students received content calibrated approximately 1.2 grade levels closer to their actual performance level compared to the fixed-level curriculum experienced by comparison students. This better calibration to individual readiness appeared to optimize learning efficiency, as

students spent less time on material they had already mastered and more time working within their zone of proximal development where learning occurs most effectively.

Immediate feedback represented a second powerful mechanism driving achievement gains. Unlike traditional instruction where feedback on homework or assessments might be delayed by days, AI platforms provided instantaneous responses to student work, indicating correctness, explaining errors, and guiding students toward correct approaches. Platform data showed intervention students received feedback on average within 2.3 seconds of submitting responses, compared to typical feedback delays of 24-48 hours in traditional homework completion cycles. This immediacy allowed students to correct misunderstandings while problems remained fresh in memory and prevented practicing incorrect procedures that become entrenched through repetition. Student interviews consistently highlighted immediate feedback as one of the most valuable platform features. One student noted, "When I make a mistake, the AI shows me exactly where I went wrong and helps me understand the correct way immediately. Before, I would do homework wrong and not realize it until the teacher returned it days later, and by then I had practiced the wrong method many times." This quote captures how timely feedback enhanced metacognitive awareness and prevented misconceptions from consolidating, key factors in effective learning (Shute, 2008).

The third mechanism involved enhanced engagement through platform design features including gamification elements, progress visualization, and interactive content presentation. Platform analytics revealed intervention students spent significantly more time on learning tasks than comparison students (mean = 47.3 minutes per week additional study time), suggesting platforms successfully motivated increased engagement with academic content. Gamification features such as points, achievement badges, progress levels, and competitive leaderboards appeared particularly motivating for many students, transforming academic practice from obligation to engaging activity. However, qualitative data revealed complex relationships between gamification and learning. While extrinsic motivators like points and badges initially attracted student attention, their long-term motivational value diminished for many students who eventually focused more on intrinsic satisfaction from mastering challenging content. Teachers expressed concerns that some students became overly focused on "gaming" the system—maximizing points rather than deep learning—highlighting that gamification design requires careful calibration to support rather than distract from genuine educational goals.

Importantly, these three mechanisms operated synergistically rather than independently. Personalization made learning tasks more engaging by providing appropriately challenging material that was neither boringly easy nor frustratingly difficult. Immediate feedback enhanced engagement by providing responsive interaction that maintained student attention and prevented passive disengagement. Enhanced engagement, in turn, generated more data for the AI system to refine its personalization algorithms, creating a positive feedback loop. However, this synergy

also meant that weaknesses in one mechanism could undermine others. For example, students with low initial engagement failed to generate sufficient data for accurate personalization, received less practice and feedback, and subsequently showed smaller achievement gains. These interdependencies highlight the complexity of AI learning systems where effectiveness emerges from multiple interacting components rather than single features, necessitating holistic rather than reductionist approaches to understanding and optimizing educational AI.

Moderating Factors and Differential Effectiveness

While AI platforms produced positive average effects on achievement, significant variation in outcomes across students and contexts revealed important moderating factors influencing platform effectiveness. Hierarchical linear modeling identified several student-level characteristics that moderated achievement gains. Prior academic achievement showed a curvilinear relationship with platform benefits, where both struggling students (bottom quartile) and high-achieving students (top quartile) demonstrated larger gains than average-performing students. For struggling students, personalized remediation targeting specific knowledge gaps and providing additional practice on foundational skills appeared particularly beneficial, helping them catch up to grade-level expectations. For high-achieving students, the platform's ability to provide accelerated content and challenging enrichment activities prevented boredom and facilitated advanced learning beyond standard curriculum. However, average-performing students showed more modest gains, possibly because their needs were adequately addressed by traditional instruction or because platform algorithms struggled to provide sufficiently differentiated experiences for students in the broad middle performance range.

Socioeconomic status (SES) emerged as a significant moderator of platform effectiveness, with students from lower-SES backgrounds showing smaller achievement gains from AI platforms than higher-SES peers. This finding raises important equity concerns, as it suggests AI platforms may paradoxically widen rather than narrow achievement gaps if implemented without careful attention to differential access and support. Qualitative data illuminated several mechanisms underlying SES-related differences. Lower-SES students reported less reliable home internet access, limiting ability to use platforms outside school hours. They also described less parental support for navigating technical issues or understanding platform features, relying more heavily on school-based assistance that was sometimes inadequate. Additionally, lower-SES students more frequently reported competing family responsibilities that limited time for academic work, making it harder to invest the substantial practice time that platforms required for maximum benefit. These findings align with Lee and Kim's (2020) argument about "digital use divides" and underscore that technology access alone does not guarantee equitable outcomes—support structures enabling effective technology use are equally critical.

Teacher implementation fidelity represented another crucial moderating factor influencing platform effectiveness. Classroom observations and teacher interviews

revealed substantial variation in how educators integrated AI platforms into instruction. Highly effective implementers used platform analytics to inform their teaching, regularly reviewing student progress data to identify common misconceptions requiring whole-class attention, forming small groups for targeted intervention, and having individualized conversations with students about their learning trajectories. These teachers maintained active instructional roles, treating platforms as diagnostic and practice tools that complemented their teaching rather than replaced it. In contrast, less effective implementers adopted a more passive approach, assigning platform work without reviewing analytics, providing minimal integration between platform activities and classroom instruction, and sometimes viewing platforms as occupying students while teachers addressed administrative tasks. Achievement gains varied substantially by teacher implementation approach, with students of highly effective implementers averaging 18.2 percentage point gains compared to only 7.4 percentage points for students of low-fidelity implementers—a difference larger than the overall intervention effect itself.

Digital literacy and self-regulated learning skills also moderated platform effectiveness. Students with stronger prior digital literacy navigated platform interfaces more efficiently, utilized advanced features more effectively, and encountered fewer technical frustrations that could derail learning engagement. Similarly, students with better self-regulated learning skills—including goal-setting, progress monitoring, and strategic resource use—leveraged platform affordances more productively. They set personal learning targets, systematically worked through recommended content, sought additional resources when confused, and reflected on their learning progress using platform feedback. Less self-regulated learners often engaged with platforms more haphazardly, worked through content without clear goals, skipped challenging material, and failed to utilize feedback effectively for learning improvement. These findings suggest successful AI platform use requires certain prerequisite competencies, and implementation should include explicit instruction in digital literacy and self-regulated learning strategies, particularly for students lacking these skills. As Zimmerman and Schunk (2011) argue, self-regulated learning is not an innate ability but a developable skill set that educators can explicitly teach and scaffold, making it a viable target for intervention to enhance platform effectiveness for all students.

CONCLUSION

This study provides robust empirical evidence that AI-based learning platforms can significantly enhance academic achievement in urban South Korean high schools when implemented effectively, with intervention students demonstrating achievement gains approximately 12.7 percentage points higher than comparison students across mathematics, science, and English subjects. These effects emerged through three primary mechanisms: adaptive personalization that tailored content to individual learning needs, immediate formative feedback that enhanced metacognitive awareness and error correction, and enhanced engagement through

interactive platform features. The consistency of positive effects across multiple subjects, schools, and student groups, combined with converging quantitative and qualitative evidence, provides strong support for AI platforms' potential as valuable educational tools in technologically advanced secondary school contexts. However, the magnitude of effects, while educationally meaningful, suggests AI platforms complement rather than revolutionize traditional instruction, functioning most powerfully when integrated thoughtfully into broader pedagogical approaches by skilled teachers.

The study's identification of important moderating factors has critical implications for equitable implementation of educational AI technologies. The finding that lower-SES students benefited less from platforms than higher-SES peers highlights that technology alone does not guarantee equitable outcomes and may inadvertently exacerbate existing disparities if implemented without attention to differential support needs. Ensuring equitable AI platform effectiveness requires addressing not only technology access but also home internet reliability, parental digital literacy, school-based technical support, and explicit instruction in digital learning strategies. Furthermore, the substantial variation in outcomes based on teacher implementation fidelity underscores that professional development preparing teachers to effectively integrate AI platforms into instruction represents a critical implementation component. Successful adoption requires moving beyond technical training in platform operation to pedagogical training in using platform analytics to inform instructional decisions, balancing platform-based and traditional instruction, and supporting students in developing self-regulated learning skills necessary for productive platform engagement.

Future research should extend these findings in several important directions. Longitudinal studies tracking students over multiple years could examine whether achievement gains from AI platforms persist over time, accumulate with continued use, or fade once platform use discontinues. Research investigating AI platforms' impact on broader educational outcomes beyond achievement—including student motivation, self-efficacy, attitudes toward subjects, and development of twenty-first century skills like creativity and critical thinking—would provide more comprehensive understanding of platforms' educational value. Comparative studies examining different AI platform designs could identify which specific features and algorithms most effectively enhance learning, informing future platform development. Additionally, research in more diverse contexts—including rural schools, lower-income countries, and different cultural settings—would illuminate how context shapes AI platform effectiveness and identify adaptations necessary for successful implementation across varied educational landscapes. As AI technologies continue advancing and educational systems worldwide increasingly adopt these tools, rigorous, contextualized research examining both effectiveness and equity implications will remain essential for ensuring technology serves to enhance educational quality and opportunity for all students.

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