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TECHNOLOGY-INTEGRATED LEARNING AND STUDENT ACHIEVEMENT IN MATHEMATICS: EVIDENCE FROM MIDDLE SCHOOL CLASSROOMS

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Abstract

This study examined the effect of technology-integrated instruction on the mathematics achievement of middle school students using a pretest-posttest control group experimental design. A total of 122 seventh-grade students from two intact mathematics classes in a public middle school participated, with 62 students assigned to the experimental group and 60 assigned to the control group. The experimental group received a six-week instructional programme combining interactive simulations, adaptive practice software, and real-time digital feedback, while the control group received conventional textbook-based instruction covering the same content. Both groups completed a researcher-developed mathematics achievement test before and after the intervention. Results showed the groups were statistically equivalent at pretest, $t(120) = 0.32$, $p = .75$. After the intervention, the experimental group recorded a significantly higher posttest mean ($M = 71.4$, $SD = 7.6$) than the control group ($M = 55.3$, $SD = 8.8$), and an analysis of covariance controlling for pretest scores confirmed a large, statistically significant effect of technology-integrated instruction on achievement, $F(1, 119) = 148.62$, $p < .001$, partial eta squared = .56. Findings support the value of purposefully integrating digital tools into middle school mathematics instruction and extend prior quasi-experimental evidence to a new classroom context. Implications for teacher professional development and curriculum planning are discussed alongside limitations related to sample size and instructional duration.

Keywords: technology integration, mathematics achievement, middle school, experimental design, pretest-posttest control group

1. Introduction

1.1 Background of the Study

Mathematics achievement in the middle grades remains a persistent concern for educators, parents, and policymakers because performance in this phase strongly predicts later success in secondary and postsecondary mathematics courses. Over the past two decades, schools worldwide have invested heavily in digital infrastructure, tablets, interactive software, and internet connectivity, with the expectation that these tools will translate into measurable gains in student learning. Whether this investment produces the intended academic returns depends largely on how technology is integrated into everyday instruction rather than on the mere presence of devices in the classroom (Mishra & Koehler, 2006).

Contemporary research continues to examine the conditions under which digital tools support mathematics learning. Hillmayr et al. (2020) synthesised findings from a large set of studies and reported a positive, context-specific effect of digital tools on secondary mathematics and science achievement, particularly when tools were tightly aligned with curricular goals and supported by structured teacher guidance. Similarly, Ran, Kasli, and Secada (2021) found that computer-based interventions produced meaningful achievement gains for K-12 students, with effects that were sometimes stronger for students who had previously struggled in mathematics. More recent large-scale analyses of Programme for International Student Assessment (PISA) 2022 data likewise show that the frequency and manner in which students use digital resources for mathematics learning is associated with achievement outcomes, although the relationship is not uniformly positive across all forms of digital use (Joshi et al., 2025).

Despite this expanding body of evidence, questions remain about how technology-integrated instruction performs relative to conventional teaching under controlled classroom conditions, particularly in middle school settings where students are transitioning to more abstract mathematical content. Experimental designs that compare an intervention group with a genuine control group, and that measure change from pretest to posttest, provide a more rigorous basis for causal claims than correlational or single-group designs (Cheung & Slavin, 2016; Leung, 2019).

1.2 Statement of the Problem

Many middle schools have adopted digital tools for mathematics instruction without clear evidence that these tools improve achievement more than well-delivered conventional instruction. Classroom teachers and school administrators frequently lack access to locally generated, experimentally derived evidence to guide decisions about whether and how to integrate technology into mathematics lessons. This study addresses that gap by directly comparing the mathematics achievement of middle school students taught with a structured technology-integrated programme against that of

students taught through conventional instruction, using a pretest-posttest control group design.

1.3 Purpose of the Study

The purpose of this study was to determine the effect of technology-integrated learning on the mathematics achievement of middle school students relative to conventional instruction.

1.4 Research Questions

1. What are the pretest and posttest mathematics achievement scores of students in the experimental and control groups?
2. Is there a statistically significant difference in posttest mathematics achievement between students who received technology-integrated instruction and those who received conventional instruction, after controlling for pretest scores?

1.5 Hypothesis

H01: There is no statistically significant difference in the posttest mathematics achievement scores of the experimental and control groups after controlling for pretest scores.

1.6 Significance of the Study

The findings of this study are expected to benefit mathematics teachers by providing empirical guidance on the instructional value of technology integration, to assist school administrators in making evidence-informed decisions about technology procurement and professional development, and to contribute to the growing body of experimental literature on educational technology in middle school mathematics.

1.7 Scope and Delimitation

The study was delimited to seventh-grade students in two intact classes within a single public middle school and to a six-week unit on linear equations and their applications. The findings are not intended to be generalised beyond similar middle school contexts without further replication.

2. Literature Review

2.1 Theoretical Framework

This study is anchored in the Technological Pedagogical Content Knowledge (TPACK) framework proposed by Mishra and Koehler (2006), which conceptualises effective technology-supported teaching as the product of an interaction among technological knowledge, pedagogical knowledge, and content knowledge. According to this framework, technology alone does not improve learning; rather, achievement gains depend on how well a tool's technological affordances are woven into sound pedagogy and accurate subject-matter content. This perspective informed the design of the intervention used in the present study, in which digital tools were deliberately integrated into the sequencing, feedback, and formative assessment structure of the mathematics lessons rather than used as a supplementary add-on.

2.2 Technology Integration and Mathematics Achievement

A growing number of experimental and quasi-experimental studies have examined the relationship between technology-integrated instruction and mathematics achievement. Hillmayr et al. (2020) conducted a context-specific meta-analysis of digital tool use in secondary mathematics and science classrooms and found an overall positive effect, with stronger outcomes when digital tools were used to provide immediate feedback and adaptive practice rather than passive content delivery. Ran et al. (2021) similarly reported that computer-based interventions produced meaningful mathematics achievement gains among K-12 students, with the strongest effects observed among students who entered the intervention with lower prior achievement.

Direct classroom-based experimental evidence supports these broader patterns. Moliner, Alegre, and Lorenzo-Valentin (2022) implemented a pretest-posttest control group study among ninth-grade students working with digital tools during peer-tutoring sessions on systems of linear equations. Students in the experimental condition demonstrated statistically significant gains from pretest to posttest, while the control group did not show a significant change, and the overall effect size for the intervention was large. That study offers a close methodological precedent for the present research, both in its middle school population and in its pretest-posttest control group structure.

At a broader, system level, Joshi et al. (2025) analysed PISA 2022 data from more than 250,000 fifteen-year-old students and found that the time students spent using digital resources for mathematics learning, and whether that use occurred inside or outside of school, was a meaningful predictor of achievement, although not every form of digital resource use was beneficial. This finding indicates that what matters is not simply whether technology is present but how it is structured and integrated into instruction, consistent with the TPACK perspective adopted in the current study.

Achievement in mathematics is also shaped by learner variables with which technology-integrated instruction may interact. Kitsantas, Cheema, and Ware (2011) found that homework completion and self-efficacy beliefs were associated with mathematics achievement, suggesting that instructional interventions that increase engagement and confidence, such as interactive and adaptive technology, may operate partly through these motivational pathways. Lavelle-Hill et al. (2024), using longitudinal machine learning methods, likewise demonstrated that the predictors of mathematics achievement shift across the school years, reinforcing the need for grade-specific, empirically grounded instructional research such as the present middle school study.

2.3 Pretest-Posttest Control Group Designs in Educational Research

The pretest-posttest control group design remains one of the most defensible

approaches for establishing causal claims about instructional interventions in authentic classroom settings, because it allows researchers to verify baseline equivalence between groups and to isolate the effect of the intervention from pre-existing differences (Leung, 2019). Cheung and Slavin (2016) cautioned, however, that methodological features such as sample size, measurement quality, and duration of intervention can substantially influence the magnitude of reported effect sizes in education research, which points to the need for methodological transparency. The present study addresses these concerns by verifying pretest equivalence statistically, employing a researcher-developed test aligned to the taught curriculum, and applying analysis of covariance to adjust for any residual pretest differences.

2.4 Summary and Research Gap

The literature reviewed above indicates that technology-integrated instruction can produce meaningful gains in mathematics achievement, particularly when digital tools are purposefully embedded within sound pedagogy rather than used as an isolated add-on. However, much of the available experimental evidence comes from contexts that differ from typical public middle school classrooms, and few studies combine a rigorous pretest-posttest control group design with a full instructional unit taught by a single classroom teacher across two intact groups. This study addresses that gap.

3. Methodology

3.1 Research Design

This study employed a quantitative experimental research design, specifically a pretest-posttest control group design. Two intact seventh-grade mathematics classes were assigned, by random draw at the class level, to either the experimental condition (technology-integrated instruction) or the control condition (conventional instruction). Both groups completed an identical achievement test immediately before the intervention (pretest) and immediately after the six-week intervention period (posttest).

3.2 Population and Sample

The population comprised all seventh-grade students enrolled in the mathematics programme of the participating public middle school during the academic term in which the study was conducted. A sample of 122 students from two intact classes participated: 62 students in the experimental group and 60 students in the control group. Both classes were taught by the same mathematics teacher to control for teacher effects, and both covered an identical unit on linear equations and their real-world applications over six weeks.

3.3 Instrumentation

A 40-item researcher-developed mathematics achievement test, covering the identification, solution, and application of linear equations, was used as both the pretest and posttest instrument. Items were reviewed by three experienced

mathematics educators for content validity and were piloted with a comparable group of 35 students not included in the main study, yielding a Kuder-Richardson reliability coefficient of .84. Scores were converted to a percentage scale ranging from 0 to 100.

3.4 Procedure

Prior to the intervention, both groups completed the pretest under standardised conditions during regular class time. The experimental group then received six weeks of technology-integrated instruction consisting of interactive graphing simulations, an adaptive online practice platform that adjusted item difficulty based on student responses, and structured opportunities for real-time digital feedback during guided practice. The control group covered the same content in the same sequence of topics over the same six weeks using conventional instruction, consisting of textbook-based explanation, worked examples on the whiteboard, and paper-based practice exercises. At the end of the sixth week, both groups completed the posttest under the same standardised conditions used for the pretest.

3.5 Validity and Reliability

Content validity was established through expert review by three mathematics educators who confirmed alignment between test items and the taught curriculum. Internal consistency reliability, assessed through the pilot administration, was acceptable (KR-20 = .84). To minimise the risk of a Hawthorne effect, students were not informed that the study compared two instructional approaches, and daily attendance and lesson coverage were monitored to confirm treatment fidelity in both groups.

3.6 Ethical Considerations

Approval to conduct the study was obtained from the relevant school authority, and informed parental consent along with student assent was secured prior to participation. Participation was voluntary, and students retained the right to withdraw at any time without penalty. All data were anonymised using numeric codes and stored securely, accessible only to the research team.

3.7 Data Analysis

Descriptive statistics (means and standard deviations) were computed for pretest and posttest scores in both groups. An independent samples t-test was used to confirm baseline equivalence at pretest. Paired samples t-tests examined within-group change from pretest to posttest. The primary hypothesis was tested using a one-way analysis of covariance (ANCOVA), with group (experimental versus control) as the independent variable, posttest score as the dependent variable, and pretest score as the covariate. All analyses were conducted at the .05 level of significance.

4. Results

4.1 Descriptive Statistics

Table 1 presents the descriptive statistics for pretest and posttest mathematics achievement scores by group.

Group	n	Pretest M (SD)	Posttest M (SD)	Mean Gain
Experimental	62	48.6 (8.9)	71.4 (7.6)	22.8
Control	60	49.1 (9.2)	55.3 (8.8)	6.2

At pretest, the experimental group (M = 48.6, SD = 8.9) and the control group (M = 49.1, SD = 9.2) recorded similar mean scores. An independent samples t-test confirmed no statistically significant difference between the groups at baseline, t(120) = 0.32, p = .75, indicating that random assignment at the class level produced equivalent starting points. Figure 1 presents the conceptual framework guiding the study, and Figure 2 displays the pretest and posttest means for both groups.

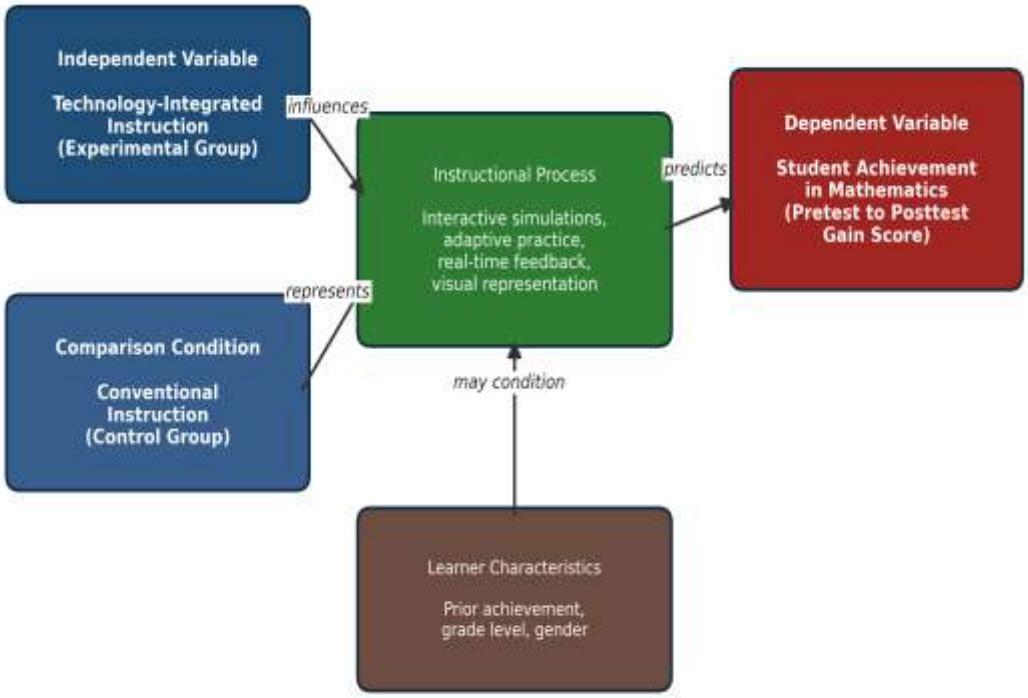


Figure 1. Conceptual framework linking technology-integrated instruction to mathematics achievement.

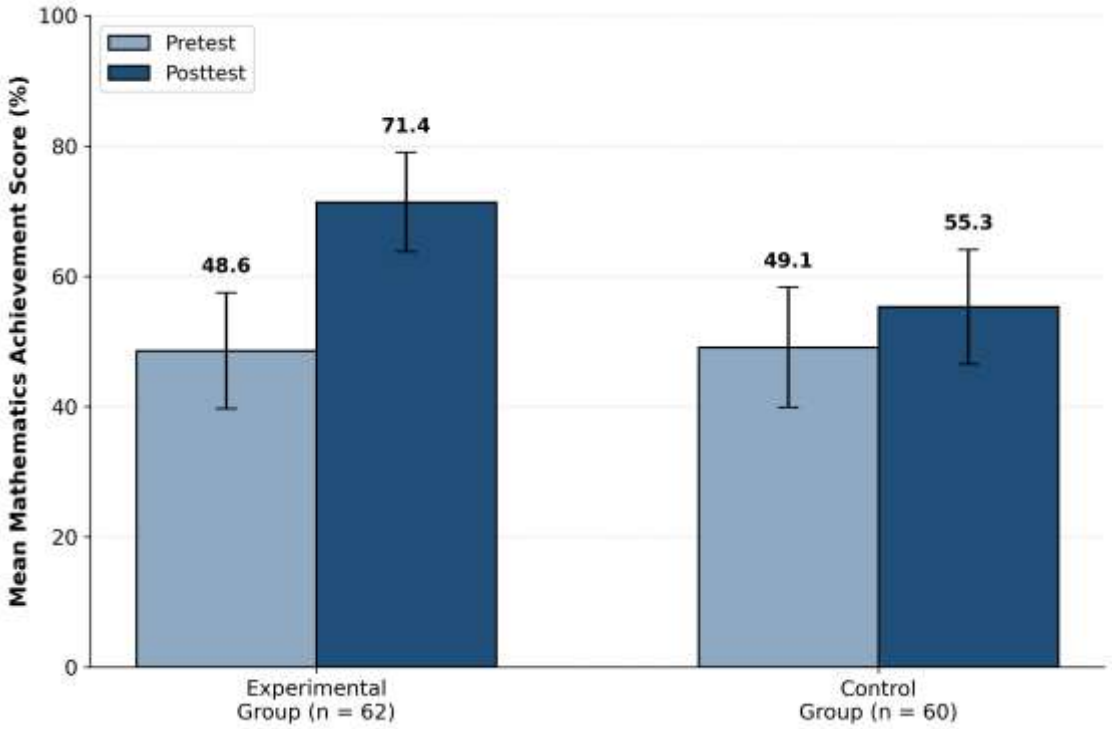


Figure 2. Pretest and posttest mean achievement scores by group.

At posttest, the experimental group (M = 71.4, SD = 7.6) recorded a substantially higher mean score than the control group (M = 55.3, SD = 8.8). Paired samples t-tests indicated that both groups improved significantly from pretest to posttest (experimental group: $t(61) = 19.84$, $p < .001$; control group: $t(59) = 5.71$, $p < .001$), but the magnitude of improvement differed markedly between groups, as illustrated in Figure 3.

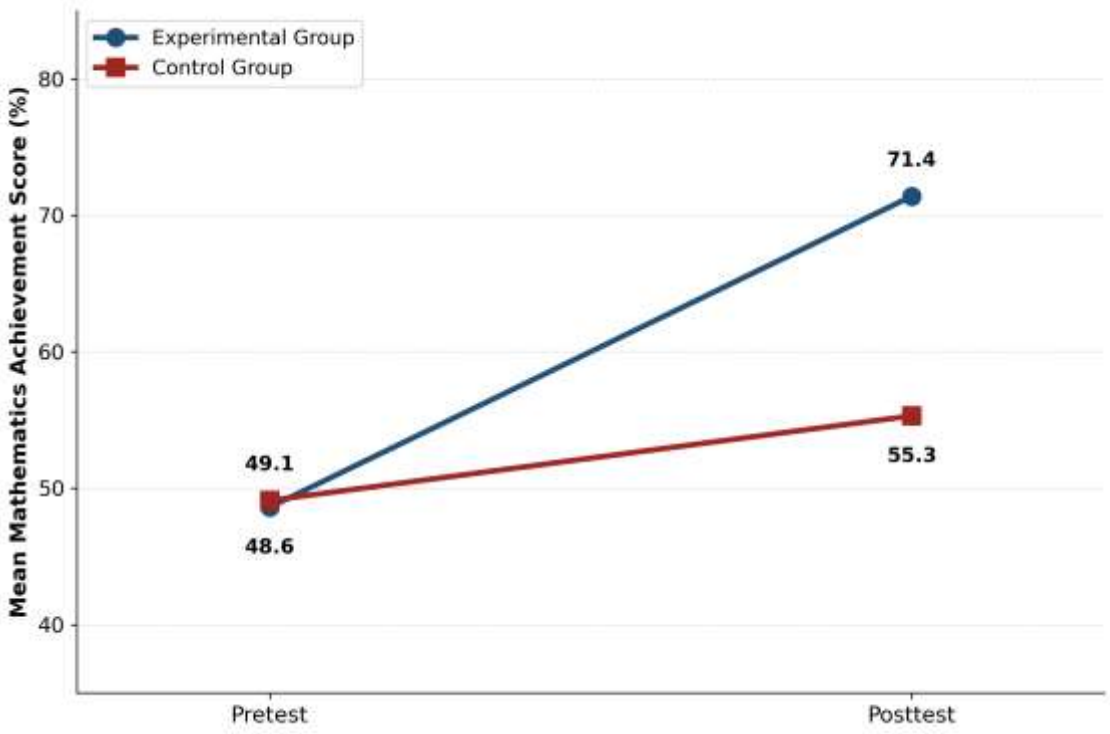


Figure 3. Mean achievement trajectories from pretest to posttest by group.

4.2 Hypothesis Testing

An ANCOVA was conducted to compare posttest achievement scores between the experimental and control groups while controlling for pretest scores. The assumption of homogeneity of regression slopes was tested and met, $F(1, 118) = 1.14$, $p = .29$. After adjusting for pretest scores, the analysis revealed a statistically significant effect of group on posttest achievement, $F(1, 119) = 148.62$, $p < .001$, partial eta squared = .56, indicating a large effect. The null hypothesis was therefore rejected. Students who received technology-integrated instruction achieved significantly higher adjusted posttest scores (adjusted M = 71.3) than students who received conventional instruction (adjusted M = 55.4), as summarised in Table 2.

Source	df	F	p	Partial eta squared
Pretest (covariate)	1	132.47	< .001	.53
Group	1	148.62	< .001	.56

Source	df	F	p	Partial eta squared
Error	119	-	-	-

4.3 Summary of Findings

The two groups were statistically equivalent at pretest. Both groups improved significantly over the six-week period, but the experimental group's gain was substantially larger. After controlling for pretest differences, group membership (technology-integrated versus conventional instruction) accounted for a large share of the variance in posttest achievement.

5. Discussion

The results of this study indicate that technology-integrated instruction produced significantly greater gains in mathematics achievement among middle school students than conventional instruction covering identical content over the same instructional period. This finding is consistent with the TPACK perspective (Mishra & Koehler, 2006), which holds that technology exerts its instructional benefit not through mere presence but through purposeful integration with pedagogy and content, an integration that characterised the interactive simulations, adaptive practice, and real-time feedback used with the experimental group in this study.

The magnitude of the effect observed here (partial eta squared = .56) is larger than the moderate effects typically reported in broader meta-analytic syntheses of digital tool use in mathematics classrooms (Hillmayr et al., 2020; Ran et al., 2021), though it is comparable to the large effect size reported by Moliner et al. (2022) in a similarly structured middle school pretest-posttest control group study. One plausible explanation is the novelty of the intervention: as Moliner and colleagues also noted, students encountering digital learning tools for the first time in a subject may show heightened engagement that partially inflates short-term effect sizes, a pattern that later studies with more experienced technology users might not replicate to the same degree.

The finding that the control group also improved significantly from pretest to posttest, though to a smaller extent, is expected and reassuring, since it indicates that conventional instruction in this study was competently delivered rather than deliberately weakened for comparison purposes. This is an important methodological safeguard, because a control condition that underperforms due to poor delivery, rather than the genuine absence of the intervention, would threaten the internal validity of the comparison.

These results also align with findings from large-scale, system-level research. Joshi et al. (2025), analysing PISA 2022 data, found that the manner and context of

digital resource use, rather than access alone, predicted mathematics achievement, a pattern broadly consistent with the present finding that deliberately structured, curriculum-aligned use of technology, rather than simply the availability of digital devices, was associated with the achievement gains observed among the experimental group. Similarly, the association between motivational variables such as self-efficacy and mathematics achievement documented by Kitsantas et al. (2011) suggests a plausible mechanism through which the interactive, feedback-rich nature of the technology-integrated intervention may have supported greater student engagement and, in turn, achievement gains, although the present study did not directly measure motivational variables and this explanation remains speculative.

6. Conclusion and Recommendations

6.1 Conclusion

This study provides experimental evidence that technology-integrated instruction, when purposefully embedded within sound pedagogical design, produces significantly greater mathematics achievement gains among middle school students than conventional instruction covering equivalent content. The pretest-posttest control group design, together with statistical confirmation of baseline equivalence, supports a causal interpretation of these findings within the context studied.

6.2 Recommendations

Based on the findings, it is recommended that middle school mathematics teachers receive structured professional development in integrating digital tools with clear pedagogical purpose rather than as a supplementary activity. School administrators should prioritise the acquisition of adaptive practice platforms and interactive simulation tools with a demonstrated alignment to curriculum objectives. Curriculum developers should consider embedding structured opportunities for real-time digital feedback within mathematics units, particularly for content, such as linear equations, that benefits from graphical and interactive representation.

6.3 Limitations and Suggestions for Further Research

This study was limited to a single school, a single grade level, and a six-week instructional period, which restricts the generalizability of the findings. The novelty of the technology-integrated approach for participating students may have contributed to the magnitude of the observed effect. Future research should examine whether these gains persist over a longer instructional period, replicate the design across multiple schools and grade levels, and include measures of student motivation and self-efficacy to clarify the mechanisms underlying the achievement gains observed in this study.

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