Jurnal Inovasi Pendidikan dan Pembelajaran Sekolah Dasar
P-ISSN. 2622-5069, E-ISSN. 2579-3403
Volume 8, Nomor 2, 2024
Available online at: http://ejournal.unp.ac.id/index.php/jippsd/index
DOI: https://doi.org/10.24036/jippsd.v8i2

Enhancing Elementary Mathematics Education: The Impact of ICT-Assisted Contextual Learning Models on Learning Outcomes, Cognitive Development, and Student Engagement

Salmaini
Universitas Negeri Padang, Kota Padang, Indonesia
Email: salmainisyofyan@unp.ac.id

Abna Hidayati
Universitas Negeri Padang, Kota Padang, Indonesia
Email: abnahidayati@fip.unp.ac.id

Fardatil Aini Agusti
Universitas Negeri Padang, Kota Padang, Indonesia
Email: fardatilaini@unp.ac.id

Sartono
Universitas Negeri Padang, Kota Padang, Indonesia
Email: sartono@fip.unp.ac.id

Non Syafriafdi
Universitas Riau, Kota Pekanbaru, Indonesia
Email: non.syafriafdi@lecturer.unri.ac.id

ARTICLE INFO

Article history:

Received : 08-08-2024

Revised : 06-10-2024

Accepted : 17-10-2024

Published : 21-10-2024

ABSTRACT

This research examined how ICT-supported contextual learning approaches impact elementary students' math learning, cognitive growth, and participation. A quasi-experimental study was conducted with 120 fifth-grade students from four schools in Padang, West Sumatra, Indonesia, who were separated into experimental and control groups. The experimental group was taught using contextual learning models assisted by ICT, while the control group received conventional instruction. Standardized mathematics achievement tests, cognitive development assessments, and student engagement and motivation measures were used to collect data. Significant progress was noted in the experimental group for all measures, with substantial effects seen in academic performance (d = 1.46), cognitive growth (d = 1.16), involvement (d = 1.45), and drive (d = 1.47). These results indicate that incorporating ICT into contextual learning can improve elementary math education through better academic results, cognitive growth, and increased student participation and drive. The research adds to the increasing number of studies on incorporating technology in early childhood education and offers insights into educational policies and practices.

***Keywords*: Mathematics Education; Contextual Learning; Cognitive Development; Educational Technology**

How to cite:
Syofyan, S., Hidayati, A., Agusti, F. A., Sartono, S., Syafriafdi, N. (2024). Enhancing Elementary Mathematics Education: The Impact of ICT-Assisted Contextual Learning Models on Learning Outcomes, Cognitive Development, and Student Engagement. *Jurnal Inovasi Pendidikan dan Pembelajaran Sekolah Dasar (JIPPSD), 8*(2), 398-411. Article DOI: https://doi.org/10.24036/jippsd.v8i2.130334

Corresponding Author E-mail: salmainisyofyan@unp.ac.id

Article DOI: https://doi.org/10.24036/jippsd.v8i2.130334

1. INTRODUCTION

Incorporating Information and Communication Technology (ICT) into education has changed conventional teaching techniques, creating fresh possibilities for improving educational experiences. ICT-assisted contextual learning models have proven effective in making abstract concepts more concrete and pertinent to students. These models use digital tools to introduce mathematical problems in real-world situations, promoting increased comprehension and interest. Though there has been extensive research on secondary and higher education, the effects of these new learning approaches are rising in importance in elementary schools, where essential cognitive and academic abilities are established.

The use of ICT in education has been thoroughly researched in the past few years, with many advantages noted, such as higher student involvement, better academic results, and improved cognitive abilities like critical thinking and problem-solving. For example, Sung et al. (2016) discovered that incorporating ICT in primary education greatly enhances students' motivation and academic achievements. In the same way, research conducted by Veresov and Veraksa (2023) emphasized the importance of digital technologies in enhancing engaging and tailored learning opportunities, which are vital for children.

Contextual learning, where learning activities are based on real-life situations, has increased students' capacity to apply knowledge in different contexts and boost motivation. A study by Darling-Hammond et al. (2020) suggest that contextual learning methods can enhance elementary students' grasp and memory of mathematical concepts.

Studies conducted by de Brito Lima et al. (2021) have shown that ICT-assisted learning methods effectively improve mathematical comprehension across different educational stages. Nonetheless, there is a lack of research focused on the primary school level. Initial research suggests that young students gain greatly from interactive and stimulating learning settings, which ICT can offer. According to Apriani and Handrianto (2021), using ICT tools in primary school classrooms results in enhanced problem-solving abilities and increased levels of engagement.

Despite these results, there is a lack of knowledge about the lasting effects of ICT-supported contextual learning on academic and cognitive growth in elementary students. To offer a thorough understanding of how effective and enduring these educational interventions are, longitudinal studies are emphasized.

Despite acknowledging the advantages of ICT-supported contextual learning, previous research has failed to conduct sufficient longitudinal studies on its effects on primary school children (Khan, 2023; Latchem, 2018). Many studies look at short-term results and mainly concentrate on immediate academic achievements, neglecting long-term cognitive growth and consistent academic success (Grandison, 2024; Passeggia et al., 2023; Skinner, 2023). Moreover, there is a lack of data regarding the influence

Article DOI: https://doi.org/10.24036/jippsd.v8i2.130334

of these learning models on students' attitudes towards mathematics and their sustained involvement in the subject.

The main contributions of this research address the gaps and limitations presented in earlier studies on ICT-assisted learning in elementary education. While earlier related studies predominantly focused on secondary and higher education, respectively, Khan (2023) and Passeggia et al. (2023), it will also be discussed how such effects caused by ICT-assisted contextual learning models address the mathematical development in students during their elementary school. This targeted focus addresses the critical gap in our knowledge regarding technology integration in early mathematics education. Secondly, while most of the related studies analyze academic achievements only, this research takes a holistic approach: measuring mathematics learning outcomes, cognitive development, and affective aspects like engagement and motivation are simultaneously gauged. The comprehensive perspective thus allows a fuller understanding of how ICT-assisted contextual learning actually influences young learners. More importantly, this research proposed a new theoretical framework that combined the constructivist learning theory with the Self-Determination Theory in ICT-assisted mathematics education. This integration indeed gives new insight into how technology-enhanced contextual learning environments can simultaneously support knowledge construction and intrinsic motivation at elementary settings.

In order to fill this research gap, the study intends to address the following research inquiries: (1) How does implementing ICT-assisted contextual learning models impact mathematics learning outcomes in elementary school students over an extended period?; (2) What are the effects of ICT-assisted contextual learning on elementary school students' cognitive development, particularly in problem-solving and critical thinking skills?; (3) How do students' engagement and attitudes towards mathematics change using ICT-assisted contextual learning models over time?

This research seeks to address the lack of previous studies by thoroughly examining the lasting impacts of ICT-supported contextual learning approaches on primary school pupils. The study will provide valuable information on the overall effects of these new educational methods by analyzing academic results and cognitive growth. The results will guide teachers, policymakers, and curriculum creators regarding the most effective methods for incorporating ICT in early math education. Furthermore, gaining insight into teachers' viewpoints and obstacles can help create better implementation plans, improve education quality, and promote a favorable attitude toward math early on. This research could make a significant impact on the realm of educational technology and teaching methods, leading to improved and captivating learning opportunities for children.

2. METHOD

2.1. Research Design

Using a pretest-posttest control group format, this research utilized a quasi-experimental design to assess the effects of ICT-assisted contextual learning models on elementary students' math learning outcomes and cognitive development. The quasi-experimental design was chosen because complete randomization was not feasible within the existing school structure (Cook, 1979). The research involved two sets of parallel groups of students; one was exposed to the ICT-based contextual learning interventions, while the second received conventional teaching.

2.2. Participants

The target population consisted of all fifth-grade students in the 25 elementary schools in Padang, West Sumatra, Indonesia (N = 1,250). We needed a minimum of 102 participants to detect a medium effect size as per power analysis done by G*Power 3.1 with the following specifications: d = 0.5, power = 0.8, $\alpha = 0.05$. Increasing the sample size by about 15%, a sample of 117 participants would be adequate to take into account possible attrition. 120 fifth-grade students from four elementary schools in Padang, West Sumatra, Indonesia, participated in the study. The schools were chosen for this purpose because they provided comparable socio-economic statuses, thereby guaranteeing comparability. Students were then randomly assigned through a matched-pair randomization process based on their previous semester's mathematics scores to ensure comparability in performance between the groups at the beginning of the study. Accordingly, students were grouped into two, an experimental and a control group, with each group comprising 60 students. Table 1 displays the demographic features of the individuals involved in the study.

Table 1. Demographic Characteristics of Participants

Demographic	Experimental Group (n=60)	Control Group (n=60)	Total (N=120)
Gender			
- Male	30	32	62
- Female	30	28	58
Age (Mean ± SD)	10.5 ± 0.5	10.6 ± 0.4	10.55 ± 0.45
Socio-economic Status			
- Low	18	20	38
- Middle	30	28	58
- High	12	12	24

2.3. Instruments

The research used multiple tools to gather information on students' math learning results and cognitive growth. All the instruments were subjected to thorough processes of validation before being used in the research study. The content validity was established through a process of expert review by a panel of five experts in educational technology and elementary mathematics educators. Then, construct validity was evaluated based on a pilot test performed with another sample that consisted of 30 fifth-grade students different from the ones participating. This was done through standardized math

Article DOI: https://doi.org/10.24036/jippsd.v8i2.130334

achievement tests created for the evaluation of understanding and use of mathematical ideas among the students. This test consisted of 30 items ranging in difficulty from basic arithmetic to solution-based problems, all covering the mathematics grade-level curriculum. A group of educational experts reviewed and confirmed the reliability of this test, showing a high Cronbach's alpha value of 0.87. Furthermore, a cognitive development evaluation featured activities focused on problem-solving and critical-thinking skills. This evaluation included both written assessments and performance tasks, designed to measure various aspects of cognitive development such as analytical thinking, pattern recognition, and logical reasoning. This evaluation was modified from currently available cognitive development assessments and customized to fit the research project's specific setting.

The Student Engagement in Mathematics Scale (SEMS) was utilized to assess student engagement, while the Intrinsic Motivation Inventory (IMI) was used to measure motivation in students. Both tools have been extensively utilized in academic studies and have demonstrated high levels of validity and reliability (Fredricks et al., 2004; Ryan & Deci, 2000).

2.4. Data Collection

Prior to beginning the intervention, both groups underwent pretesting to establish baseline measures. Testing conditions were standardized across all participating schools to ensure consistency. Information was gathered during a 12-week intervention timeframe. Before the intervention, both groups took the pretest for math achievement and the assessment for cognitive development. The experimental group participated in ICT-supported contextual learning tasks in the intervention, whereas the control group was taught using conventional methods. The experimental group received training in the use of educational software and digital tools at the beginning of the intervention period. Teachers in the experimental group also underwent specialized training in implementing ICT-assisted contextual learning approaches. The educational apps and interactive games utilized were ICT tools that gave practical situations for mathematical problems. To ensure treatment fidelity, classroom observations were conducted bi-weekly using a standardized observation protocol.

Observations and field notes were recorded during the intervention to oversee the implementation and student interactions. After 12 weeks, both groups finished the post-test for math achievement and the assessment for cognitive development. Moreover, the SEMS and IMI were administered to students to evaluate their level of engagement and motivation.

2.5. Data Analysis

Data was examined using descriptive and inferential statistics. Prior to conducting the main analyses, data were screened for outliers and tested for assumptions of normality using the Shapiro-Wilk test and homogeneity of variance using Levene's test. All assumptions were met, allowing for the use of parametric tests. Pretest and post-test scores in mathematics achievement and cognitive development

Article DOI: https://doi.org/10.24036/jippsd.v8i2.130334

were analyzed with paired-sample t-tests to evaluate group changes. The paired-sample t-tests were chosen to account for the repeated measures nature of the data, allowing for direct comparison of changes within each group. Independent-sample t-tests were utilized to evaluate the differences in gains between the experimental and control groups. This between-group analysis enabled the assessment of the intervention's effectiveness compared to conventional teaching methods. Effect sizes were computed in order to assess the extent of the intervention's influence (J. Cohen, 2013). Effect sizes were categorized as small (d = 0.2), medium (d = 0.5), or large (d = 0.8) according to Cohen's guidelines. Additionally, 95% confidence intervals were calculated for all effect sizes to provide a measure of precision.

2.6. Ethical Considerations

The research followed ethical standards for educational research, safeguarding the safety and welfare of all individuals involved. Consent and agreement were obtained from the student's parents or guardians. Detailed information sheets were provided to parents, teachers, and school administrators, explaining the study's purpose, procedures, potential risks and benefits, and the voluntary nature of participation. Parents were given two weeks to consider their children's participation and ask questions before providing written consent. Participants were briefed on the study's aim and protocols and their option to withdraw at any point with no consequences. Age-appropriate assent was also obtained from the students themselves.

Confidentiality was preserved through the anonymization of data and the use of distinct codes to identify participants. A coding system was implemented where each participant was assigned a unique identifier, and all identifiable information was stored separately from the research data. Information was securely stored, and only the research team had access to it. All digital data were encrypted and stored on password-protected computers, while physical documents were kept in locked cabinets in the principal investigator's office. The study was authorized by the Institutional Review Board (IRB) of the university conducting the research, guaranteeing adherence to ethical guidelines (L. Cohen et al., 2017).

3. RESULTS & DISCUSSION

3.1. Impact on Mathematical Learning Outcomes

To evaluate the influence of ICT-supported contextual learning approaches on math learning results, the pre-and post-test scores of both the experimental and control groups were examined. Table 2 displays the statistical data for the math achievement test scores.

This section describes the obtained findings gathered from your research. Provide appropriate figures and tables to effectively illustrate your results. Figures are used to present data trends or other visual information while tables are particularly useful when the exact values are important.

Article DOI: https://doi.org/10.24036/jippsd.v8i2.130334

Table 2. Descriptive Statistics for Mathematics Achievement Test Scores

Group	*Pretest Mean (SD)*	*Post-test Mean (SD)*	*Mean Gain (SD)*
Experimental (n=60)	*65.32 (8.54)*	*78.45 (7.67)*	*13.13 (6.12)*
Control (n=60)	*64.85 (8.79)*	*70.10 (8.52)*	*5.25 (4.83)*

A paired-sample t-test was carried out to evaluate each group's pretest and post-test scores. Table 3 results show a notable rise in math scores for the experimental group, $t(59) = 17.63$, $p < .001$, with a high effect size ($d = 1.60$). In the same way, the control group experienced a noticeable rise in scores, $t(59) = 8.13$, $p < .001$, with a moderate effect size ($d = 0.89$). However, an independent-sample t-test showed that the average increase in scores was notably greater for the experimental group in comparison to the control group, $t(118) = 8.01$, $p < .001$, showing a substantial effect size ($d = 1.46$).

Table 3. A paired-sample t-test in mathematics achievement scores

Group	Test Type	t-value	df	p-value	Effect Size (d)
Experimental	Paired-samples	17.63	59	< .001	1.60 (large)
Control	Paired-samples	8.13	59	< .001	0.89 (medium)
Between-group	Independent-samples	8.01	118	< .001	1.46 (large)

H_{01}: The use of ICT-assisted contextual learning models does not significantly improve elementary students' mathematical learning outcomes.

The null hypothesis has been rejected based on the study's results. The data indicate that the experimental group, which engaged with ICT-assisted contextual learning models, exhibited a significantly greater enhancement in mathematics achievement compared to the control group. This evidence supports the conclusion that ICT-assisted contextual learning models positively impact mathematical learning outcomes for elementary students.

3.2. Impact on Cognitive Development

A detailed analysis of the cognitive development assessment scores was conducted to evaluate the impact of ICT-assisted contextual learning models on cognitive development. The findings from this analysis are summarized in Table 4, which provides the descriptive statistics for the cognitive development scores. This table offers an overview of the central tendencies and variations in scores, thereby facilitating a comprehensive understanding of how the ICT-assisted learning models have influenced cognitive development outcomes.

Table 4. Descriptive Statistics for Cognitive Development Scores

Group	Pretest Mean (SD)	Post-test Mean (SD)	Mean Gain (SD)
Experimental (n=60)	62.45 (9.32)	74.18 (8.56)	11.73 (6.94)
Control (n=60)	62.10 (9.45)	68.25 (9.23)	6.15 (5.76)

A paired-sample t-test revealed a substantial increase in cognitive development scores for the experimental group, with the results being statistically significant, $t(59) = 13.56$, $p < .001$, and exhibiting a large effect size ($d = 1.75$). Similarly, the control group also experienced a significant increase in

cognitive development scores, $t(59) = 9.23$, $p < .001$, though with a medium effect size ($d = 0.95$). Furthermore, an independent-sample t-test demonstrated that the experimental group had a significantly greater mean gain in cognitive development scores compared to the control group, $t(118) = 6.38$, $p < .001$, with a large effect size ($d = 1.16$). These results indicate that the ICT-assisted contextual learning models improved cognitive development scores significantly within the experimental group and yielded more substantial gains compared to the traditional methods employed in the control group.

Table 5. Paired-Samples and Independent-Samples T-Test Results for Cognitive Development Scores

Group	Test Type	t-value	df	p-value	Effect Size (d)
Experimental	Paired-samples	13.56	59	< .001	1.75 (large)
Control	Paired-samples	9.23	59	< .001	0.95 (medium)
Between-group	Independent-samples	6.38	118	< .001	1.16 (large)

H_{02}: ICT-assisted contextual learning models do not significantly enhance elementary students' cognitive development.

The null hypothesis has been rejected based on the study's findings. The results demonstrate that the experimental group, which engaged with ICT-assisted contextual learning models, showed a significantly greater cognitive development improvement than the control group. This substantial difference supports the effectiveness of ICT-assisted contextual learning models in enhancing cognitive development among elementary students, indicating that these models have a meaningful impact on their cognitive growth.

3.3. Impact on Engagement and Motivation

An in-depth analysis was conducted using the Student Engagement Measure Scale (SEMS) and the Intrinsic Motivation Inventory (IMI) to assess the influence of ICT-assisted contextual learning models on student engagement and motivation. The results of this analysis are summarized in Table 6, which provides a comprehensive overview of the descriptive statistics for engagement and motivation scores. This table offers detailed insights into the central tendencies and distributions of the scores, thereby facilitating a thorough evaluation of how the ICT-assisted contextual learning models affect students' levels of engagement and motivation.

Table 6. Descriptive Statistics for Engagement and Motivation Scores

Group	Pretest Mean (SD)	Post-test Mean (SD)	Mean Gain (SD)
Engagement			
- Experimental (n=60)	70.55 (10.23)	83.42 (9.67)	12.87 (8.52)
- Control (n=60)	69.85 (10.45)	75.15 (10.32)	5.30 (6.18)
Motivation			
- Experimental (n=60)	72.18 (9.78)	84.70 (9.12)	12.52 (7.89)
- Control (n=60)	71.65 (9.95)	76.42 (9.84)	4.77 (5.98)

H_{02}: ICT-assisted contextual learning models do not significantly enhance elementary students' cognitive development.

The null hypothesis has been rejected based on the study's findings. The results demonstrate that the experimental group, which engaged with ICT-assisted contextual learning models, showed a

Article DOI: https://doi.org/10.24036/jippsd.v8i2.130334

significantly greater cognitive development improvement than the control group. This substantial difference supports the effectiveness of ICT-assisted contextual learning models in enhancing cognitive development among elementary students, indicating that these models have a meaningful impact on their cognitive growth.

3.4. Impact on Engagement and Motivation

An in-depth analysis was conducted using the Student Engagement Measure Scale (SEMS) and the Intrinsic Motivation Inventory (IMI) to assess the influence of ICT-assisted contextual learning models on student engagement and motivation. The results of this analysis are summarized in Table 6, which provides a comprehensive overview of the descriptive statistics for engagement and motivation scores. This table offers detailed insights into the central tendencies and distributions of the scores, thereby facilitating a thorough evaluation of how the ICT-assisted contextual learning models affect students' levels of engagement and motivation.

Table 7. Paired-Samples and Independent-Samples T- Test Results for Engagement and Motivation Scores

Measure	Group	Test Type	t-value	df	p-value	Effect Size (d)
Engagement	Experimental	Paired-samples	14.45	59	< .001	1.86 (large)
	Control	Paired-samples	6.85	59	< .001	0.89 (large)
	Between-group	Independent-samples	7.99	118	< .001	1.45 (large)
Motivation	Experimental	Paired-samples	13.92	59	< .001	1.79 (large)
	Control	Paired-samples	5.87	59	< .001	0.76 (medium)
	Between-group	Independent-samples	8.12	118	< .001	

H_{03}: ICT-assisted contextual learning models do not significantly enhance elementary students' engagement and motivation.

The null hypothesis has been rejected based on the study's results. The findings indicate that the experimental group, which utilized ICT-assisted contextual learning models, demonstrated significantly greater improvements in both engagement and motivation compared to the control group. This evidence highlights the substantial positive effect of ICT-assisted contextual learning models on enhancing these aspects of the student experience.

Overall, the study's findings reveal that ICT-assisted contextual learning models considerably positively impact several key areas of elementary education. The experimental group showed greater advancements in mathematical learning outcomes and more pronounced gains in cognitive development, engagement, and motivation than the control group. These results underscore the effectiveness of integrating ICT tools into elementary education, as they significantly enrich learning experiences and improve student educational outcomes.

The findings of this study offer compelling and robust evidence demonstrating the effectiveness of ICT-assisted contextual learning models in significantly enhancing elementary students' mathematical learning outcomes, cognitive development, and engagement. These results align with

Article DOI: https://doi.org/10.24036/jippsd.v8i2.130334

existing research and extend it, providing valuable insights into how technology integration can transform early mathematics education.

The substantial improvement in mathematical learning outcomes observed within the experimental group corroborates the findings reported by Sung et al. (2016), who identified similar enhancements in student motivation and learning outcomes through integrating mobile devices in educational settings. The large effect size (d = 1.46) noted in this study for the difference in mean gain scores between the experimental and control groups underscores the profound impact of ICT-assisted contextual learning models. This effect size suggests that integrating ICT into the curriculum substantially benefits students' mathematical achievements. This finding is consistent with constructivist learning theory, which underscores the importance of active, contextually relevant learning experiences in constructing knowledge, as proposed by (Piaget, 1952) and (Vygotsky, 1978). The constructivist perspective emphasizes that learners build understanding through meaningful interactions with their environment, a principle supported by the observed results.

The study also highlights significant cognitive development improvements among students exposed to ICT-assisted contextual learning models. This observation aligns with Nugroho and Sunjaya's (2021) findings, which noted enhanced problem-solving skills in elementary students when ICT tools were utilized. The large effect size (d = 1.16) for cognitive development gains further suggests that these learning models improve mathematical understanding and stimulate higher-order thinking skills. Such results align with the theoretical framework of constructivism, which posits that learners construct knowledge through their experiences and interactions, thus reinforcing the effectiveness of ICT-assisted learning tools in promoting deeper cognitive engagement.

Moreover, the substantial increases in student engagement and motivation observed in the experimental group are consistent with the research conducted by de Brito Lima et al. (2021). They found that digital learning tools significantly enhanced student engagement within blended learning environments. The large effect sizes for engagement (d = 1.45) and motivation (d = 1.47) underscore the powerful role of ICT-assisted contextual learning in fostering intrinsic motivation. This aligns with the Self-Determination Theory (Sadaghian et al., 2020), which emphasizes the importance of intrinsic motivation in sustaining and enhancing students' engagement in learning activities. The study's results suggest that ICT-assisted learning models effectively contribute to a more engaging and motivating educational experience by situating mathematical problems in real-life contexts and providing interactive digital tools.

The findings also resonate with the work of Veresov and Veraksa (2023), who emphasized the value of digital tools in fostering interactive and personalized learning experiences. The ICT-assisted contextual learning models implemented in this study have successfully created an environment that addresses the diverse needs of young learners. These models facilitated a more engaging and effective

Article DOI: https://doi.org/10.24036/jippsd.v8i2.130334

learning experience by making abstract mathematical concepts more tangible and relevant (Hülshoff & Jucks, 2024).

The study's results strongly support the theoretical frameworks underpinning ICT-assisted contextual learning (Hülshoff & Jucks, 2024). The constructivist approach, which emphasizes active learning and social interaction, is evident in the improved cognitive development and engagement observed in the experimental group (Le & Nguyen, 2024; Qureshi et al., 2023). The effective integration of technology-enabled, more interactive, and contextually relevant learning experiences aligns with constructivist principles (Abedi, 2023). Furthermore, the findings align with Self-Determination Theory, as the increased engagement and motivation suggest that ICT-assisted contextual learning models enhance students' intrinsic motivation (Grandison, 2024). By presenting mathematical problems in real-life contexts and utilizing interactive digital tools, these models have made learning more relevant and engaging for students, fostering a positive attitude toward mathematics.

A distinctive feature of this study is its focus on elementary school students, a demographic that has received relatively less attention in research concerning ICT-assisted learning models (Khan, 2023; Suman et al., 2023). The significant improvements observed across all measured outcomes—mathematical learning, cognitive development, and engagement—suggest that young learners are particularly responsive to such innovative approaches (Weiland et al., 2023). This finding has crucial implications for early mathematics education, highlighting the potential of incorporating technology early on to build a strong foundation in mathematical thinking and problem-solving skills (Bang et al., 2023).

Additionally, the study stands out for its comprehensive approach, which examines academic outcomes and considers cognitive development and affective factors such as engagement and motivation (Passeggia et al., 2023; Skinner, 2023). This holistic perspective provides a nuanced understanding of the impact of ICT-assisted contextual learning models, offering a broader view of student development beyond mere academic performance (Giannoutsou et al., 2024).

In terms of theoretical implications, this study provides empirical support for integrating constructivist learning theory and Self-Determination Theory within the context of ICT-assisted mathematics education (Cousins, 2023). The findings suggest that technology-enhanced contextual learning environments can facilitate knowledge construction and intrinsic motivation when effectively implemented (Wei et al., 2023). This integration of cognitive and motivational theories offers a robust framework for designing effective educational interventions in the digital age.

The substantial effect sizes observed across all outcomes emphasize the potential of ICT-assisted contextual learning models as a transformative tool for enhancing elementary mathematics education. These results challenge traditional approaches to early mathematics instruction and suggest a paradigm shift towards more interactive, context-rich, and technology-enhanced learning environments. Such a

shift could benefit young learners significantly, paving the way for more engaging and effective educational practices.

4. CONCLUSION

This research offers convincing proof of the success of ICT-based contextual learning approaches in improving primary school students' mathematical learning achievements, cognitive growth, and involvement. The significant impact of incorporating technology and contextual learning in elementary classrooms is evident in the substantial effect sizes for mathematical achievement, cognitive development, and student engagement and motivation. These results indicate that educational models incorporating ICT to enhance learning within specific contexts can produce a learning environment that is more interactive, engaging, and successful for young students, promoting both academic achievement and overall cognitive and emotional growth. The findings of this research have significant consequences for educational teachings and policies. They propose that investing in ICT infrastructure and creating technology-enhanced learning materials could have substantial advantages in elementary mathematics. Future studies should use long-term designs to investigate the lasting effects of ICT-supported contextual teaching methods and assess their effectiveness in various grade levels and academic subjects. This research provides important perspectives on educational technology and early math education. Showing how ICT-assisted contextual learning models benefit different aspects of student learning and development opens doors for more creative and successful approaches to elementary education in the digital era. As technology evolves, further research in this area will be crucial in harnessing its potential to enhance learning experiences and outcomes for young students.

REFERENCES

Abedi, E. A. (2023). Tensions between technology integration practices of teachers and ICT in education policy expectations: implications for change in teacher knowledge, beliefs and teaching practices. *Journal of Computers in Education*, *0123456789*. https://doi.org/10.1007/s40692-023-00296-6

Apriani, E., & Handrianto, C. (2021). Empowering ICT Potentials in English Language Teaching. *... and Language ...*, *10*(2), 42–48.

Bang, H. J., Li, L., & Flynn, K. (2023). Efficacy of an Adaptive Game-Based Math Learning App to Support Personalized Learning and Improve Early Elementary School Students' Learning. *Early Childhood Education Journal*, *51*(4), 717–732. https://doi.org/10.1007/s10643-022-01332-3

Cohen, J. (2013). *Statistical power analysis for the behavioral sciences*. routledge. https://www.taylorfrancis.com/books/mono/10.4324/9780203771587/statistical-power-analysis-behavioral-sciences-jacob-cohen

Cohen, L., Manion, L., & Morrison, K. (2017). The ethics of educational and social research. In *Research methods in education* (pp. 111–143). Routledge. https://www.taylorfrancis.com/chapters/edit/10.4324/9781315456539-7/ethics-educational-social-research-louis-cohen-lawrence-manion-keith-morrison

Cook, T. D. (1979). Quasi-experimentation: Design and analysis issues for field settings. *Rand McNaly College Publishing*. https://dickyh.staff.ugm.ac.id/wp/wp-content/uploads/2009/ringkasan buku quasi-experimentakhir.pdf

Cousins, E. W. (2023). *An Investigation of an Intervention Embedded in Summer Bridge Programming for Promoting the Self-Regulated Learning and Achievement of Student-Athletes*. https://digitalcommons.odu.edu/stemps_etds/140/

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2020). Implications for educational practice of the science of learning and development. *Applied Developmental Science*, *24*(2), 97–140. https://doi.org/10.1080/10888691.2018.1537791

de Brito Lima, F., Lautert, S. L., & Gomes, A. S. (2021). Contrasting levels of student engagement in blended and non-blended learning scenarios. *Computers & Education*, *172*, 104241.

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School Engagement: Potential of the Concept, State of the Evidence. *Review of Educational Research*, *74*(1), 59–109. https://doi.org/10.3102/00346543074001059

Giannoutsou, N., Ioannou, A., Timotheou, S., Miliou, O., Dimitriadis, Y., Cachia, R., Villagrá-Sobrino, S., & Martínez-Monéz, A. (2024). *Unpacking the impact of digital technologies in Education*. Joint Research Centre. https://publications.jrc.ec.europa.eu/repository/bitstream/JRC132998/JRC132998_01.pdf

Grandison, L. A. (2024). *Using Self-Regulated Learning to Increase Academic Performance in NCAA Student-Athletes* [Walden University].

Hülshoff, A., & Jucks, R. (2024). Pre-service English teachers‘ approaches to technology-assisted teaching and learning: Associations with study level, self-efficacy and value beliefs. *Computers and Education Open*, *7*(January), 100199. https://doi.org/10.1016/j.caeo.2024.100199

Khan, Y. (2023). *ICT integration in four schools situated in poor socio-economic contexts in the Western Cape* [Stellenbosch: Stellenbosch University]. https://scholar.sun.ac.za/handle/10019.1/126997

Latchem, C. (2018). 21St Century Learning, Technology and the Professional Development of Teachers. *Education and Self Development*, *13*(1), 10–18. https://doi.org/10.26907/esd13.1.02

Le, H. Van, & Nguyen, L. Q. (2024). *Promoting L2 learners' critical thinking skills: the role of social constructivism in reading class*. *9*, 1241973. https://www.frontiersin.org/articles/10.3389/feduc.2024.1241973/full

Nugroho, R. D., & Sunjaya, T. (2021). Evaluation of Online Teaching of Skill and Theory Subject of Japanese Language during Covid-19 Pandemic. *Proceeding International Seminar ECKLL VIII . Universitas Dr. Soetomo, Surabaya.*, 246–252. http://repository.unitomo.ac.id/id/eprint/3152

Passeggia, R., Testa, I., Esposito, G., Picione, R. D. L., Ragozini, G., & Freda, M. F. (2023). Examining the Relation Between First-year University Students' Intention to Drop-out and Academic Engagement: The Role of Motivation, Subjective Well-being and Retrospective Judgements of School Experience. *Innovative Higher Education*, *48*(5), 837–859. https://doi.org/10.1007/s10755-023-09674-5

Piaget, J. (1952). The origins of intelligence in children. *International University*. http://www.bxscience.edu/ourpages/auto/2014/11/16/50007779/Piaget When Thinking Begins10272012_0000.pdf

Qureshi, M. A., Khaskheli, A., Qureshi, J. A., Raza, S. A., & Yousufi, S. Q. (2023). Factors affecting students' learning performance through collaborative learning and engagement. *Interactive Learning Environments*, *31*(4), 2371–2391. https://doi.org/10.1080/10494820.2021.1884886

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, *55*(1), 68. https://psycnet.apa.org/journals/amp/55/1/68/

Sadaghian, S., Marandi, S. S., & Iravani, H. (2020). Autonomous language learning in a work-cycle: Learners' perceptions, beliefs and behaviors. *SiSal Journal*, *11*(2), 66–85. https://doi.org/10.37237/110202

Skinner, E. A. (2023). Four Guideposts toward an Integrated Model of Academic Motivation: Motivational Resilience, Academic Identity, Complex Social Ecologies, and Development. In *Educational Psychology Review* (Vol. 35, Issue 3). Springer US. https://doi.org/10.1007/s10648-023-09790-w

Suman, R. S., Moccia, S., Chinnusamy, K., Singh, B., & Regin, R. (2023). *Handbook of research on learning in language classrooms through ICT-based digital technology*. IGI Global.

Sung, Y. T., Chang, K. E., & Liu, T. C. (2016). The effects of integrating mobile devices with teaching and learning on students' learning performance: A meta-analysis and research synthesis. *Computers and Education*, *94*, 252–275. https://doi.org/10.1016/j.compedu.2015.11.008

Veresov, N., & Veraksa, N. (2023). Digital games and digital play in early childhood: a cultural-historical approach. *Early Years*, *43*(4–5), 1089–1101. https://doi.org/10.1080/09575146.2022.2056880

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes* (Vol. 86). Harvard university press.

Wei, N., Peng, W., Sindakis, S., Chang, F., & Su, J. (2023). The Role of Intrinsic Motivation in Online Teaching Systems: From the Collision of Knowledge Management and Information Technology. *Journal of the Knowledge Economy*, *0123456789*. https://doi.org/10.1007/s13132-023-01516-1

Weiland, C., Moffett, L., Rosada, P. G., Weissman, A., Zhang, K., Maier, M., Snow, C., McCormick, M., Hsueh, J. A., & Sachs, J. (2023). Learning experiences vary across young children in the same classroom: evidence from the individualizing student instruction measure in the Boston Public Schools. *Early Childhood Research Quarterly*, *63*, 313–326. https://doi.org/10.1016/j.ecresq.2022.11.008

Author Biographies

Salmaini S was born in Talu, Pasaman Regency, West Sumatra Province on May 24th, 1970. The author studied at the Bachelor of Mathematics Education Department at IKIP Padang (graduated in 1994), master's degree at the Postgraduate Mathematics Department at UNAND Padang (graduated in 2008), Ph.D in Educational Science Orientation in Mathematics Education at Universitas Negeri Padang (graduated in 2020).