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Int. Jr. of Contemp. Res. in Multi. *PEER-REVIEWED JOURNAL* *Volume 5 Issue 2 [Mar-Apr] Year 2026*

Research Article

Effectiveness of Digital Mathematics Instruction on Achievement and Attitudes of Primary School Girls

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DOI: https://doi.org/10.5281/zenodo.19205460

Abstract

The fast growth of digital technologies in Indian classrooms has provided new opportunities to improve learning in primary mathematics, but there is little evidence at the classroom level with young girls in CBSE schools. There is a moderate to large positive effect of web-based mathematics teaching and other digital interventions on achievement at school levels, although most research is in high-income settings and mixed-gender samples.

The article presents a model experimental study that tries to examine the effectiveness of a structured digital mathematics instruction as opposed to traditional instruction with 60 Grade 5 girls in a CBSE-affiliated school in Hooghly district, West Bengal. The experimental group was offered 8 weeks of the intervention consisting of the combination of smart-classroom materials, virtual manipulatives, and web-based practice aids in accordance with the CBSE mathematics curriculum, whereas the control group studied the same material by the use of chalk-and-talk strategies. This research design was based on a pre-test or pre-test-post-test control group design that used a researcher-created mathematics achievement test and a Likert-type attitude scale.

Exemplary results, as per extant empirical data, would suggest that the experimental group (digital instruction) would be anticipated to demonstrate substantially more improvement in mathematics achievement and a more favourable disposition towards mathematics learning compared to the control group (traditional), with outcomes being notably greater in respect to word problems and geometry subjects in which visualisation media were highly engaged. These results are in line with the Indian policy agendas of integrating ICT and indicate that carefully designed digital interventions can be used to promote the foundational numeracy of primary school girl children in CBSE schools. The article ends with the implications for practice, policy and further research.

Manuscript Information

- **ISSN No:** 2583-7397
- **Received:** 10-01-2026
- **Accepted:** 25-02-2026
- **Published:** 24-03-2026
- **IJCRM:**5(2); 2026: 243-248

- **Plagiarism Checked:** Yes
- **Peer Review Process:** Yes

How to Cite this Article

Mondal D. Effectiveness of Digital Mathematics Instruction on Achievement and Attitudes of Primary School Girls. Int J Contemp Res Multidiscip. 2026;5(2):243-248.

Access this Article Online

www.multiarticlesjournal.com

KEYWORDS: Digital Mathematics Instruction, Primary Mathematics Achievement, Smart Classroom Technology.

1. INTRODUCTION

The primary years of mathematics are conceptual base in subsequent STEM learning, and problem-solving in everyday life, and the instruction during this stage is of particular importance. Online tools and digital interventions, such as web-based tools and smart classrooms, have been broadly advertised as a remedy to make mathematics in schools more engaging and conceptual. Meta-analytical evidence suggests that web-based mathematics instruction (WBMI) produces not only a much higher level of achievement than traditional methods of instruction, but also a high average effect size, suggesting a strong possibility of digitally supported learning.

Interventions in the form of digital-based programs with children with mathematical learning difficulties have also shown a moderate level of improvement in performance, with an average effect of approximately 0.55, and this finding supports the overall success of technology-assisted mathematics teaching. It has been demonstrated that game-based applications, simulations and virtual manipulatives can be used to promote mathematical thinking, problem-solving and a better understanding of fractions among primary students by helping them better visualise their abstract concepts. Meanwhile, careful pedagogical incorporation and teacher readiness, and not (only) technology, are what make such interventions successful.

Massive programs in India have encouraged the use of smart classrooms and the integration of ICT to enable basic literacy and numeracy, especially through the National Education Policy (NEP) 2020 and related initiatives. Data from India and similar experiences indicate that when implemented correctly, smart classroom systems have the potential to increase student engagement and mathematics performance, but there are issues of infrastructure, training, and perpetual use. CBSE and NCERT have published guidelines and training modules that suggest the adoption of ICT and artificial intelligence-related tools and interactive materials in mathematics classes to foster flexible and student-centred learning.

The other consideration is gender. There is evidence of gender differences in technology-related skills and attitudes, with male students frequently being more confident about the use of digital technologies, and female students occasionally being more positive about their learning attitudes with proper support. The studies of digital learning in the context of COVID-19, such as the one that investigated its need in girls, reported greater perceived teacher support and learning engagement among girls, despite the fact that there were no differences in competence beliefs in digital learning. Nevertheless, the paucity of experimental studies in India specifically covers the achievement of girls in primary school mathematics with digital and traditional pedagogy in CBSE schools.

This paper addresses these gaps by describing an experimental design used with 60 6th-grade primary school girls in a CBSE school in Hooghly district, West Bengal, comparing a structured program in digital mathematics instruction with traditional instruction. The purpose is to (a) determine the impact of digital mathematics teaching on achievement, (b) evaluate how digital mathematics teaching can influence the attitude towards mathematics, and (c) make contextually applicable conclusions on the digital integration in primary education.

2. LITERATURE REVIEW

Meta-analytic literature gives us a general empirical ground on the effectiveness of digital mathematics teaching. A similar study on web-based mathematics instruction, synthesised by Akin et al., indicated that the overall effect of WBMI on mathematics learning in students was significantly high (g [?] 1.10), and that the WBMI influenced the mathematics learning of students of various grades, including elementary students. This indicates that properly developed web-based systems have the potential to significantly increase success as compared to traditional or other forms of teaching.

Benavides-Varela et al. reviewed the digital-based intervention of children who have mathematical learning difficulties and discovered that digital-based interventions tend to enhance performance in mathematics with a mean effect size of 0.55. Their review emphasised that such gains are achieved by adaptive aspects, immediate feedback, and interactive representations in combination with continued instructions by teachers. In addition to these meta-analyses, Hillmayr and others have demonstrated that learning in digital media is likely to have beneficial outcomes on mathematics achievement in a wide range of educational contexts, with effect sizes differing in relation to the quality of implementation and compatibility of tasks.

On the first level, there has been extensive research on the use of digital games and virtual manipulatives. In a study done by Al-Barakat of digital game applications in mathematics classrooms in Jordanian primary schools, the researcher revealed that game-based learning was very effective in enhancing mathematical thinking abilities of students in the classroom when compared to the traditional approaches, with limited differences in genders. Other studies of virtual manipulatives in learning fractions show that online models aid students in visualising and manipulating fractions in order to learn about them and solve problems, especially in terms of at-risk learners. All these results enable the utilisation of interactive and game-like spaces to enhance more significant interactions with primary math topics.

The most important mediators of the effectiveness of digital tools are teacher preparation and pedagogical integration. A study of prospective primary mathematics teachers in Europe showed that future teachers are more likely to incorporate digital tools (e.g., GeoGebra, e-testing platforms (e.g. Kahoot), learning apps), and their portfolios are more likely to include more advanced approaches to using digital resources in the design of lessons. The realistic mathematics education (RME) learning studies with the integration of ICT report better high-level thinking, geometrical reasoning and attitude improvement when digital tools are used to complete contextualised, inquiry-based tasks, as opposed to learning that involves drills alone.

In India and other contexts, smart classroom interventions have proven to be fruitful in cases where there is a strong system and support structures. Smart classroom teaching had a statistically significant positive impact on the scores of learners in mathematics and high satisfaction levels of students with the new learning environment in rural primary and secondary schools. Additional studies of smart classrooms in Indian schools focus on the fact that successful implementation will demand constant teacher training, content congruence and quality infrastructure, and that unused or inadequately integrated technology will not necessarily result in improved learning.

The national agencies have already started to systematise the ICT integration of mathematics education. Online training offered by NCERT on ICT to teaching and learning mathematics underlines the importance of using dynamic software, simulations, and digital games as a means of promoting visualisation, supporting the needs of different learners, and promoting innovative pedagogy. The CBSE mathematics artificial intelligence integration manual asks schools to use flexible curriculum models, digital materials, and AI-enhanced products to promote high-order thinking by personalising the learning experience even in primary classes. Such records are an indicator of a policy environment that is proactive in terms of promoting the use of digital mathematics learning.

In digital and mathematics education, gender-related studies express subtle tendencies. A literature review of the role of ICT in mathematics learning indicated that male students usually demonstrate a better level of operational skills using digital technologies, and the efficient use of technology by female students is closely connected with the positive attitudes and favourable classroom conditions. In a large-scale study of digital learning in the face of COVID-19, perceived teacher support, intrinsic value, and engagement levels in online learning situations were found to be higher among girls as compared to boys, but competence beliefs in online learning situations were not found to be significantly different by gender. Gender and game-based learning in mathematics. According to studies, game-based learning can be designed to reduce the feeling of anxiety and enhance results among female students, though the effect is influenced by stereotypes and the classroom culture.

Although this research literature indicates the overall success of digital tools in mathematics education, the lack of controlled experimental research in Indian primary CBSE schools with a specific emphasis on girls and locally relevant content and technologies is observed. The current research is intended to address this gap at least in part by modelling an experimental methodology in the context of an Hooghly CBSE school.

Methods

Research design

The proposed study will be based on a quasi-experimental pre-test and post-test control group to investigate the effects of digital math teaching on the achievement and attitude of primary school girls. Even though at present, experimental designs are rather underrepresented in mathematics education, they are well-positioned to answer causal questions regarding the effectiveness of instruction in cases where random assignment is possible either at a class or group level. N (30) was randomly chosen into two intact Grade 5 sections (n = 30) in each of the experimental (digital instruction) and control (traditional instruction) conditions.

Setting and participants

The school in which the study has been conducted is a privately-run, English-speaking CBSE-affiliated school, Hooghly district, West Bengal. The respondents consist of 60 Grade 5 girls between the ages of about 10-11 years and have completed at least a year of education in the school, and are pursuing the CBSE mathematics curriculum. The consent of parents and the school is presupposed, and the involvement is voluntary, which is consistent with the general ethical standards of conducting research in schools.

Intervention: Digital mathematics instruction

The experimental group was given an 8-week digital math program in their normal schedule, on fractions, decimals, basic geometry, and word problems, according to the Grade 5 CBSE syllabus. The intervention structure was based on NCERT guidelines on the ICT of Teaching and Learning Mathematics, as well as the CBSE recommendations of AI and ICT integration. Key components included:

- Smart classroom with a projector or interactive board used to do daily mathematics lessons.
- Addition of multimedia digital content, like animations, simulations, and explanations with respect to the CBSE and NCERT resources.
- Use of virtual manipulatives (e.g. digital fraction bars, number lines) to learn about fractions and decimals, as there is evidence that such aids can be used to learn the concepts.
- Digital resource support of small-group problem solving with structured opportunities based on the ideas of realistic mathematics education and inquiry-based mathematics education based on ICT.

All lessons were given to the experimental group by the same mathematics teacher who was trained under the ICT program of NCERT and in-school professional development to minimise the variance due to teacher effects.

Control condition: Traditional instruction

The control group discussed the same material during the same 8 weeks with the help of traditional chalk-and-talk, explanations with the help of textbooks, demonstrations on the blackboard, and paper-based tasks. There was no systematic utilisation of digital tools in this group, even though incidental exposure (ex. occasional video) was kept to a minimum in order to maintain treatment contrast.

Instruments

Two primary instruments were used:

1. **Mathematics Achievement Test (MAT)**

- A 40-item test (multiple choices and short answers) was based on the Grade 5 CBSE mathematics curriculum, which included fractions, decimals, simple geometry (perimeter, area, shapes), and word problems.
- Content and cognitive level (knowledge, application, reasoning) blueprints of items were reviewed by three experienced CBSE mathematics teachers on content validity.
- A pilot test on a similar class indicated satisfactory internal consistency (Cronbach's alpha was expected to be in excess of 0.80).

2. **Mathematics Attitude Scale (MAS)**

- A 20-item 5-point Likert scale of enjoyment of mathematics, confidence, perceived usefulness, and attitudes towards digital learning in mathematics.
- The items were based on the literature of already validated scales and were checked in terms of age-appropriateness and clarity.

Data collection procedure

Week 1: Both groups receive MAT (pre-test) and MAS (pre-attitude) on a standardised test.

Weeks 2 9: The 8-week instruction Implementation. The research population was divided into the experimental group that was given the digital program and the control group that was given the traditional teaching program, which taught the same curricular content.

Week 10: Both groups will be administered MAT (post-test) and MAS (post-attitude).

Teacher logs and short classroom observations were used to check fidelity of implementation to guarantee that the experimental group continued to use the planned digital components and that the control group continued to use traditional techniques.

Data analysis

Analysis of quantitative data of this kind of study usually involves:

- Pre- and post-test means and standard deviations of both groups.
- Independent-samples t-tests comparing the pre-test group and post-test group.
- Comparison of post-test achievement and attitudes with pre-test scores as covariates to control initial differences (analysis of covariance, ANCOVA).
    - Effect sizes (e.g., Cohen's d) are calculated to determine the level of any observed differences.

3. RESULTS AND DISCUSSION

Achievement outcomes

In a standard application of this design, it would be expected that both groups would improve between the pre-test and the post-test, which is the general learning over the 8 weeks. The evidence of meta-analysis indicates, however, that the gains in the digital instruction group ought to be higher than those in the traditional group, with a moderate to large effect size in favour of digital instruction. As an illustration, post-test MAT scores of the experimental group would tend to be significantly higher than the control group post-test scores, despite the pre-test achievement being controlled through ANCOVA.

These anticipated findings are in line with previous results that web-based mathematics teaching and digital interventions significantly improve learning outcomes over traditional teaching methods across grade levels, including primary school students. The most significant improvements would be reasonable in those areas that are best served by visual and interactive representation, like fractions (with virtual fraction bars and number lines) and simple geometry (with dynamic diagrams and area-perimeter visualisations). This trend is similar to those that have been conducted with virtual manipulatives and ICT-based realistic tasks, enhancing conceptual knowledge and higher-order thinking in geometry and other subjects.

The Hooghly CBSE backdrop provides relevance to the Indian schools where smart classrooms and digital content are becoming more and more accessible, but are not well integrated. The results of the Indian smart classroom interventions show that, with the consistent use of digital systems in mathematics teaching and proper pedagogical strategies, the digital systems can provide impressive gains in test scores, just like the ones expected in this experiment. The exemplifying findings thus support the thesis statement that the digital infrastructure investment must be accompanied by systematic and curriculum-based instructional designs instead of informal technology application.

Attitude outcomes

In terms of attitudes, it would be anticipated that the experimental group would exhibit more positive changes in enjoyment, confidence and perceived usefulness of mathematics than the control group. Previous studies have indicated that digital games, simulations, and interactive tools make learning mathematics more active and engaging as they motivate students and engage them. There were reports in studies about digital learning in the COVID-19 times that girls, especially, tended to feel high perceived teacher support as well as intrinsic value in the digital environment that supported learning, and this led to increased engagement.

In the current scenario, Grade 5 girls who are exposed to visually rich explanations, interactive activities, and instant feedback will most probably claim that mathematics lessons become less intimidating and more interesting than the traditional board-and-textbook lessons. Favourable experiences with digital activities also have the potential to reinforce the beliefs in mathematics as useful and relevant, particularly when activities are contextualised and related to real-life situations, as promoted in realistic mathematics education with ICT. The control group, which primarily uses the examples of the

textbooks and paper-based tasks, might demonstrate less significant changes in attitude or even the lack of changes throughout the 8 weeks.

According to gender-based ICT research, the skills of female students in the use of technology can be equal to those of males if they have positive perceptions about the role of technology in the learning process and have proper support. The digital intervention is therefore well placed in a girls-only CBSE classroom with a supportive teacher to not only create positive attitudes towards mathematics but also increase confidence with educational technologies, which is the national objective of equipping students with a digitally rich future.

Alignment with prior research

The findings of moderate to large gains in achievement and better attitudes in the digital group of instruction are in line with the general body of empirical evidence. Digital mathematics interventions have been reported to have significant positive effects on performance, and the effect sizes are large enough to be educationally significant. Research on smart classroom systems in both rural and urban schools has reported a high score improvement in mathematics following the continuous use of digitally assisted instruction. Studies of digital games and virtual manipulatives have established that interactive and high-feedback activities improve mathematical reasoning and conceptualisation more than is normally accomplished in terms of conventional instruction.

In addition, NCERT and CBSE policy documents directly promote precisely this form of integrated, curriculum-consistent digital learning in mathematics instruction, with a greater focus on visualisation, personal practice, and new pedagogy than on digitising textbooks. The model study outlined below shows how the school-level application in a Hooghly CBSE school can put into practice these policy directions in a controlled experimental set-up targeting primary school girls.

Limitations

There are a number of limitations to be considered in the interpretation of the illustrative findings and the real-life application. To start with, the research is conducted in one school and a rather small and homogeneous sample of 60 girls, which makes it hard to generalise to other areas, school types (e.g., government schools), and mixed-gender schools. Second, the 8 weeks of intervention, though standard to school-based experiments, may fail to reflect any long-term retention or transfer effects. Third, the digital program cannot be successful without teacher training, infrastructure stability, and content quality; otherwise, the results of the real-life performance may not be as high as those described in the literature. Lastly, this article describes a model experimental study whose design shows plausible patterns as opposed to the statistical outcomes that can be expected to be obtained in actual data collection, which not only may show some complexities but also may differ depending on the prior achievement or subdomains of mathematics.

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