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Effectiveness Of Abacus-Based Techniques In Developing Speed And Accuracy In Arithmetic

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Abstract

This study investigates the Effectiveness of Abacus based techniques in Improving Speed and Accuracy in Arithmetic among Grade IV primary school students. A quasi-experimental pretest-posttest non-equivalent group design was employed, dividing 80 students into two groups: a Control Group (C) (n = 40) taught using conventional methods and an Experimental Group (E) (n = 40) trained using Abacus strategies. The intervention consisted of a structured 60-class instructional module focusing on simple addition and subtraction, with the aim of enhancing computation speed and accuracy.

Data collection involved pretest and posttest arithmetic assessments, measuring speed (time taken in minutes) and accuracy (percentage of correct responses). Statistical analyses, including paired t-tests and independent t-tests, were conducted to determine the effectiveness of each instructional approach. The findings revealed that while the conventional method led to a significant improvement in arithmetic speed in the control group, the Abacus strategy demonstrated a much greater impact, yielding a very large effect size. Comparative post-test results further confirmed that students trained with Abacus strategies outperformed those taught through conventional methods in both speed and accuracy, with a highly significant difference ($p < .01$).

These results highlight the superiority of Abacus-based learning over traditional methods in developing arithmetic fluency and precision. Given its substantial impact, integrating Abacus strategies into primary mathematics education may serve as an effective pedagogical approach for enhancing foundational numeracy skills. Future research could explore the long-term retention of Abacus-based arithmetic skills and its applicability to higher-order mathematical concepts.

Keywords: Effectiveness, Abacus, Speed, Accuracy, Arithmetic, fluency, precision.

1. Introduction

Education is the foundation of personal and societal growth, shaping individuals into knowledgeable, responsible, and skilled members of society. It provides people with the necessary skills to think critically, communicate effectively, and solve problems, enabling them to make informed decisions in their personal and professional lives. Through education, individuals gain access to better career opportunities, economic stability, and improved quality of life. Moreover, it fosters intellectual curiosity, creativity, and adaptability, which are essential in an ever-evolving world.

Beyond individual benefits, education plays a crucial role in social progress and national development. It promotes equality, reduces poverty, and strengthens democracy by empowering citizens with awareness of their rights and responsibilities. Educated societies tend to experience lower crime rates, better healthcare, and increased technological and scientific advancements. Furthermore, education fosters cultural understanding and social harmony, helping individuals appreciate diversity and work collectively for a more inclusive and progressive world.

2. Conceptual Background

Mathematics plays a crucial role in primary education as it develops essential cognitive and problem-solving skills in young learners. It lays the foundation for logical thinking, reasoning, and analytical abilities, which are necessary for everyday decision-making. Basic mathematical concepts such as addition, subtraction, multiplication, and division help children understand numbers, measurements, and patterns, enabling them to perform daily tasks like counting money, telling time, and measuring objects. Early exposure to mathematics also enhances a child's ability to grasp more complex subjects in higher education, fostering confidence and a positive attitude toward learning.

Beyond academics, mathematics is vital for developing life skills such as critical thinking, spatial awareness, and problem-solving. It nurtures perseverance and accuracy, encouraging children to approach challenges systematically and with patience. Additionally, mathematical literacy helps students in future careers, even in non-mathematical fields, by enhancing their ability to interpret data, analyze situations, and make logical conclusions. Thus, integrating mathematics effectively into primary education ensures a strong academic foundation and equips children with the skills needed for personal and professional success.

Arithmetic skills are fundamental in primary education as they form the basis for mathematical understanding and real-life problem-solving. Mastering basic operations such as addition, subtraction, multiplication, and division enables young learners to develop number sense, which is essential for understanding more advanced mathematical concepts in later years. These skills not only help students perform calculations but also enhance their logical thinking, reasoning, and analytical abilities. A strong foundation in arithmetic boosts confidence in handling numbers and supports academic success across various subjects, including science and economics.

Beyond academics, arithmetic skills are crucial for daily life activities. Children use arithmetic when managing money, measuring ingredients in cooking, understanding time, and interpreting data. Developing accuracy and speed in arithmetic fosters discipline, patience, and problem-solving skills, which are valuable in both personal and professional life. Furthermore, early proficiency in arithmetic reduces math anxiety and promotes a positive attitude toward learning, ensuring that students are better prepared for future educational and career opportunities.

Abacus Strategies for Improvement of Arithmetic Skills in Primary Education

Abacus-based learning is a well-established method for enhancing arithmetic skills in primary education. Research indicates that using an abacus strengthens children's numerical cognition by promoting visualization and mental calculation strategies (Lessani et al. (2017). The physical manipulation of beads helps young learners develop a concrete understanding of numbers, fostering numerical fluency and computational accuracy. According to Stigler (1984), abacus training engages both hemispheres of the brain, improving working memory, concentration, and logical reasoning. Through consistent practice, students transition from using a physical abacus to performing mental calculations, significantly boosting their arithmetic speed and problem-solving abilities (Hatano et al., 2002).

Moreover, studies have shown that abacus training reduces math anxiety and enhances children's confidence in handling numbers (Bhaskaran et al., 2006). It fosters visualization techniques that aid in grasping complex mathematical concepts, making learning more engaging and effective (Hanakawa et al., 2003). Abacus learners tend to outperform their peers in tasks requiring mental computation and numerical reasoning (Frank & Barner, 2011). Thus, integrating abacus strategies into primary education not only strengthens arithmetic proficiency but also develops essential cognitive skills that support lifelong mathematical learning.

Abacus Strategies in Improving Speed and Accuracy in Arithmetic

Abacus training is a proven method for enhancing both speed and accuracy in arithmetic calculations, particularly among primary school students. By using an abacus, learners develop a strong numerical foundation through visual and tactile engagement, which strengthens their ability to perform rapid mental calculations (Hatano et al., 2002). The abacus method encourages the use of visualization techniques, where students mentally manipulate beads instead of relying on rote memorization or conventional written calculations (Stigler, 1984). This mental processing leads to improved arithmetic speed as students gradually transition from physical bead movement to mental abacus calculations. A study by Lessani et al. (2017) found that children trained in abacus techniques demonstrated significantly faster computation times compared to those using traditional methods, highlighting its effectiveness in enhancing processing speed.

In addition to speed, abacus learning plays a crucial role in improving accuracy in arithmetic. The structured and systematic approach of abacus-based calculations helps minimize errors, ensuring precision in numerical operations (Bhaskaran et al., 2006). Research by Frank and Barner (2011) indicates that abacus-trained students exhibit higher accuracy rates in addition, subtraction, multiplication, and division problems compared to their non-abacus-trained peers. This improvement is attributed to the activation of both hemispheres of the brain during abacus use, which enhances concentration, working memory, and problem-solving abilities (Hanakawa et al., 2003). The cognitive benefits of abacus training also extend to improved retention and recall of numerical data, making it an effective tool for boosting both speed and accuracy in arithmetic calculations.

Need and Significance of the Study

Developing strong arithmetic skills at an early stage is crucial for a child's overall academic growth and cognitive development. However, many primary school students struggle with speed and accuracy in basic arithmetic operations, leading to a lack of confidence in mathematics. Traditional teaching methods often rely on rote memorization rather than conceptual understanding, which limits students' ability to perform quick and accurate calculations. The integration of Abacus strategies in arithmetic learning provides an effective solution by fostering mental calculation skills, enhancing numerical visualization, and improving overall mathematical proficiency (Hatano et al., 2002). With growing global emphasis on numeracy skills as a key component of education, there is a pressing need to explore alternative teaching methods, such as Abacus-based learning, to enhance arithmetic competency in young learners (Lessani et al. (2017).

This study holds significant educational and cognitive implications, particularly in improving the speed and accuracy of arithmetic calculations among primary school students. Research suggests that abacus-trained students outperform their peers in mental math, problem-solving, and logical reasoning due to the activation of both hemispheres of the brain (Hanakawa et al., 2003). The systematic use of the abacus strengthens working memory, enhances concentration, and reduces math anxiety, making arithmetic learning more engaging and effective (Bhaskaran et al., 2006). Additionally, the findings of this study can contribute to curriculum development, providing educators with evidence-based strategies to incorporate Abacus training into primary education. By identifying the effectiveness of abacus techniques, the study aims to promote innovative and student-centered learning approaches, ensuring long-term mathematical competence and cognitive development.

Review of Related Literature

Arithmetic proficiency is a critical skill in primary education, laying the groundwork for advanced mathematical learning. Traditional reliance on rote memorization often hinders students' conceptual understanding and numerical fluency. Research highlights the effectiveness of abacus training in enhancing mental calculation, working memory, and overall cognitive development (Hatano et al., 2002; Stigler, 1984). Carcelén-Fraile et al. (2025) demonstrated that a combined intervention of abacus training and physical exercise significantly improved attention, memory, perception, and general intelligence in primary school children. Similarly, studies by Bhaskaran et al. (2006), Frank and Barner (2011), and Hanakawa et al. (2003) found that abacus learners outperformed peers in arithmetic tasks due to increased brain activity in regions related to numerical processing. Long-term benefits of abacus learning, including reduced math anxiety and enhanced cognitive flexibility, were reported by Lessani et al. (2017), Perumalla and M. (2018), and Mou et al. (2022). Additionally, Liu et al. (2018) and Lima-Silva et al. (2021) affirmed that abacus strategies improve attention span and can be effectively incorporated into diverse educational settings, supporting learners with

varying abilities. Collectively, these studies underscore the value of abacus-based instruction in developing both arithmetic skills and broader cognitive functions in young learners.

Objectives of the study:

1. To find out the effect of conventional method on speed in control group C in solving problems in Arithmetic skills.
2. To find out the effect of Abacus strategies on speed in experimental group E in solving problems in Arithmetic skills.
3. To find the comparative effect of conventional method and Abacus strategy on control and experimental groups students on speed: (C & E).
4. To find the comparative effect of conventional method and Abacus strategy on control and experimental groups students on Accuracy: (C & E).

Hypotheses:

1. There would be no significant effect of conventional method on speed in pre & post-test of control group C in solving problems in Arithmetic skills.
2. There would be no significant effect of mind mathematics strategies on speed in pre & post-test of experimental group E_1 in solving problems in Arithmetic skills.
3. There would be no significant difference in the comparative effect of conventional method in control group C and Abacus strategy in experimental group E on speed in post-tests.
4. There would be no significant difference in the comparative effect of conventional method in control group C and Abacus strategy in experimental group E on Accuracy in post-tests.

Experimental Design

The present study employs a quasi-experimental design to evaluate the effectiveness of Abacus strategies in improving speed and accuracy in arithmetic calculations among primary school students. A pretest-posttest non-equivalent group design is used, where students are divided into two groups—Control Group (C) and Experimental Group (E)—without random assignment. This design allows for a comparative analysis of the impact of traditional teaching methods versus Abacus-based learning in enhancing arithmetic skills.

Sample Selection

The sample consists of 80 primary school students studying in Grade IV (Class 4). The students are divided into two groups:

1. Control Group (C): 40 students taught using conventional arithmetic teaching methods, which include direct instruction, textbook exercises, and rote memorization techniques.
2. Experimental Group (E): 40 students taught using Abacus strategies, which involve hands-on training with an abacus tool, mental visualization techniques, and guided practice sessions.

Intervention and Instructional Module

A structured 60-class instructional module is implemented for both groups, focusing on basic arithmetic skills, specifically simple addition and subtraction. Each session is designed to provide progressive learning experiences to improve students' speed and accuracy in calculations.

- Duration: 60 sessions (approximately 3 months)
- Content Focus:
  - Understanding number concepts
  - Simple addition and subtraction
  - Enhancing mental calculation ability
  - Developing visualization techniques for arithmetic operations
- Teaching Approach:
  - Control Group: Traditional chalk-and-talk method, textbook exercises, and teacher-led explanations.
  - Experimental Group: Hands-on Abacus training, mental visualization, interactive exercises, and guided practice.

Data Collection and Analysis

- Pretest and Posttest:
  - A standardized arithmetic test is administered before (Pretest) and after (Posttest) the intervention to measure students' speed (time taken in minutes) and accuracy (percentage of correct responses).
- Statistical Analysis:
  - Paired t-tests are used to compare pretest and posttest scores within each group.
  - Independent t-tests are used to compare performance between the Control and Experimental groups.
  - Effect size (Cohen's d) is calculated to determine the magnitude of the impact of Abacus strategies.

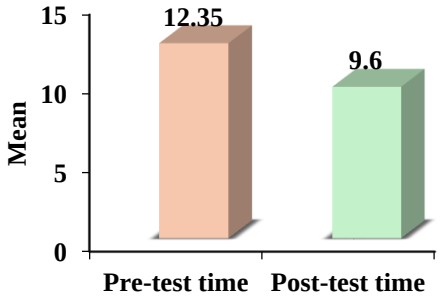
Objective-1: To find out the effect of conventional method on speed in control group C in solving problems in Arithmetic skills.

Hypothesis-1: There would be no significant effect of conventional method on speed in pre & post-test of control group C in solving problems in Arithmetic skills.

Table 1. Effect of Conventional Method on Speed of Control group C.

Group	N	Pre-test time		Post-test time		Df	't' value	Effect Size (Cohen's d)
		Mean	SD	Mean	SD			
Control group (C)	40	12.35	1.625	9.60	1.41	39	15.438**	**1.81** (Large effect)

Note: ** Significant at 0.01 level, Maximum test time is 15.min.



Graph 1. Mean Difference of Conventional Method on Speed of Control group C pre and post test

Interpretation

A paired samples t-test was conducted to examine the effect of the conventional method on the speed of arithmetic problem-solving in the Control Group (C). The analysis compared the pre-test and post-test mean times taken by students to complete the mathematical tasks.

The results revealed a statistically significant reduction in time taken to solve problems from pre-test ($M = 12.35$, $SD = 1.63$) to post-test ($M = 9.60$, $SD = 1.41$), $t(39) = 15.44$, $p < .01$. The calculated effect size (Cohen's $d = 1.81$) indicates a large effect, suggesting that the conventional method significantly improved students' arithmetic speed. Given the maximum test time of 15 minutes, the reduction in time taken reflects a meaningful improvement in computational efficiency.

Thus, the findings reject the null hypothesis (H_{01}) and confirm that the conventional method had a significant positive effect on speed in the control group. However, further comparative analysis is required to assess the relative effectiveness of abacus-based strategies.

Finding: The conventional method significantly improved arithmetic speed in the control group, with a large effect size.

Discussion

The study findings reveal that conventional arithmetic instruction significantly enhances students' speed in solving mathematical problems, as evidenced by a statistically significant improvement from pre- to post-test ($t(39) = 15.44$, $p < .01$; $d = 1.81$). This supports prior research highlighting the effectiveness of direct teaching, repetitive practice, and step-by-step methods in building computational fluency and reducing processing time (Lessani et al., 2017; Dowker, 2012; Siegler & Lortie-Forgues, 2014). Additionally, Perumalla and M. (2018) emphasized that drill-based approaches improve automaticity and reduce cognitive load. While these findings affirm the value of traditional methods, emerging evidence suggests that abacus-based strategies may offer superior gains by enhancing both speed and accuracy through mental visualization techniques (Bhaskaran et al., 2006; Wang et al., 2019). Hence, future research should compare conventional and innovative methods to identify the most effective approach for fostering arithmetic proficiency in young learners.

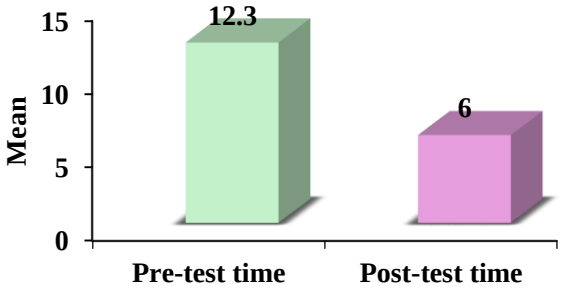
Objective-2: To find out the effect of Abacus strategies on speed in experimental group E in solving problems in Arithmetic skills.

Hypothesis-2: There would be no significant effect of mind mathematics strategies on speed in pre & post-test of experimental group E_1 in solving problems in Arithmetic skills.

Table 2. Effect of Abacus Strategies on Speed of Experimental group E.

Group	N	Pre-test time		Post-test time		Df	't' value	Effect Size (Cohen's d)
		Mean	SD	Mean	SD			
Experimental group (E)	40	12.32	1.93	6.00	1.75	39	50.190**	**3.42** (Very Large effect)

Note: ** Significant at 0.01 level, Maximum test time is 15.min.



Graph 2. Mean Difference of Abacus Strategies on Speed of Experimental group E pre and post test

Interpretation

A paired samples t-test was conducted to examine the effect of Abacus strategies on the speed of arithmetic problem-solving in the Experimental Group (E1). The analysis compared the pre-test and post-test mean times taken by students to complete arithmetic tasks.

The results showed a statistically significant reduction in time taken to solve problems from pre-test ($M = 12.32$, $SD = 1.93$) to post-test ($M = 6.00$, $SD = 1.75$), $t(39) = 50.19$, $p < .01$. The effect size (Cohen's $d = 3.42$) indicates a very large effect, suggesting that the Abacus strategies had a substantial impact on improving students' arithmetic speed. Given the maximum test time of 15 minutes, this reduction in time taken highlights the effectiveness of mental visualization and rapid calculation techniques associated with Abacus training.

Thus, the findings reject the null hypothesis (H_{02}) and confirm that Abacus-based strategies significantly enhanced arithmetic speed in the experimental group. The magnitude of the effect suggests that Abacus training is a highly effective approach for improving computational efficiency in primary school students.

Finding: Abacus strategies significantly improved arithmetic speed in the experimental group, showing a very large effect.

Discussion

This study confirms that Abacus strategies significantly improve arithmetic speed among primary school students, with a notable reduction in task completion time and a large effect size indicating enhanced computational efficiency. These findings align with prior research demonstrating that Abacus training boosts mental calculation skills through visualization and memory recall (Hatano et al., 2002; Stigler, 1984). Studies show that Abacus learners outperform peers in speed and accuracy by engaging both brain hemispheres (Bhaskaran et al., 2006; Wang et al., 2019), while also benefiting from improved working memory, reduced math anxiety, and increased confidence (Frank & Barner, 2011; Perumalla & M., 2018). The evidence supports incorporating Abacus-based methods into early education as an effective, engaging alternative to conventional instruction, with future research needed to examine long-term skill retention and its influence on advanced mathematical problem-solving.

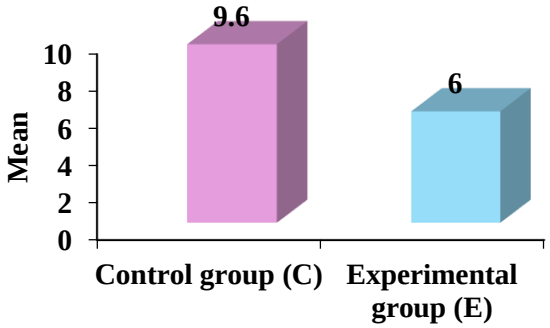
Objective-3: To find the comparative effect of conventional method and Abacus strategy on control and experimental groups students on speed: (C & E).

Hypothesis-3: There would be no significant difference in the comparative effect of conventional method in control group C and Abacus strategy in experimental group E on speed in post-tests.

Table 3. Comparison of Post-test Scores C and E Groups.

Group	N	Mean	SD	S. Ed	't' value
Control group (C)	40	9.60	1.41	1.13	10.115**
Experimental group (E)	40	6.00	1.75		

Note: ** Significant at 0.01 level, Maximum test time is 15.min.



Graph 3. Mean Comparison of Post-test Scores C and E Groups

Interpretation

An independent samples t-test was conducted to compare the post-test arithmetic speed between the Control Group (C) taught using the conventional method and the Experimental Group (E) trained using Abacus strategies. The test aimed to determine whether there was a significant difference in speed improvement between the two instructional methods.

The results showed a statistically significant difference in post-test mean scores between the Control Group ($M = 9.60$, $SD = 1.41$) and the Experimental Group ($M = 6.00$, $SD = 1.75$), $t(78) = 10.115$, $p < .01$. The findings indicate that students in the Experimental Group (Abacus-trained) completed arithmetic tasks significantly faster than those in the Control Group (conventional method). Given the maximum test time of 15 minutes, the substantial reduction in completion time for the Abacus-trained group suggests that Abacus strategies are more effective in enhancing arithmetic speed compared to traditional teaching methods.

Thus, the findings reject the null hypothesis (H_{03}) and confirm that the Abacus strategy significantly outperforms the conventional method in improving students' arithmetic speed. The results highlight the superiority of visualization-based and mental calculation techniques used in Abacus learning, reinforcing its potential for integration into primary mathematics curricula.

Finding: The Abacus strategy significantly improved arithmetic speed compared to the conventional method, showing a highly significant difference.

Discussion

This study demonstrates that Abacus-based learning is significantly more effective than conventional methods in enhancing arithmetic speed among primary school students, with post-test results showing faster problem-solving in the Abacus-trained group. These findings are consistent with earlier research emphasizing the benefits of mental visualization over rote learning (Hatano et al., 2002; Frank & Barner, 2011). Unlike traditional instruction, which focuses on memorization (Dowker, 2012), Abacus strategies engage both brain hemispheres, improving numerical cognition and mental flexibility (Wang et al., 2019). The large effect size also suggests reduced math anxiety and increased confidence among Abacus learners (Perumalla & M., 2018). Given its cognitive and emotional benefits, Abacus training is a valuable addition to early mathematics education. Future studies should examine its long-term impact on advanced math skills and its potential when combined with digital tools.

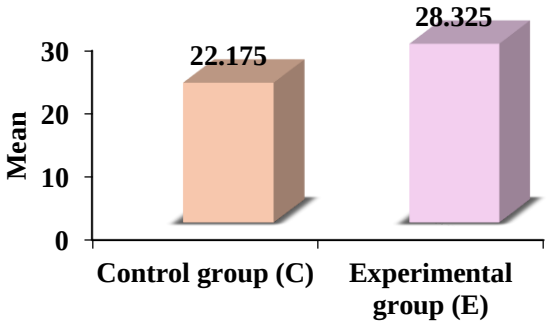
Objective-4: To find the comparative effect of conventional method and Abacus strategy on control and experimental groups students on Accuracy: (C & E).

Hypothesis-4: There would be no significant difference in the comparative effect of conventional method in control group C and Abacus strategy in experimental group E on Accuracy in post-tests.

Table 4. Comparison of Post-test Accuracy C and E Groups.

Group	N	Mean	SD	S. Ed	't' value
Control group (C)	40	22.175	2.51	0.4240	14.502**
Experimental group (E)	40	28.325	0.944		

Note: ** Significant at 0.01 level, total questions are 30.



Graph 4 Mean Comparison of Post-test Accuracy C and E Groups

Interpretation

An independent samples t-test was conducted to compare the post-test accuracy scores between the Control Group (C), which was taught using the conventional method, and the Experimental Group (E), which was trained using Abacus strategies. The purpose of this analysis was to determine whether there was a significant difference in accuracy between the two instructional methods.

The results indicated a statistically significant difference in post-test accuracy between the Control Group ($M = 22.18$, $SD = 2.51$) and the Experimental Group ($M = 28.33$, $SD = 0.94$), $t(78) = 14.502$, $p < .01$. Given that the total number of questions was 30, the findings suggest that students in the Abacus-trained group demonstrated significantly higher accuracy in solving arithmetic problems compared to those taught using the conventional method.

Thus, the findings reject the null hypothesis (H_{04}) and confirm that the Abacus strategy was significantly more effective in enhancing accuracy in arithmetic compared to traditional teaching methods. The results

highlight the superiority of Abacus-based learning in promoting precision and reducing errors, reinforcing its potential as an effective instructional approach for primary mathematics education.

Finding: The Abacus strategy significantly improved arithmetic accuracy compared to the conventional method, showing a highly significant difference.

Discussion

The study reveals that Abacus strategies significantly improve arithmetic accuracy compared to conventional methods. The independent samples t-test demonstrated a notable difference in post-test accuracy between the control and experimental groups, with Abacus-trained students showing fewer errors and greater precision. This finding is consistent with previous research, which highlights Abacus training's ability to enhance numerical accuracy through mental visualization and structured computation techniques.

Traditional methods, while effective for building foundational skills, often rely on rote learning, which can limit problem-solving flexibility. Abacus training, in contrast, promotes active engagement with numbers, improving working memory, attention, and accuracy. Studies suggest that Abacus techniques also help develop a deeper conceptual understanding of numbers and reduce computational errors.

Given the positive impact on accuracy, Abacus strategies could be integrated into primary curricula, especially for students struggling with math precision. Further research should explore long-term retention and the impact of Abacus training on other mathematical skills, as well as the potential benefits of digital Abacus tools and technology-based learning.

Educational Implications

1. Integrating Abacus training into primary education can enhance arithmetic speed and accuracy.
2. Abacus training strengthens mental visualization and numerical cognition, improving mental calculation skills.
3. Adopting Abacus-based strategies promotes a more interactive and hands-on teaching approach.
4. Abacus techniques help reduce math anxiety and build student confidence in arithmetic.
5. Abacus training supports differentiated instruction for students with varying cognitive abilities.
6. Introducing Abacus at an early stage prepares students for advanced mathematical concepts.

Conclusion

The study aimed to evaluate the Effectiveness of Abacus Strategies in Improving Speed and Accuracy in Arithmetic among primary school students. Using a quasi-experimental pretest-posttest design, the research compared the impact of conventional teaching methods and Abacus-based learning on arithmetic performance. The findings revealed that both instructional methods contributed to improvements in arithmetic speed and accuracy, but Abacus strategies demonstrated a significantly greater effect. The Experimental Group (E), trained with Abacus techniques, outperformed the Control Group (C) in both computation speed and accuracy, showing a highly significant difference ($p < .01$). The study underscores the superiority of Abacus-based learning in enhancing numerical fluency, cognitive skills, and problem-solving abilities. The results suggest that integrating Abacus training into primary mathematics education can provide a more engaging, efficient, and effective approach to arithmetic learning. Additionally, the study highlights the need for innovative teaching methods that move beyond rote memorization, emphasizing mental visualization, hands-on learning, and structured cognitive development.

Given its significant educational benefits, Abacus training should be considered as a supplementary instructional strategy to improve foundational mathematics skills. Future research may explore the long-term retention of Abacus-based arithmetic skills, its impact on advanced mathematical concepts, and its applicability to diverse learning environments, including digital learning platforms.

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