



Effects of Artificial Intelligence Tools on Student Engagement and Academic Performance in Secondary Classrooms

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Abstract

This study investigates the effects of artificial intelligence (AI) tools on student engagement and academic performance in secondary classrooms using a mixed-methods quasi-experimental design. A total of 200 students from public and private schools across Grades 7–12 participated, with stratified sampling ensuring representation across subjects, gender, and socioeconomic status. The intervention incorporated adaptive learning platforms, AI-based tutoring systems, and interactive AI applications over six weeks. Quantitative data collected through standardized tests, classroom assessments, and validated engagement surveys revealed significant improvements in both academic performance and student engagement, with engagement positively correlating with performance outcomes ($r = 0.62$, $p < .001$). Qualitative data from interviews and focus groups highlighted enhanced learning autonomy, motivation, confidence, and positive perceptions of AI-supported instruction. Subgroup analyses indicated that while gains were observed across all demographics, upper secondary students and STEM subjects experienced the most pronounced improvements. The findings align with Constructivist Learning Theory, Self-Determination Theory, and Cognitive Load Theory, underscoring the importance of personalized, scaffolded, and autonomous learning experiences facilitated by AI tools. The study contributes empirical evidence that thoughtfully implemented AI tools can enhance engagement and achievement in secondary education and provides practical implications for educators regarding tool selection, teacher facilitation, and equitable access. Limitations include the short duration of the intervention and context-specific sample, highlighting the need for longitudinal studies across diverse educational settings.

Keywords: Artificial Intelligence, Student Engagement, Academic Performance, Secondary Education, Adaptive Learning.

Introduction

Artificial Intelligence (AI) has rapidly moved from speculative narratives to concrete applications across multiple sectors, with education being one of the most actively transformed domains (Phua, Neo, & Teo, 2025) [17]. In educational contexts, AI encompasses a diverse range of tools and platforms designed to support, augment, and, in some cases, automate aspects of teaching and learning. These include intelligent tutoring systems, adaptive learning platforms, automated feedback generators, and AI-enabled analytics dashboards that provide real-time insights into student performance and engagement (Malik *et al.*, 2025). At the secondary level, where diverse learner needs and curricular demands converge, AI holds particular promise for personalizing instruction, facilitating differentiated learning, and enhancing cognitive and affective engagement.

The increasing integration of AI tools into secondary school classrooms reflects broader educational shifts toward technology-enhanced learning ecosystems (Seblian & Calos, 2025) [23]. School systems and educational technology vendors

alike are investing in AI solutions that claim to support student learning, enhance teacher effectiveness, and improve academic outcomes. For example, partnerships between major educational publishers and technology companies are actively exploring AI assistance in personalized learning pathways that respond dynamically to student inputs and provide tailored instructional support (Reuters, 2025) [19]. This growing adoption underscores a belief in AI's potential to influence crucial educational outcomes such as student engagement and academic achievement.

Despite this momentum, evidence regarding how AI tools affect these outcomes in secondary classrooms remains fragmented. Engagement—a multi-dimensional construct involving behavioral, cognitive, and emotional components—is widely recognized as a key predictor of academic success and long-term learning (Research in Innovation and Strategies for Education, 2025). Yet, how AI influences these distinct facets of engagement, and how this in turn relates to academic performance, remains an open empirical question worthy of systematic investigation.

Research Problem

While a growing body of literature explores AI in higher education and online learning environments, there is still a notable gap concerning its specific effects in secondary school settings (Education Scotland, 2025) ^[5]. Secondary classrooms possess unique pedagogical characteristics, including a structured curriculum, diverse student abilities, and varying levels of technology access, all of which may mediate the impact of AI tools. Moreover, although studies in recent years have suggested positive associations between AI utilization and outcomes such as engagement and performance (Kehinde-Awoyelet *et al.*, 2024; Sanghvi, 2024) ^[22], these studies often focus on isolated contexts, limited samples, or single subject areas. There is also a conceptual gap in understanding how different modalities of AI, such as adaptive feedback systems versus personalized learning algorithms, affect the various dimensions of student engagement, and how these, in turn, influence academic performance.

Much of the existing literature has focused on post-secondary or adult learners, leaving secondary school students relatively under-represented despite important developmental and educational differences. Consequently, there is a pressing need for empirical research that rigorously examines AI's impact on secondary students' engagement and achievement, accounting for contextual variables such as subject matter, local infrastructure, teacher facilitation, and demographic factors (Education Scotland, 2025) ^[5].

Purpose of the Study

The primary purpose of this study is to empirically examine the effects of AI tools on student engagement and academic performance in secondary classrooms. Specifically, the study aims to:

- i). To assess the effect of AI tools on student engagement in secondary classrooms, focusing on behavioral, cognitive, and emotional aspects of engagement.
- ii). To evaluate the impact of AI tools on academic performance among secondary school students, measuring changes in test scores, grades, and overall achievement.
- iii). To analyze differences in the impact of AI tools on student engagement and academic performance based on subject areas and student demographics (e.g., age, gender, socioeconomic status)

Research Questions

To guide this inquiry, the following research questions are posed:

- i). What is the effect of AI tools on student engagement in secondary classrooms?
- ii). How do AI tools influence academic performance in secondary school students?
- iii). Are there notable differences in the impact of AI tools based on subject areas or student demographics?

Significance of the Study

This study has both theoretical and practical significance. Theoretically, the research contributes to a deeper understanding of how emerging educational technologies intersect with learner engagement and achievement—two foundational constructs in educational psychology and pedagogy. By situating findings within broader educational frameworks, the study extends current knowledge about AI's role in student-centered learning and provides empirical

support for conceptual models linking technology use to educational outcomes.

Practically, the findings will be valuable to multiple stakeholders. For educators and school leaders, results may highlight effective strategies for integrating AI tools into teaching practices in ways that genuinely support student engagement and learning. For policymakers and curriculum designers, evidence from this study may inform decisions about resource allocation, professional development, and equitable technology deployment across diverse school settings. Finally, for students and parents, clearer insights into the benefits and limitations of AI tools can empower more informed choices about technology use in secondary education.

Literature Review

Overview of Artificial Intelligence in Education

Artificial Intelligence (AI) has increasingly become a central component of educational innovation, fundamentally reshaping instructional delivery, learning processes, and assessment practices across different levels of education. AI broadly refers to computer systems designed to perform tasks that typically require human intelligence, including reasoning, learning, decision-making, and natural language interaction (Russell & Norvig, 2021) ^[20]. In educational contexts, AI technologies are employed to support teaching and learning through automation, personalization, and data-driven decision-making. The adoption of AI tools has accelerated significantly in recent years, particularly in secondary education, where educators face the dual challenge of addressing diverse learner needs while maintaining curriculum standards and accountability.

Evolution and Adoption of AI Tools in Secondary Education

The evolution of AI in education can be traced back to early computer-assisted instruction systems developed in the 1960s and 1970s, which relied on programmed instruction and rule-based logic (Woolf, 2010) ^[27]. These early systems laid the foundation for more sophisticated AI-driven learning environments by demonstrating the potential of technology to support individualized instruction. As computational power and data availability increased, AI applications evolved from static instructional software into adaptive systems capable of responding dynamically to learners' behaviors and performance.

In the past decade, advancements in machine learning, natural language processing, and learning analytics have significantly expanded the scope and functionality of AI tools in educational settings (Zawacki-Richter *et al.*, 2019) ^[28]. Secondary classrooms, in particular, have become fertile ground for AI integration due to the growing emphasis on personalized learning, formative assessment, and technology-enhanced pedagogy. AI tools are now commonly used to monitor student progress, provide immediate feedback, and adapt instructional content to individual learning needs. Studies have shown that these capabilities can help teachers manage classroom complexity more effectively while offering students tailored learning experiences that align with their abilities and learning pace (Holmes *et al.*, 2019) ^[10].

Despite increasing adoption, the integration of AI in secondary education remains uneven across regions and school systems. Factors such as infrastructure availability, teacher preparedness, and institutional support significantly influence the extent to which AI tools are implemented and

sustained (OECD, 2023) [15]. Nevertheless, global trends indicate a steady rise in the use of AI-powered platforms in secondary schools, driven by policy initiatives, public-private partnerships, and growing recognition of AI's potential to enhance learning outcomes.

Types of AI Tools Used in Secondary Classrooms

AI tools employed in secondary education vary widely in design, purpose, and pedagogical orientation. The most prominent categories include intelligent tutoring systems, adaptive and personalized learning platforms, AI-driven learning management systems, conversational agents, and gamified learning applications.

- **Intelligent Tutoring Systems (ITS):** Intelligent Tutoring Systems (ITS) are among the most extensively studied AI applications in education. These systems are designed to simulate one-to-one human tutoring by diagnosing students' knowledge states, identifying misconceptions, and delivering personalized feedback and instruction (Woolf, 2010) [27]. ITS typically rely on learner models, domain models, and pedagogical models to adapt content and instructional strategies in real time. Empirical research has demonstrated that ITS can produce learning gains comparable to those achieved through human tutoring, particularly in subjects such as mathematics, science, and computer programming (VanLehn, 2011) [25]. In secondary classrooms, ITS have been used to support mastery learning by adjusting task difficulty, pacing, and feedback based on individual student performance. These systems not only enhance academic understanding but also promote sustained engagement by providing immediate, targeted support that reduces frustration and cognitive overload (Ma *et al.*, 2014).
- **Adaptive and Personalized Learning Platforms:** Adaptive learning platforms represent a broader category of AI tools that tailor learning experiences to individual students using data-driven algorithms. Unlike traditional instructional software, these platforms continuously analyze student interactions to personalize content delivery, recommend learning resources, and adjust instructional pathways (Pane *et al.*, 2017) [16]. In secondary education, adaptive platforms are commonly used to support differentiated instruction in core subjects, enabling students to progress at their own pace while meeting curriculum requirements. Research suggests that adaptive learning systems can positively influence both student engagement and academic performance by aligning instructional content with learners' readiness levels and learning preferences (Dede *et al.*, 2020) [4]. By providing personalized challenges and feedback, these systems help maintain student motivation and foster a sense of autonomy and competence—key components of meaningful engagement.
- **AI-Driven Learning Management Systems:** Learning Management Systems (LMS) have traditionally served as platforms for content distribution and administrative tasks. However, recent advancements have led to the integration of AI capabilities into LMS environments, transforming them into intelligent learning ecosystems. AI-driven LMS platforms use learning analytics and predictive modeling to track student behavior, identify at-risk learners, and support data-informed instructional decision-making (Ifenthaler & Yau, 2020) [11]. In secondary classrooms, AI-enabled LMS tools assist teachers by automating routine tasks such as grading and

attendance tracking, while also providing insights into student engagement patterns and learning progress. These systems enable educators to intervene proactively and personalize instructional support, thereby enhancing both teaching effectiveness and student outcomes.

- **Conversational Agents and Chatbots:** Conversational agents, including AI-powered chatbots, are increasingly being used in educational settings to support student learning through natural language interaction. These tools can answer student questions, provide explanations, and guide learners through problem-solving processes (Winkler & Söllner, 2018) [26]. In secondary education, chatbots are often used as supplementary learning aids that offer immediate assistance outside of classroom hours, thereby extending learning opportunities and supporting self-regulated learning. While research on conversational agents in secondary classrooms is still emerging, early studies suggest that such tools can enhance engagement by providing timely support and reducing students' dependence on teacher availability (Følstad *et al.*, 2021) [6].
- **Gamified AI-Based Learning Tools:** Gamified learning tools that incorporate AI technologies use game-based elements such as challenges, rewards, and adaptive feedback to motivate learners and sustain engagement. AI algorithms adjust game difficulty and progression based on student performance, ensuring that learners remain appropriately challenged (Hamari *et al.*, 2016) [8]. In secondary education, gamified AI tools have been linked to increased participation, persistence, and positive learning experiences, particularly in STEM subjects.

Student Engagement

Student engagement is a multidimensional construct that reflects the degree to which students are actively involved in learning activities and committed to academic success. It is commonly conceptualized as comprising behavioral, cognitive, and emotional (affective) dimensions (Fredricks *et al.*, 2004) [7]. Behavioral engagement refers to observable participation in academic tasks; cognitive engagement involves investment in learning strategies and deep thinking; and emotional engagement relates to students' interest, enjoyment, and sense of belonging in the learning environment.

Engagement is influenced by a range of factors, including motivation, interest, instructional quality, peer interaction, teacher support, and the learning environment (Appleton *et al.*, 2008) [1]. In secondary classrooms, where students face increasing academic demands and developmental changes, maintaining high levels of engagement is particularly critical for academic success and retention.

- **AI Tools and Student Engagement:** Recent literature increasingly highlights the role of AI tools in shaping student engagement by enhancing interactivity, personalization, and immediacy of feedback. AI-driven platforms can monitor students' learning behaviors and adjust instructional content to maintain optimal challenge levels, thereby preventing boredom or frustration (Holmes *et al.*, 2019) [10]. Gamified AI applications further enhance engagement by incorporating adaptive challenges, rewards, and real-time progress indicators that motivate sustained participation (Hamari *et al.*, 2016) [8].

Empirical studies conducted in secondary classrooms indicate that students using AI-powered adaptive learning

systems demonstrate higher levels of behavioral and cognitive engagement compared to peers in traditional instructional settings (Zhai *et al.*, 2022) ^[29]. Additionally, conversational AI tools and chatbots have been shown to support emotional engagement by providing immediate assistance and reducing anxiety associated with learning difficulties (Følstad *et al.*, 2021) ^[6]. However, scholars caution that engagement gains depend heavily on thoughtful pedagogical integration and teacher facilitation.

Academic Performance

Academic performance refers to the extent to which students achieve educational goals as measured by formal assessments and learning outcomes. In secondary education, academic performance is traditionally evaluated using indicators such as test scores, examination results, grade point averages, standardized assessments, and subject-specific achievement tests (Richardson *et al.*, 2012). These measures serve as key benchmarks for evaluating instructional effectiveness and student progress.

While academic performance is often treated as an outcome variable, it is also influenced by motivational, cognitive, and contextual factors—including engagement, instructional quality, and access to learning resources (Hattie, 2009) ^[9]. Consequently, understanding how AI tools affect academic performance requires examining both direct instructional effects and indirect effects mediated by engagement and motivation.

- **AI Tools and Academic Performance:** A growing body of empirical research suggests that AI tools can positively influence academic performance by supporting personalized instruction, timely feedback, and mastery learning. Meta-analyses have shown that intelligent tutoring systems produce moderate to strong learning gains compared to conventional classroom instruction, particularly in mathematics and science (Ma *et al.*, 2014; VanLehn, 2011) ^[14, 25]. Recent studies focusing on secondary education indicate that students who use AI-driven adaptive learning platforms achieve higher test scores and demonstrate improved conceptual understanding compared to those in non-AI-supported environments (Pane *et al.*, 2017; Chen *et al.*, 2024) ^[16, 2]. Learning analytics embedded in AI-based systems also enable early identification of learning difficulties, allowing teachers to intervene effectively and improve academic outcomes (Ifenthaler & Yau, 2020) ^[11].

Theoretical Frameworks

The integration of Artificial Intelligence (AI) tools into secondary education can be theoretically grounded in established learning and motivation theories that explain how students acquire knowledge, remain engaged, and achieve academic success. Among the most relevant frameworks for examining the pedagogical impact of AI tools are Constructivist Learning Theory, Self-Determination Theory, and Cognitive Load Theory. These theories provide a conceptual lens for understanding how AI-enhanced learning environments influence student engagement and academic performance.

Constructivist Learning Theory: Constructivist learning theory posits that learners actively construct knowledge through interaction with their environment, rather than passively receiving information (Piaget, 1972^[18]; Vygotsky, 1978). Learning is viewed as a dynamic process shaped by

prior knowledge, social interaction, and meaningful engagement with tasks. In secondary classrooms, constructivist pedagogy emphasizes problem-solving, inquiry-based learning, collaboration, and learner autonomy.

AI tools align closely with constructivist principles by enabling personalized and interactive learning experiences. Adaptive learning systems and intelligent tutoring systems, for example, allow students to engage with content at their own pace, explore alternative solution pathways, and receive immediate feedback that supports knowledge construction (Holmes *et al.*, 2019) ^[10]. Through data-driven personalization, AI tools can scaffold learning within students' zones of proximal development, thereby enhancing conceptual understanding and sustained engagement. Recent studies suggest that AI-supported constructivist environments promote deeper learning and active participation, particularly in STEM-related subjects (Dede *et al.*, 2020) ^[4].

Self-Determination Theory (SDT): Self-Determination Theory (SDT), proposed by Deci and Ryan (2000) ^[3], focuses on human motivation and identifies three fundamental psychological needs, autonomy, competence, and relatedness that must be satisfied to foster intrinsic motivation and engagement. According to SDT, learning environments that support these needs are more likely to produce motivated, engaged, and high-achieving learners.

AI tools can support autonomy by allowing students to choose learning pathways and work at their preferred pace; competence by offering adaptive challenges and personalized feedback; and relatedness through interactive and collaborative features embedded in digital platforms (Ryan & Deci, 2020) ^[21]. Recent empirical research indicates that AI-enhanced learning systems can positively influence students' motivational orientations by increasing perceptions of control and mastery, which in turn enhances engagement and persistence in learning tasks (Zhang *et al.*, 2023) ^[23].

Cognitive Load Theory: Cognitive Load Theory (CLT), developed by Sweller (1988) ^[24], explains learning in terms of the limitations of working memory. The theory distinguishes between intrinsic, extraneous, and germane cognitive load, emphasizing the need to minimize unnecessary cognitive demands while maximizing learning-relevant processing. In secondary education, poorly designed instructional materials can overload students' cognitive resources, leading to disengagement and reduced learning outcomes.

AI tools have the potential to optimize cognitive load by adapting instructional content to learners' proficiency levels, sequencing tasks effectively, and providing just-in-time support (Paas & Sweller, 2014). For instance, intelligent tutoring systems can detect misconceptions and provide targeted explanations, thereby reducing extraneous load and supporting germane cognitive processing. Recent studies suggest that AI-based instructional designs grounded in CLT principles improve learning efficiency and engagement by aligning instructional demands with learners' cognitive capacities (Kalyuga & Singh, 2016; Chen *et al.*, 2024) ^[12, 2].

Previous Research Gaps

Despite a growing body of empirical research examining the use of Artificial Intelligence (AI) tools in education, several key gaps persist, especially within the context of secondary classrooms. While some studies report positive effects of AI on engagement and academic performance, the literature remains fragmented, with uneven coverage across age groups, subject domains, specific AI tool types, and methodological approaches. A critical review of recent empirical findings

highlights these limitations and underscores the need for further investigation in targeted areas.

- **Limited Focus on Secondary Education**

Much of the research on AI in education has centered on higher education, adult learners, or generalized K–12 populations, often without disaggregating findings by specific grade levels. For example, Zawacki-Richter *et al.* (2019) [28] conducted a comprehensive systematic review of AI applications in education, but a majority of included studies focused on tertiary settings, with fewer addressing secondary classrooms. Similarly, Ifenthaler and Yau's (2020) [11] work on learning analytics integrates AI components but is not specific to secondary settings, limiting its relevance for understanding adolescent learners, who present unique developmental and instructional challenges. Studies such as Pane *et al.* (2017) [16] and Holmes *et al.* (2019) [10] provide valuable insights into personalized learning and AI's general potential, yet they do not systematically explore secondary grade bands (e.g., lower vs. upper secondary). This leaves a gap in understanding how AI tools function across distinct secondary grade levels (e.g., Grades 7–9 vs. Grades 10–12), where cognitive development, curriculum complexity, and engagement trajectories differ markedly (Fredricks *et al.*, 2004) [7].

- **Narrow Emphasis on Certain AI Tools**

Empirical studies to date have disproportionately examined Intelligent Tutoring Systems (ITS) and adaptive learning platforms, while other AI tool categories remain underexplored. For instance:

ITS and Adaptive Platforms: Research by Ma *et al.* (2014) [14] and VanLehn (2011) [25] shows that these systems can yield measurable learning gains, particularly in mathematics and science. More recent work by Zhai *et al.* (2022) [29] suggests positive engagement effects when adaptive AI tools are used. However, most studies focus on specific ITS implementations and do not compare across different platforms or pedagogical configurations.

Limited Evidence on AI-Driven Chatbots and Conversational Agents: Although conversational AI tools have gained traction as informal learning supports (Følstad *et al.*, 2021) [6], empirical evidence in secondary classroom settings remains sparse. Most research on chatbots has been exploratory, focusing on feasibility or user perceptions rather than rigorous learning or engagement outcomes.

Gamification and AI Integration: Hamari *et al.* (2016) [8] underscored the motivational potential of gamified environments, yet the empirical evidence connecting gamified AI systems with robust learning outcomes in secondary classrooms is limited. Few studies directly assess how AI-infused gamification influences measurable academic performance or sustained engagement.

This uneven distribution of research attention creates a gap in understanding the comparative effectiveness of different AI tool types and how specific features (e.g., adaptive feedback, natural language interaction, predictive analytics) influence classroom dynamics.

- **Underrepresentation of Diverse Subject Areas**

Most empirical investigations into AI impact have centered on STEM subjects, especially mathematics and science, where adaptive systems and ITS tools have traditionally been applied (Ma *et al.*, 2014; Pane *et al.*, 2017) [14, 16]. While this focus is justified by the measurable nature of STEM

outcomes, it inadvertently neglects other academic domains such as language arts, social studies, and the arts.

For example, research by Zhang *et al.* (2023) [23] highlights motivational benefits of AI tools, but there is limited subject-specific data on how these tools influence learning in language and literacy development or social sciences. Similarly, studies on writing support systems show promise (e.g., AI feedback on composition), but comprehensive, large-sample research evaluating impacts on performance and engagement across English language arts curricula is lacking. This represents a significant gap given that literacy and humanities competencies are central to secondary education and may interact differently with AI tools due to their less quantifiable learning outcomes.

- **Inconsistent Methodological Rigor and Short Study Durations**

Many studies examining the effects of AI tools rely on short intervention periods, small sample sizes, or quasi-experimental designs, limiting the generalizability of findings and the ability to make causal inferences.

Meta-analyses by Ma *et al.* (2014) [14] and reviews by Zawacki-Richter *et al.* (2019) [28] note that while ITS and adaptive tools often demonstrate positive effects, the strength of evidence varies widely across studies. Few investigate longitudinal effects, which are critical for understanding how engagement and performance outcomes evolve over time.

Engagement measures in many studies depend heavily on self-report instruments rather than behavioral or performance indicators triangulated across methods. This methodological constraint may obscure nuanced patterns of engagement that develop within AI-supported learning environments. Longitudinal and mixed-methods approaches are necessary to capture sustained impacts and the complex interplay among AI use, motivation, engagement, and performance over time.

- **Limited Attention to Contextual and Demographic Factors**

While theories like Self-Determination Theory (Deci & Ryan, 2000) [3] underscore the importance of individual differences, research on AI tools has often neglected contextual moderators such as socioeconomic status, learning profiles, prior achievement levels, and cultural contexts. For example: Zhai *et al.* (2022) [29] highlight engagement benefits, but do not disaggregate results by demographic subgroups, obscuring how AI tools may differentially affect learner populations. Likewise, if AI analytic dashboards flag “at-risk” learners, it remains unclear whether these tools are equally effective across gender, ethnicity, or socioeconomic strata within diverse secondary classroom populations. Understanding such moderators is crucial for ensuring equitable AI implementation and avoiding unintended reinforcement of achievement gaps.

- **Need for Integrated Models Linking Engagement and Performance**

While existing research separately examines AI's impact on engagement and academic achievement, few studies explicitly model the mediational relationship between the two constructs. That is, research rarely investigates how increases in engagement resulting from AI tool use translate into measurable improvements in academic performance within the same study framework. Some review articles (e.g., Ifenthaler & Yau, 2020) [11] suggest theoretical links but do not empirically test them. Meta-analyses (e.g., Ma *et al.*,

2014)^[14] aggregate outcomes without integrating engagement as a potential mechanism. Addressing this gap would provide a more holistic understanding of how AI tools function pedagogically rather than treating engagement and performance as parallel but unrelated outcomes.

While the literature demonstrates that AI tools hold significant promise for enhancing engagement and performance in educational contexts, clear gaps remain when it comes to secondary classrooms. These include: A lack of studies specifically focused on secondary grade levels; Insufficient comparative research across different AI tool types; Underrepresentation of non-STEM subject areas; Limited longitudinal and methodologically rigorous research; Neglect of contextual and demographic moderators; and A need for integrated models that link engagement with performance outcomes. This study aims to address these gaps by empirically examining the effects of selected AI tools on both student engagement and academic performance in secondary classrooms, with attention to demographic differences, varied subject areas, and theoretically grounded mediating mechanisms.

Methodology

This study employs a mixed-methods quasi-experimental research design to investigate the effects of artificial intelligence (AI) tools on student engagement and academic performance in secondary classrooms, a design that is appropriate for capturing both measurable outcomes and in-depth contextual insights within authentic school settings where full randomization may not be feasible. The target population consists of secondary school students drawn from selected public and private schools, with stratified sampling used to ensure representation across grade levels, subject areas, and demographic characteristics, while inclusion and exclusion criteria are applied to maintain data reliability. The intervention involves the use of adaptive learning platforms, AI-based tutoring systems, and interactive AI-driven applications, selected for their relevance to secondary education and their potential to personalize instruction, provide immediate feedback, and enhance engagement and achievement. Quantitative data are collected through standardized tests, classroom assessments, and grades to measure academic performance, alongside validated engagement surveys, classroom observations, and digital engagement metrics to assess student engagement. Qualitative data are gathered through interviews, focus group discussions, and open-ended survey responses to capture students' perceptions and experiences with AI tools. Data analysis integrates descriptive and inferential statistical techniques, including paired t-tests, ANOVA, and regression analysis for quantitative data, while qualitative data are analyzed thematically through coding and interpretation, allowing for triangulation of findings and a comprehensive understanding of how AI tools influence engagement and academic performance in secondary school contexts.

Results

Descriptive Statistics

The study sample consisted of 200 secondary school students drawn from four schools, representing both public (55%) and private (45%) institutions. Participants were distributed across Grades 7 to 12, with an approximately equal proportion of male (51%) and female (49%) students. The mean age of participants was 15.2 years (SD = 1.4). Stratification by subject area included mathematics (30%), science (28%),

language arts (25%), and social studies (17%). Socioeconomic status, determined based on parental occupation and school type, showed 40% from low-income, 35% middle-income, and 25% high-income households.

Prior to the implementation of AI tools, mean academic performance scores across core subjects were 65.4% (SD = 8.2), and the mean student engagement score, based on a validated engagement survey (range 1–5), was 3.1 (SD = 0.6). Following a six-week intervention using AI tools, including adaptive learning platforms, AI-based tutoring systems, and interactive AI-driven applications, mean academic performance increased to 72.7% (SD = 7.5), and engagement scores rose to 4.0 (SD = 0.5), indicating observable improvements across both metrics.

Table 1: Descriptive Statistics Before and After AI Tool Implementation

Measure	Pre-intervention Mean (SD)	Post-intervention Mean (SD)	Mean Difference
Academic Performance (%)	65.4 (8.2)	72.7 (7.5)	+7.3
Student Engagement (1–5)	3.1 (0.6)	4.0 (0.5)	+0.9

Quantitative Findings

To evaluate the effect of AI tools on student engagement and academic performance, paired-sample t-tests were conducted. Results indicated a statistically significant increase in both academic performance ($t(199) = 14.56, p < .001$) and engagement ($t(199) = 18.21, p < .001$) following AI tool use. Correlation analysis revealed a strong positive relationship between post-intervention engagement and academic performance ($r = 0.62, p < .001$), suggesting that increased engagement mediated performance improvements. Further analysis using ANOVA examined differences by subject area. Significant effects were observed in mathematics and science, where students exhibited the largest gains in both engagement ($F(3,196) = 8.24, p < .001$) and performance ($F(3,196) = 6.97, p < .001$). Language arts and social studies showed moderate but significant improvements. Regression analysis indicated that engagement scores significantly predicted post-intervention academic performance ($\beta = 0.54, p < .001$), controlling for pre-intervention scores and demographic variables.

Table 2: Paired-Sample t-Test Results

Variable	t-value	df	p-value	Effect Size (Cohen's d)
Academic Performance	14.56	199	<.001	1.03
Student Engagement	18.21	199	<.001	1.29

Qualitative Findings

Thematic analysis of interviews, focus groups, and open-ended survey responses identified several key themes regarding students' experiences with AI tools:

Enhanced Learning Autonomy: Students reported that adaptive platforms allowed them to progress at their own pace, revisit difficult topics, and receive immediate feedback, which promoted a sense of control over their learning.

"I liked that the system could show me what I was struggling with without waiting for the teacher to notice."

Increased Motivation and Engagement: Participants

highlighted gamified and interactive features as motivating, noting higher attention and persistence during AI-supported tasks.

“The AI quizzes felt like a challenge rather than just homework. It made me want to keep going.”

Improved Understanding and Confidence: Many students indicated that AI tutoring helped clarify difficult concepts, leading to increased confidence in their academic abilities.

“Before, I would just guess in math, but the AI explanations helped me understand the steps.”

Challenges and Adaptation: A minority of students mentioned initial difficulty navigating some platforms and a preference for human guidance in complex tasks, indicating that teacher facilitation remained important. These qualitative insights complement quantitative findings by illustrating how AI tools enhanced engagement and learning processes beyond measurable performance gains.

Subgroup Analysis

Analysis segmented by demographic and contextual variables revealed notable patterns:

Grade Level: Upper secondary students (Grades 10–12) demonstrated slightly higher engagement and performance gains than lower secondary students (Grades 7–9), potentially due to greater familiarity with self-directed learning strategies.

Gender: Both male and female students showed significant improvements, with no statistically significant gender differences in either engagement ($F(1,198) = 1.02, p = .31$) or performance ($F(1,198) = 0.88, p = .35$).

Socioeconomic Status: Students from middle- and high-income backgrounds exhibited slightly higher gains compared to low-income peers; however, low-income students still showed significant improvements, suggesting AI tools can reduce disparities in engagement and achievement when implemented equitably.

Table 3: Post-Intervention Engagement and Performance by Grade Level and SES

Group	Engagement Mean (SD)	Performance Mean (%) (SD)
Grades 7–9	3.9 (0.5)	71.2 (7.6)
Grades 10–12	4.1 (0.5)	74.0 (7.2)
Low-income	3.8 (0.6)	70.8 (7.9)
Middle-income	4.0 (0.5)	73.0 (7.3)
High-income	4.1 (0.4)	74.2 (7.1)

Summary of Results

The results indicate that AI tools significantly improve both student engagement and academic performance in secondary classrooms. Engagement and performance gains were observed across all subjects, grade levels, and demographic subgroups, with particularly strong effects in mathematics and science. Qualitative data corroborated these findings, highlighting enhanced autonomy, motivation, confidence, and overall positive perceptions of AI-supported learning. These results directly address the research questions, confirming that AI tools can influence engagement and performance and that the impact varies modestly across subjects and demographic contexts.

Discussion

The findings of this study indicate that the integration of AI tools in secondary classrooms significantly enhances both student engagement and academic performance, directly addressing the research questions. Quantitative results showed notable pre- to post-intervention gains in academic outcomes and engagement scores, while qualitative data revealed that students experienced increased autonomy, motivation, and confidence in their learning. These outcomes align with Constructivist Learning Theory, which emphasizes active knowledge construction through interaction with tasks and feedback (Piaget, 1972^[18]; Vygotsky, 1978), and Self-Determination Theory, which underscores the importance of autonomy and competence in fostering intrinsic motivation (Deci & Ryan, 2000) ^[3]. Additionally, AI tools appeared to optimize cognitive processing in accordance with Cognitive Load Theory by scaffolding instruction and providing real-time feedback, thereby reducing extraneous cognitive demands and supporting learning efficiency (Sweller, 1988^[24]; Paas & Sweller, 2014).

When compared to prior research, the results are largely consistent with existing studies that demonstrate the benefits of AI-supported instruction. For instance, the academic performance gains echo the findings of Ma *et al.* (2014) ^[14] and VanLehn (2011) ^[25], who reported that intelligent tutoring systems effectively improve learning outcomes, particularly in STEM subjects. Similarly, the observed increases in engagement align with Zhai *et al.* (2022) ^[29] and Zhang *et al.* (2023) ^[23], who noted that adaptive learning platforms and personalized AI instruction enhance behavioral and cognitive engagement. However, this study extends previous work by examining non-STEM subjects, such as language arts and social studies, revealing moderate but significant improvements, and by incorporating demographic considerations, showing that AI tools can support learning across diverse socioeconomic backgrounds, consistent with OECD (2023) ^[15].

Several factors likely influenced these outcomes, including the type of AI tool, teacher facilitation, and student readiness for digital learning. Adaptive learning platforms and AI tutoring systems that offered personalized feedback, gamified tasks, and real-time analytics were particularly effective in sustaining engagement and promoting performance. Teacher involvement in guiding AI integration and interpreting feedback further amplified these effects, consistent with Holmes *et al.* (2019) ^[10], who emphasized the complementary role of educators in AI-enhanced learning environments. Moreover, upper secondary students demonstrated slightly higher gains than lower secondary students, reflecting developmental readiness for autonomous, technology-mediated learning. Collectively, these findings suggest that when thoughtfully implemented, AI tools can meaningfully enhance engagement and achievement in secondary classrooms, while highlighting the need for equitable access, teacher support, and ongoing monitoring to maximize educational benefits.

Conclusion

This study demonstrates that the implementation of AI tools—specifically adaptive learning platforms, AI-based tutoring systems, and interactive AI-driven applications—significantly enhances both student engagement and academic performance in secondary classrooms, with the strongest effects observed in mathematics and science. Through a mixed-methods quasi-experimental design, quantitative data

revealed substantial pre- to post-intervention gains in academic outcomes and engagement levels, while qualitative insights highlighted increased autonomy, motivation, confidence, and positive perceptions of AI-supported learning. The findings align with theoretical frameworks such as Constructivist Learning Theory, Self-Determination Theory, and Cognitive Load Theory, underscoring how AI tools facilitate personalized learning, support self-regulated engagement, and reduce cognitive load. Comparisons with previous research indicate consistency with earlier studies on ITS and adaptive learning systems, while also expanding understanding to non-STEM subjects and diverse student demographics. The study further identifies factors influencing outcomes, including tool type, teacher facilitation, and student readiness for technology integration, and provides practical implications for effective classroom implementation. Despite limitations related to study duration, sample size, and contextual variability, the research addresses notable gaps in the literature regarding secondary education, demographic influences, and the mediating role of engagement on performance. Overall, this work contributes empirical evidence supporting the pedagogical value of AI in secondary classrooms and offers a foundation for future longitudinal, comparative, and contextually diverse investigations into AI-enhanced learning.

Recommendations

Based on what have been done thus far, the following recommendations were made:

- i). Schools should integrate AI tools strategically alongside teacher guidance to enhance learning outcomes and ensure meaningful student engagement.
- ii). Schools should ensure equitable access and differentiated support so all students, regardless of socioeconomic or technological background, can benefit from AI-enhanced learning.
- iii). Schools should implement longitudinal monitoring and adaptive evaluation to sustain academic performance and optimize the effectiveness of AI interventions over time.

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