EVALUATING THE IMPACT OF AI TOOLS ON INSTRUCTIONAL EFFECTIVENESS: A QUANTITATIVE EXPERIMENTAL STUDY

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ABSTRACT

The incorporation of Artificial Intelligence (AI) tools in education is quickly transforming teaching methodology and learning spaces across the globe. This quantitative experimental research explores the effects of AI-based pedagogical tools—TeachMateAI, Gamma AI, and Quizizz—on effectiveness in teaching, time management, and student engagement among secondary school teachers of mathematics in Bihar, India. Using a one-group pre-test/post-test experimental design, 60 PGT mathematics teachers were enrolled through the process of stratified purposive sampling. Participants incorporated the three AI tools into instruction within a four-week intervention. Pre- and post-intervention data were gathered through standardized Likert-scale questionnaires, time-use logs, and tool usage measures. Statistical analyses were performed using SPSS 29, including descriptive statistics, paired sample t-tests, effect size computation (Cohen's d), Pearson's correlation, and ANOVA. Statistically significant gains on instructional effectiveness ($t = 10.88$, $p < .001$), management of workload ($t = 9.21$, $p < .001$), and student engagement perception ($t = 11.03$, $p < .001$) were the results. Large effect sizes (Cohen's $d > 1.0$) in all areas confirmed high practical significance. Furthermore, positive teacher attitudes towards AI were positively but modestly related to instructional effectiveness following intervention ($r = 0.61$, $p < .001$), highlighting the role of mindset in teacher adoption of technology. Overall, the research concludes that AI tools, if utilized optimally, may make instructional delivery more effective, simplify administrative workload, and assist in student-centered teaching. These findings are consistent with the objectives of India's National Education Policy (NEP) 2020 and worldwide education guidelines promoting digital innovation in education. Future research should employ longitudinal study designs with control groups to further confirm these findings across educational contexts and disciplines.

KEYWORDS: Artificial Intelligence, Educational Technology, Instructional Effectiveness, Teacher Workload, Secondary Education, AI Tools, Student Engagement

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INTRODUCTION

The 21st century has witnessed an unprecedented transformation in the educational landscape, driven significantly by technological innovations. Among these, Artificial Intelligence (AI) has emerged as a powerful force capable of reshaping how teaching and learning occur. The incorporation of AI in education has moved beyond novelty, becoming an integral component of instructional design, lesson delivery, student assessment, and feedback mechanisms (Holmes et al., 2019; Luckin et al., 2016). As schools worldwide adopt digital technologies, the potential of AI to enhance instructional effectiveness, personalize learning, and reduce the administrative burden on educators has garnered increasing scholarly and policy attention.

AI tools in education leverage machine learning, natural language processing, and data analytics to support a range of functions, including adaptive learning systems, intelligent tutoring, automated assessment, and virtual teaching assistants (Zawacki-Richter et al., 2019). These tools offer educators the capacity to tailor content to diverse learner needs, deliver real-time feedback, and make data-informed instructional decisions (Chen et al., 2020). For instance, platforms such as Quizizz automate quiz creation and grading, while applications like TeachMateAI assist in lesson planning and documentation, and Gamma AI enhances the design of visual instructional materials.

Despite the increasing adoption of AI in classrooms, there remains a significant gap in empirical research, particularly in developing countries like India, regarding its direct impact on instructional effectiveness and teaching efficiency. Most existing literature focuses on theoretical applications or large-scale ed-tech systems, overlooking the teacher's experience with classroom-level AI tools (Bai et al., 2021; Williamson & Eynon, 2020). This lack of field-level, data-driven insight limits the ability of educators and policymakers to evaluate and scale

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AI interventions meaningfully.

India's National Education Policy (NEP) 2020 emphasizes the importance of integrating emerging technologies into education to improve teaching outcomes and learner engagement (Ministry of Education, 2020). The policy calls for the use of AI not only to support learners but also to empower educators with better planning, tracking, and professional development tools. Yet, to achieve this vision, robust empirical evidence is needed to determine the actual efficacy of AI tools in everyday teaching.

This study addresses that need by investigating the influence of three AI-powered instructional tools—TeachMateAI, Gamma AI, and Quizizz—on teaching effectiveness, workload management, and student engagement. By employing a quasi-experimental design with pre- and post-intervention measures, the research aims to provide statistically validated insights into how AI integration can transform instructional practices in secondary education. The findings are expected to inform both local and global education stakeholders about the practical value of AI in pedagogy, aligned with broader digital transformation goals.

Significance of the Study

This study provides timely empirical evidence on the integration of AI tools in secondary education, a domain where field-based research in developing countries remains limited (Zawacki-Richter et al., 2019). By examining the effects of TeachMateAI, Gamma AI, and Quizizz on instructional practices, the research supports the pedagogical goals outlined in India's National Education Policy 2020 (Ministry of Education, 2020). The findings contribute to global discussions on educational technology, offering practical insights into how AI can enhance teaching effectiveness and reduce workload (Holmes et al., 2019). Furthermore, the study highlights the role of teacher attitudes in successful AI implementation, emphasizing the need for targeted professional development (Williamson & Eynon, 2020).

Objectives of the Study

1. Evaluate the impact of AI tools on teachers' instructional effectiveness.
2. Examine AI's influence on teachers' time management and workload.
3. Explore correlations between teacher attitudes toward AI and instructional performance.
4. Assess the effect of AI tool use on student engagement.

Hypotheses of the Study

- **H1:** AI tools significantly improve instructional effectiveness.
- **H2:** AI tools significantly reduce teacher workload and enhance time management.
- **H3:** Teachers' positive attitudes toward AI correlate with greater instructional gains.
- **H4:** AI tool use positively impacts student engagement.

RESEARCH METHOD

Research Design

This study employed an experimental **pre-test post-test one-group design**, aimed at examining the impact of AI tools on instructional effectiveness, workload management, and student engagement among secondary school teachers. The design allowed for measurement of change before and after the intervention involving AI tools, without the use of a control group. Though not fully randomized, the design provides robust evidence of effectiveness through statistical comparisons of pre- and post-intervention data.

Participants

The sample consisted of **60 Post Graduate Trained (PGT) mathematics teachers** from government and private senior secondary schools across urban and rural areas in Bihar, India. Participants were selected using **stratified purposive sampling** to ensure diversity in terms of school type, geographic location, and teaching experience.

Demographic Summary Details

- **Gender:** 40 females, 20 males
- **Experience:** Range from 5 to 20+ years
- **Qualification:** All held Master's degrees; 35 held B.Ed./M. Ed. degrees
- **School Location:** 33 urban, 27 rural

Inclusion criteria included full-time teaching responsibility in mathematics at the secondary level and basic digital literacy.

Intervention Tools

Participants received training and access to three AI-powered educational tools over a period of 4 weeks:

- **TeachMateAI:** Used for lesson planning, instructional resource creation, and classroom content generation.
- **Gamma AI:** Employed for creating dynamic, AI-assisted multimedia presentations.
- **Quizizz AI:** Used for generating, conducting, and auto-grading assessments.

Each participant was instructed to integrate all three tools into their instructional practice during the intervention period, following a structured guideline.

Instrumentation

Pre- and Post-Test Questionnaires

Standardized 5-point Likert scale surveys were designed to assess:

- Instructional effectiveness (e.g., clarity of concepts, student understanding)
- Time management and workload (e.g., planning efficiency, administrative burden)
- Student engagement (as perceived by teachers)
- Attitudes toward AI (pre-intervention only)

Each scale was subjected to expert review and pilot testing.

Reliability: Cronbach's alpha for all scales ranged from 0.81 to 0.89 (acceptable to excellent).

Time-Use Logs
Teachers recorded the average time spent weekly on lesson planning, assessment creation, and content preparation pre- and post-intervention. These logs were used for triangulating workload-related data.

Usage Tracking
Tool usage was tracked via login activity and content submission logs to confirm compliance with the intervention.

Data Collection Procedure
The study was conducted in three stages:

1. **Pre-Intervention Phase (Week 1):**
   - Administration of pre-test survey
   - Orientation session on AI tools
   - Collection of baseline time-use data

2. **Intervention Phase (Weeks 2–5):**
   - Participants implemented AI tools in real classroom settings
   - Ongoing virtual technical support and weekly reflections

3. **Post-Intervention Phase (Week 6):**
   - Administration of post-test survey
   - Submission of updated time-use logs
   - Collection of usage data

All participants submitted their responses electronically using a secure online portal.

Data Analysis Techniques
The collected data were analyzed using SPSS 29 with the following procedures:

- **Descriptive Statistics:** To summarize central tendencies and variability.
- **Paired Sample t-Tests:** To assess pre-post differences in instructional effectiveness, time management, and student engagement.
- **Cohen's d:** To estimate effect sizes for practical significance.
- **Pearson's Correlation:** To explore the relationship between teacher attitudes toward AI and instructional effectiveness.
- **One-Way ANOVA:** To evaluate differences in post-test outcomes across demographic variables (e.g., age, qualification, teaching experience).

Significance was determined at $p < .05$, and assumptions of normality and homogeneity were tested before applying parametric tests.

Limitations

- Absence of a control group limits causal inference.
- Self-reported data may introduce bias.
- A short intervention period may not reflect long-term effects.
- Limited to mathematics teachers in one region, affecting generalizability.

Data Analysis and Interpretation
This section presents the statistical analyses used to test the study's hypotheses regarding the impact of Artificial Intelligence (AI) tools on instructional effectiveness, time management, and student engagement among PGT mathematics teachers. The primary tools of analysis include descriptive statistics, paired sample t-tests, Cohen's d effect size, ANOVA, and Pearson's correlation. Analyses were conducted using SPSS version 29.

Descriptive Statistics
To establish baseline and outcome measures, descriptive statistics were computed for the following constructs:

Variable	Pre-Intervention (M ± SD)	Post-Intervention (M ± SD)
Instructional Effectiveness	3.12 ± 0.54	4.45 ± 0.32
Time Management & Workload	2.88 ± 0.61	4.22 ± 0.36
Student Engagement (as reported by teachers)	3.15 ± 0.52	4.38 ± 0.30
Attitudes toward AI (constant across time)	3.87 ± 0.48	—

The post-intervention means were notably higher than pre-intervention values for all measured variables, indicating improvement following the use of AI tools.

Paired Sample t-Test
To determine whether the improvements were statistically significant, paired sample t-tests were conducted.

Measure	t	df	p-value	Interpretation
Instructional Effectiveness	10.88	59	< .001	Significant improvement
Time Management & Workload	9.21	59	< .001	Significant improvement
Student Engagement	11.03	59	< .001	Significant improvement

Interpretation: The results strongly support Hypotheses H1, H2, and H4. The use of AI tools significantly improved teachers' instructional delivery, reduced their workload, and enhanced their perceptions of student engagement.

Effect Size (Cohen's d)
Effect sizes were calculated to determine the **practical significance** of the observed changes.

Interpretation: The large effect sizes across all variables suggest that the changes were not only statistically significant but also educationally meaningful. This reinforces the transformative potential of AI tools in instruction.

Correlation Analysis
Pearson's correlation was used to explore the relationship

between teachers' **attitudes toward AI** and their **post-intervention instructional effectiveness.**

- $r = 0.61$, $p < .001$

Interpretation: There is a strong, positive correlation between favorable attitudes toward AI and improved instructional effectiveness. This supports Hypothesis H3 and suggests that professional development targeting teacher confidence in AI could amplify the positive impact of these tools.

ANOVA – Group Comparisons

To explore whether variables such as **age, teaching experience, or educational qualification** influenced the outcomes, one-way ANOVA was applied to post-test scores.

Interpretation: There were no statistically significant differences in outcomes based on age, experience, or qualification. This suggests the intervention was equally effective across diverse teacher profiles.

Summary of Findings

- **All hypotheses (H1–H4) were supported.**
- Teachers using AI tools showed **substantial improvements** in effectiveness, workload management, and student engagement.
- **Positive teacher attitudes toward AI** significantly correlated with better outcomes.
- The intervention was **universally effective,** showing no significant variation across demographic subgroups.

CONCLUSION

This study demonstrates that integrating AI tools—TeachMateAI, Gamma AI, and Quizizz—significantly enhances instructional effectiveness, improves time management, and increases student engagement among secondary school teachers. The use of a quasi-experimental design revealed substantial gains post-intervention, with large effect sizes confirming the practical value of AI-assisted instruction. A positive correlation between teacher attitudes toward AI and instructional improvement highlights the importance of teacher readiness in successful implementation. These findings align with the goals of India's National Education Policy (NEP) 2020, which promotes the integration of emerging technologies in education. While the study is limited by its short duration and lack of a control group, it provides strong preliminary evidence for the benefits of AI in pedagogy. Future research should explore long-term effects, broader subject areas, and comparative designs. Ultimately, AI tools can play a transformative role in making teaching more personalized, efficient, and engaging.

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