Impact of AI-Powered Chatbots Utilizing Big Data on Student Academic Performance: Evidence from Secondary Education in Sri Lanka

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ABSTRACT

The integration of Artificial Intelligence (AI) powered chatbots utilizing big data analytics is transforming educational environments by enabling personalized and adaptive learning experiences (Zawacki-Richter et al., 2019). AI-powered chatbots have been increasingly adopted in educational contexts to enhance student engagement, provide real-time feedback, and support individualized instruction (Winkler & Söllner, 2018). This study investigates the impact of AI-powered chatbots on student academic performance in a secondary school in Sri Lanka. A quantitative research design was adopted using a positive philosophy and deductive approach. Data were collected from 165 students selected through stratified sampling from a population of 1,600 students across grades 10 to 13. Primary data were gathered through structured online questionnaires and analysed using descriptive statistics, correlation analysis, and multiple regression analysis.

The overall regression model was statistically significant ($p < 0.001$) and explained 17.5% of the variance in student academic performance ($R^2 = 0.175$). Findings indicate that internet requirement and cost, student engagement, usage of AI-powered chatbots, and quality of AI-powered chatbots all have significant positive relationships with student academic performance. These findings align with previous research suggesting that infrastructure accessibility and student engagement are critical factors influencing technology-enhanced learning outcomes (Zhai et al., 2021). The results suggest that effective infrastructure, increased engagement, and improved chatbot quality contribute to enhanced academic outcomes. The study provides empirical evidence supporting the role of AI-driven educational technologies in secondary education and highlights the importance of accessibility and engagement in maximizing their impact.

Keywords: Artificial Intelligence, Big Data, AI-Powered Chatbots, Student Academic Performance, Educational Technology

INTRODUCTION

The rapid advancement of Artificial Intelligence (AI) technologies has significantly transformed modern educational environments. Among these innovations, AI-powered chatbots utilizing big data analytics have emerged as interactive tools capable of delivering personalized learning experiences, real-time feedback, and adaptive instructional support(Manyika, et al., 2011) (Chen, Chen, & Lin, 2020). By leveraging machine learning algorithms and large datasets, these systems analyse student interactions, identify learning patterns, and provide tailored responses that enhance academic engagement and performance.

The increasing integration of digital technologies in secondary education has created opportunities for data-driven decision-making and customized learning pathways. AI-powered chatbots are particularly relevant in this context, as they facilitate immediate academic assistance, automate routine guidance, and support self-directed learning. While existing research highlights the benefits of AI technologies in higher education and online learning platforms, limited empirical evidence exists regarding their measurable impact on student academic performance within secondary education settings, particularly in developing countries (Deng & Yu, 2023).

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Student academic performance is influenced by multiple factors, including accessibility to technological infrastructure, quality of digital tools, frequency of usage, and levels of student engagement (Dasanayake & Jayasinghe, 2021), (Al Husaini & Ahmad Shukor, 2023). In technology-enhanced learning environments, the effectiveness of AI-powered chatbots may depend not only on their algorithmic capabilities but also on internet accessibility, affordability, system reliability, and student interaction levels. Understanding the combined influence of these determinants is essential for maximizing the educational value of AI-driven systems.

Therefore, this study aims to examine the impact of AI-powered chatbots utilizing big data on student academic performance in a secondary school context in Sri Lanka. Specifically, the study investigates the influence of internet requirement and cost, quality of AI-powered chatbots, usage levels, and student engagement on academic outcomes. By employing quantitative analysis and regression modelling, this research provides empirical evidence to support data-driven integration of AI technologies within secondary education systems.

The findings contribute to the growing body of literature on educational technology by offering insights into the determinants of effective AI implementation and their implications for improving academic performance in developing educational contexts.

Research Objectives

The primary aim of this study is to investigate the effect of AI-powered chatbots utilizing big data on student academic performance in secondary education. To achieve this aim, the study pursues the following specific objectives:

1. To examine the effect of internet requirement and cost on student academic performance.
2. To evaluate the influence of AI-powered chatbot quality on student academic performance.
3. To assess the impact of usage levels of AI-powered chatbots on student academic performance.
4. To analyse the role of student engagement in influencing academic performance within AI-enhanced learning environments.

LITERATURE REVIEW

Big Data in Education

Big data has transformed decision-making across industries through its ability to process large-scale, high-velocity and diverse datasets (Manyika, et al., 2011). The defining characteristics of big data volume, velocity, variety, veracity and value enable organizations to extract meaningful insights from complex information systems (McAfee & Brynjolfsson, 2012). In educational contexts, big data facilitates predictive analytics, performance tracking and adaptive learning pathways (Chen, Chen, & Lin, 2020).

The integration of analytics platforms allows institutions to monitor academic progression in real time and identify students at risk of underperformance (Zaharia, Chowdhury, Franklin, Shenker, & Stoica, 2010). However, technological infrastructure and accessibility significantly influence the effectiveness of data-driven systems, particularly in developing educational environments (Dasanayake & Jayasinghe, 2021). Therefore, internet requirement and cost remain critical determinants in AI-enhanced learning ecosystems.

Artificial Intelligence and Chatbots in Education

Artificial intelligence has reshaped education through intelligent tutoring systems, adaptive learning models and conversational agents (Chen, Chen, & Lin, 2020). AI-powered chatbots utilize natural language processing and machine learning algorithms to provide personalized academic assistance and automated feedback (Okonkwo & Ade-Ibijola, 2021).

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Empirical studies indicate that chatbot technologies enhance learning efficiency and engagement levels (Okonkwo & Ade-Ibijola, 2021) (Deng & Yu, 2023). However, system effectiveness depends heavily on response accuracy, reliability and perceived quality (Mahmoud, 2022). Ethical data handling and algorithmic transparency further influence student trust and long-term adoption (Bender & Friedman, 2021).

While prior studies have demonstrated positive effects in higher education environments, limited regression-based research has examined how usage level, system quality and infrastructural access collectively influence measurable academic performance in secondary school contexts.

Student Academic Performance

Student academic performance is shaped by multiple socio-economic, institutional and behavioural determinants (Sirin, 2005). Educational research highlights that learning outcomes are influenced by instructional quality, feedback mechanisms and environmental factors (Hattie, 2009). Institutional integration and student persistence further contribute to academic achievement (Tinto, 1993).

Technology-enhanced learning environments can improve outcomes when structured appropriately (Robbins, et al., 2004). However, performance improvement requires more than technological access; it requires active engagement and sustained participation (Al Husaini & Ahmad Shukor, 2023).

Student Engagement and Theoretical Foundation

Student engagement plays a pivotal role in translating technological tools into measurable academic gains. Self-determination theory emphasises intrinsic motivation, autonomy and competence as key drivers of learning success (Deci & Ryan, 2000). Engagement-enhancing strategies improve both academic and social-emotional outcomes (Abla & Fraumeni, 2019). In AI-enhanced learning systems, engagement determines whether chatbot interactions produce meaningful academic improvements.

Research Gap

Although big data analytics and AI-powered chatbots have demonstrated positive impacts on engagement and learning efficiency (Chen, Chen, & Lin, 2020) (Deng & Yu, 2023), existing research predominantly focuses on higher education or experimental settings. There remains limited empirical evidence examining the combined influence of infrastructural readiness, chatbot quality, usage intensity and student engagement on academic performance within secondary education contexts in developing countries.

Moreover, few studies employ regression-based predictive modelling to analyse these determinants simultaneously. Therefore, this study addresses a contextual and empirical gap by investigating the effect of AI-powered chatbots utilising big data on student academic performance within a Sri Lankan secondary school environment.

Determinants of AI Chatbot Effectiveness

Based on existing literature and the conceptual framework, four key determinants influence the impact of AI-powered chatbots on academic performance:

1. **Internet Requirement and Cost** – Reliable and affordable internet access determines students' ability to interact consistently with AI systems.

2. **Usage of AI-Powered Chatbots** – Frequency and duration of interaction affect learning reinforcement.

3. **Quality of AI-Powered Chatbots** – Accuracy, relevance, and clarity of responses influence trust and effectiveness.

4. **Student Engagement** – Higher engagement enhances the translation of technological support into measurable academic outcomes.

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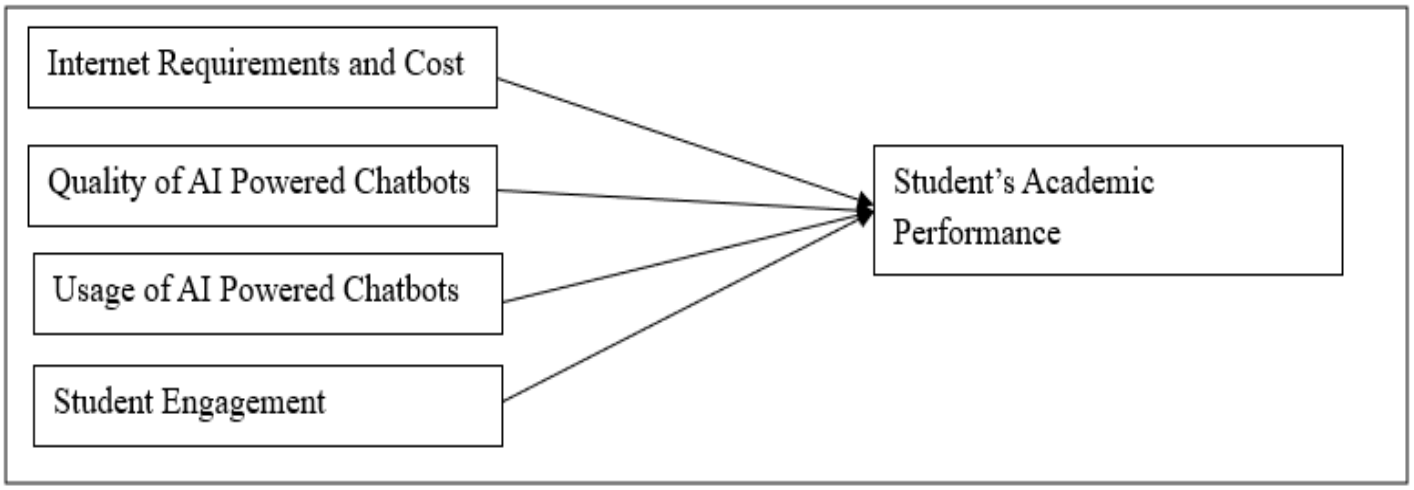
Conceptual framework

Based on the reviewed literature, this study proposes that student academic performance is influenced by four key determinants- internet requirement and cost, usage of AI-powered chatbots, quality of AI-powered chatbots, and student engagement. These variables are derived from prior theoretical and empirical findings suggesting that technological accessibility, system effectiveness, interaction frequency, and engagement levels collectively shape academic outcomes. Figure 1 presents the conceptual framework illustrating the proposed relationships among the study variables.

Figure 1- Conceptual framework



Hypothesis Development

Based on the reviewed literature and conceptual model, the following hypotheses are proposed:

H1: Internet requirement and cost have a significant positive effect on student academic performance.

H2: Usage of AI-powered chatbots has a significant positive effect on student academic performance.

H3: Quality of AI-powered chatbots has a significant positive effect on student academic performance.

H4: Student engagement has a significant positive effect on student academic performance.

METHODOLOGY

Research Design

This study adopted a quantitative research design grounded in a positivist philosophy and deductive approach. A cross-sectional survey strategy was employed to examine the relationship between AI-powered chatbot determinants and student academic performance. The quantitative approach was selected to enable statistical testing of hypotheses and objective measurement of relationships among variables.

Population and Sample

The target population consisted of 1,600 students enrolled in grades 10 to 13 at a secondary school in Sri Lanka. A sample size of 169 respondents was determined using the Morgan sampling table. Data were successfully collected from 165 students, yielding a high response rate. A stratified sampling technique was applied to ensure proportional representation across grade levels, thereby enhancing the reliability and generalisability of findings within the school context.

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Data Collection Instrument

Primary data were collected using a structured online questionnaire administered through Google Forms. The instrument was designed based on constructs identified in the literature review and aligned with the study's conceptual framework. The questionnaire measured five main constructs:

- Student Academic Performance (dependent variable)
- Internet Requirement and Cost
- Usage of AI-Powered Chatbots
- Quality of AI-Powered Chatbots
- Student Engagement

Items were measured using a Likert scale to capture students' perceptions regarding chatbot effectiveness and academic outcomes.

Reliability Analysis

To assess internal consistency, Cronbach's alpha coefficients were calculated for all constructs. The results indicate acceptable to good reliability levels. Student Academic Performance ($\alpha = 0.82$), Internet Requirement and Cost ($\alpha = 0.79$), Usage of AI-Powered Chatbots ($\alpha = 0.84$), Quality of AI-Powered Chatbots ($\alpha = 0.88$), and Student Engagement ($\alpha = 0.86$) all exceeded the recommended threshold of 0.70 (Nunnally, 1978) . These values confirm that the measurement instrument demonstrates satisfactory internal consistency and reliability.

Operationalization of Variables

Student academic performance was measured using indicators such as perceived improvement in test scores, grade point average, class ranking, and academic confidence. Independent variables were operationalised as follows:

- **Internet Requirement and Cost:** accessibility, reliability, affordability, and infrastructure support.
- **Usage of AI-Powered Chatbots:** frequency, duration, satisfaction, and relevance of interactions.
- **Quality of AI-Powered Chatbots:** accuracy, clarity, response time, and error frequency.
- **Student Engagement:** motivation, task completion, attendance improvement, and participation levels.

Data Analysis Techniques

Collected data were analyzed using statistical methods including descriptive analysis, correlation analysis, and regression analysis. Descriptive statistics were used to summarize respondent characteristics and variable distributions. Pearson correlation analysis was conducted to examine the strength and direction of relationships between variables. Multiple regression analysis was employed to assess the predictive impact of independent variables on student academic performance. Statistical significance was determined at the 0.05 level. The regression model evaluated the extent to which internet requirement and cost, usage, quality, and student engagement explain variations in academic performance.

RESULTS

Descriptive Statistics

A total of 165 valid responses were analysed. Descriptive statistics indicated moderate mean values across all independent variables. Internet requirement and cost reported a mean of 3.58, usage of AI-powered chatbots

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3.69, quality of AI-powered chatbots 3.77, and student engagement 3.73. These findings suggest generally positive perceptions toward AI-powered chatbot integration in the educational setting.

Correlation Analysis

Pearson correlation analysis revealed statistically significant positive relationships between all independent variables and student academic performance ($p < 0.05$). Internet requirement and cost demonstrated a moderate positive correlation ($r = 0.345$, $p < 0.01$), while usage, quality, and student engagement also showed significant positive associations. These results indicate that improvements in technological accessibility, system quality, interaction frequency, and engagement are associated with enhanced academic performance.

Multiple Regression Analysis

Multiple regression analysis was conducted to examine the combined influence of internet requirement and cost, usage of AI-powered chatbots, quality of AI-powered chatbots, and student engagement on student academic performance.

The overall regression model was statistically significant ($F = 8.483$, $p < 0.001$) and explained 17.5% of the variance in student academic performance ($R^2 = 0.175$), indicating moderate explanatory power.

Table 1-Multiple Regression Results

Variable	**Beta (β)**	**t-value**	**Sig. (p)**
Internet Requirement & Cost	0.345	4.691	0.000
Usage of AI-Powered Chatbots	0.196	2.554	0.012
Quality of AI-Powered Chatbots	0.169	2.195	0.030
Student Engagement	0.269	3.572	0.000

Model Summary: $R^2 = 0.175$, $F = 8.483$, $p < 0.001$

Internet requirement and cost emerged as the strongest predictor of student academic performance ($\beta = 0.345$), indicating that reliable and affordable internet access plays a crucial role in enabling effective AI chatbot usage. Student engagement also demonstrated a significant positive effect ($\beta = 0.269$), suggesting that active participation enhances the academic benefits of AI systems.

Usage of AI-powered chatbots ($\beta = 0.196$) and quality of AI-powered chatbots ($\beta = 0.169$) were also significant predictors, though their effect sizes were comparatively smaller. Overall, all proposed hypotheses (H1–H4) were supported.

DISCUSSION

The findings of this study demonstrate that AI-powered chatbots utilizing big data exert a statistically significant positive influence on student academic performance within a secondary education context. All four investigated determinants internet requirement and cost, usage frequency, perceived quality, and student engagement were found to significantly predict academic outcomes. These results suggest that the effectiveness of AI-driven educational technologies is shaped by a combination of infrastructural readiness and behavioral engagement rather than technological sophistication alone. This interpretation is consistent with prior research indicating that the effectiveness of chatbot technologies in education depends heavily on contextual integration and user engagement (Okonkwo & Ade-Ibijola, 2021).

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Among the predictors, internet requirement and cost emerged as the strongest determinant of student academic performance ($\beta = 0.345$, $p < 0.001$). This finding highlights the foundational role of reliable and affordable digital infrastructure in enabling meaningful AI integration. In developing educational contexts, stable connectivity and accessibility remain essential prerequisites for effective digital learning (Dasanayake & Jayasinghe, 2021). While advancements in big data and AI algorithms continue to evolve, their educational impact depends substantially on the availability and reliability of supporting infrastructure (Manyika, et al., 2011). The present results empirically demonstrate that infrastructural readiness exerts a greater influence on academic performance than perceived system quality within this secondary school environment.

Student engagement was identified as the second strongest predictor ($\beta = 0.269$, $p < 0.001$), suggesting that behavioral and motivational involvement functions as a critical mechanism through which AI interaction translates into measurable academic improvement. From a motivational perspective, academic success is closely associated with autonomy, competence, and consistent behavioral involvement (Deci & Ryan, 2000).

AI-powered chatbots may facilitate personalized feedback and adaptive learning experiences; however, measurable academic gains appear to occur only when students meaningfully engage with these tools. Engagement therefore functions as a behavioral mechanism that translates technological support into performance improvement (Abla & Fraumeni, 2019).

Although usage frequency ($\beta = 0.196$, $p = 0.012$) and perceived quality of AI-powered chatbots ($\beta = 0.169$, $p = 0.030$) were statistically significant predictors, their explanatory power was comparatively smaller. This suggests that technological refinement and frequency of interaction, while beneficial, are insufficient to independently drive substantial academic improvement. These findings align with prior conclusions that chatbot effectiveness depends not only on algorithmic sophistication but also on contextual and behavioral conditions (Deng & Yu, 2023). In practical terms, high system quality cannot compensate for inadequate infrastructure or limited student engagement.

The regression model explained 17.5% of the variance in student academic performance ($R^2 = 0.175$, $F = 8.483$, $p < 0.001$), indicating moderate explanatory power. While statistically significant, this suggests that a considerable proportion of performance variation remains influenced by additional determinants beyond the four variables examined. Academic achievement is inherently multifactorial and may also depend on instructional quality (Hattie, 2009), socio-economic status (Sirin, 2005), prior academic ability, parental involvement, and institutional support structures. Therefore, AI-powered chatbots should be conceptualized as complementary educational tools embedded within a broader academic ecosystem rather than as independent drivers of student success.

From a practical standpoint, these findings suggest that educational institutions seeking to integrate AI technologies should prioritize equitable digital infrastructure and promote sustained student engagement strategies. Investments focused exclusively on increasing technological complexity without addressing accessibility and behavioral participation may yield limited academic returns. Particularly in developing educational contexts, policy emphasis on digital equity appears fundamental to maximizing the benefits of AI-driven learning systems.

Several methodological considerations should be acknowledged. The study relied on self-reported perceptions of academic performance, which may introduce response bias. Furthermore, the cross-sectional research design limits the ability to infer long-term causal relationships. As the data were collected from a single secondary school in Sri Lanka, the findings may not be generalizable to other educational institutions, regions, or national contexts that differ in infrastructural readiness, socio-economic conditions, or pedagogical practices. Variations in digital access, institutional policies, and cultural learning environments may influence the effectiveness of AI-powered chatbots. Therefore, caution should be exercised when applying these findings beyond the context studied. Future research employing longitudinal designs, objective performance metrics, and multi-institutional samples would strengthen external validity and provide deeper insight into sustained academic impact. Overall, this study contributes empirical evidence to the growing literature on AI in education by demonstrating that infrastructural accessibility and behavioral engagement exert stronger influence on academic outcomes than perceived system quality alone.

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