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To cite this article:

Yulianto, D., Umami, M.R., Junaedi, Y., Anwar, S., Juniawan, E.A., & Sanjaya, T.M. (2025). Empowering early math education: The role of web 2.0 tools in improving counting skills in early learners. *International Journal of Education in Mathematics, Science, and Technology (IJEMST), 13*(4), 872-894. https://doi.org/10.46328/ijemst.4887

International Journal of Education in Mathematics, Science and Technology

2025, Vol. 13, No. 4, 872-894 https://doi.org/10.46328/ijemst.4887

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Article Info

Article History

Received:
19 January 2025

Accepted:
19 May 2025

Keywords

Elementary education
Integration of web 2.0 technologies
Mathematics instruction
Number sense competencies
Numerical reasoning.

Abstract

Despite the increasing integration of technology in early childhood education, empirical research on the effectiveness of Web 2.0-based numeracy learning remains limited, particularly in developing countries. This study investigates the impact of a Web 2.0-based Numeracy Education Program on first-grade students' numeracy skills using a quasi-experimental design. A total of 44 students (23 in the experimental group, 21 in the control group) were assessed with a modified *Number Sense Screener (NSS)* over a 12-week intervention. The experimental group engaged in interactive Web 2.0-based learning, while the control group followed the standard curriculum. Statistical analyses, including the Wilcoxon Signed-Rank Test and Mann-Whitney U Test, revealed significant improvements in numerical comparison, number identification, nonverbal calculation, word problem-solving, and number combinations ($p < .05$) with moderate to high effect sizes. However, no significant gains were observed in counting skills ($p > .05$), suggesting the need for refined pedagogical strategies to enhance foundational numerical fluency. These findings underscore the potential of Web 2.0 technologies in fostering early numeracy development and advocate for their systematic integration into mathematics curricula. Future research should explore large-scale implementation, long-term effects, and teacher training models to maximize the educational benefits of Web 2.0 technology.

Introduction

Early mathematics education plays a fundamental role in children's cognitive development and long-term academic success. Research indicates that young children possess a greater capacity for understanding complex mathematical concepts than previously assumed (Björklund et al., 2020). Early proficiency in pattern recognition, measurement, and numerical concepts significantly predicts later achievements in literacy and science (Ten Braak et al., 2022). Executive functions and numerical skills serve as the foundation for early mathematical comprehension, reinforcing long-term problem-solving and critical thinking abilities (Raghubar & Barnes, 2017; Onoshakpokaiye, 2024). While effective mathematics instruction requires the integration of numerical concepts, shapes, spatial reasoning, and measurement through structured curricula and play-based activities (Zippert et al., 2019), the lack of specialized training among early childhood educators in mathematics instruction remains a critical challenge (Wilson & Kelley, 2022). This gap is particularly concerning given that early numeracy skills are a primary predictor of academic success, especially in mathematics and science. A foundational understanding of patterns, measurement, and numerical concepts has been shown to contribute significantly to academic achievement through secondary education (Nguyen et al., 2016). Moreover, mathematical proficiency at 54 months of age strongly correlates with the selection of advanced subjects in secondary school and higher college participation rates, irrespective of demographic factors (Davis-Kean et al., 2021). Furthermore, research highlights that early numeracy exerts a more substantial influence on long-term academic success than literacy or socio-emotional skills (Ten Braak et al., 2022). For students with developmental disabilities, deficits in foundational numeracy skills further hinder access to standard curricula (Zhang & Holden, 2023). Therefore, prioritizing early mathematics education within early childhood learning frameworks is imperative and cannot be overlooked.

Traditional mathematics instruction for young children often fails to sustain student engagement. Interactive, technology-based approaches, particularly virtual object manipulation, have proven more effective than conventional methods (Santilli et al., 2025). Learning trajectories play a crucial role in understanding children's mathematical thinking and guiding instruction to enhance its relevance (Clements & Sarama, 2014; Clements et al., 2023). However, significant gaps in mathematical knowledge and pedagogical skills persist among early childhood and primary school teachers, particularly in remote areas (Sabri et al., 2023), underscoring the urgent need for targeted professional development. Effective mathematics instruction must align with children's interests, engagement levels, and cognitive development through research-based strategies (Clements et al., 2023). Well-designed assessments have been shown to enhance motivation and engagement (Sortwell et al., 2024). Furthermore, teachers play a pivotal role in fostering emotional involvement by creating structured learning environments, providing autonomy support, and encouraging active participation (Lietaert et al., 2015). Intrinsic motivation tends to decline with age, influenced by factors such as gender, culture, ethnicity, and family and school environments (Wigfield et al., 2015). However, appropriately challenging tasks, emotional support, and high expectations can mitigate this decline (Wigfield et al., 2015). In mathematics learning, extrinsic motivation has been found to be more effective than intrinsic motivation in promoting engagement and deeper understanding (Kanellopoulou & Giannakoulopoulos, 2020). Nevertheless, fostering intrinsic motivation remains essential for cultivating a conducive learning environment and optimizing long-term academic outcomes.

Web 2.0 technologies have transformative potential in early mathematics education by fostering active collaboration, knowledge sharing, and co-creation of content (Clark-Wilson et al., 2020). In the United States and Europe, these technologies have become integral to mathematics education standards, enhancing student engagement through interactive applications (Mokter Hossain & Quinn, 2012; Redecker, 2009). The Technological Mathematical Leadership Diversity (TMLD) approach further reinforces inclusive learning for students from diverse backgrounds (Ahmad et al., 2024). However, existing research predominantly focuses on advanced learners, while studies on the implementation of Web 2.0 in early mathematics education remain limited (Murphy & Ingram, 2023). As education shifts towards collaborative learning, Web 2.0 presents opportunities for active student engagement, yet challenges persist in its curricular integration (Clark-Wilson et al., 2020). In early childhood education, these technologies have demonstrated effectiveness in developing numeracy skills and number sense (Akbabaoğlu & Uyanık, 2024). While Web 2.0 fosters innovative learning environments (Zhao et al., 2022), concerns have been raised regarding potential distractions in classroom settings (Özçelik Akay & Cakir, 2023), necessitating flexible instructional strategies to maximize its benefits (Haleem et al., 2022). In e-learning contexts, Web 2.0 enhances interactivity, collaboration, and personalization, optimizing knowledge management and learning resource efficiency (Karunasena et al., 2013). Tools such as wikis, blogs, and RSS feeds support constructivist, student-centered pedagogies (Ünal, 2020). In higher education, Web 2.0 facilitates personalized learning (Alamri et al., 2021), yet challenges such as technical barriers, collaboration issues, and plagiarism concerns must be effectively addressed (Bower, 2017). Overall, while Web 2.0 continues to transform modern pedagogical paradigms, its implementation in early mathematics education requires further research to ensure its effectiveness and sustainability.

Innovative approaches to mathematics instruction, such as interactive tools and modern learning strategies, have been shown to enhance student engagement and comprehension. Web-based applications and educational games significantly boost motivation and reinforce conceptual understanding (Li et al., 2024; Tukiman et al., 2024), with *RoadMath* demonstrating high effectiveness in increasing interest and enjoyment in learning (Tukiman et al., 2024). The Generative Learning Model, which integrates interactive tools with contextual approaches, also contributes to improved conceptual understanding and student participation (Salinas-Navarro et al., 2024; Parni & Akmam, 2023). Additionally, the combination of cooperative learning, portfolio-based assessments, and mathematics journals has been found to enhance both engagement and mastery of concepts simultaneously (Bognar et al., 2025; Birgin & Baki, 2007). The *flipped classroom* approach has been recognized for fostering behavioral, emotional, and cognitive engagement (Lo & Hew, 2021), while Inquiry-Based and Collaborative Learning strategies strengthen critical thinking, interpersonal skills, and academic performance (Lee & Paul, 2023). Collectively, these approaches address the limitations of traditional lecture-based methods by accommodating diverse learning styles, ultimately improving students' mathematical understanding and appreciation. In early childhood education, gamification has proven to be more effective than conventional methods in enhancing literacy and numeracy skills. Gamification-based applications significantly improve phonemic awareness, vocabulary, and reading comprehension (Liu Li et al., 2024), as well as arithmetic proficiency (Sallik et al., 2022). Moreover, its integration across multiple subjects, particularly in science, has been shown to foster motivation, academic achievement, and independent learning (Zambrano-Vera et al., 2024). The effectiveness of gamification is attributed to four core elements: attention, active engagement, feedback, and consolidation (Lorenzo-Lledó et al., 2023). Therefore, integrating gamification into early education not only enhances student engagement but also strengthens learning outcomes, making it a valuable strategy for educators and policymakers in designing more adaptive and engaging learning systems.

The integration of Web 2.0 technologies in education and professional sectors is increasing; however, their implementation in developing countries, including Indonesia, faces significant challenges. Despite educators' willingness to adopt these technologies (Adnan et al., 2021), limitations in digital infrastructure, unclear policies, and inadequate technical and pedagogical support hinder effective implementation (Idiegbeyan-Ose et al., 2019). The digital divide between urban and rural areas further exacerbates disparities in access to educational technology

(Mathevula & Uwizeyimana, 2014). In Indonesia, these challenges are compounded by inconsistent assessment standards, weak inter-agency coordination, and a lack of sustained professional development programs for educators (Mutohar & Hughes, 2016). Additionally, misalignment between curriculum design and digital learning frameworks constrains the effective integration of technology into pedagogical practices (Hennessy et al., 2022). Low teacher competency, exacerbated by insufficient training and technical support, further impedes the effectiveness of digital learning (Moila, 2024; Aidoo & Chebure, 2024). Addressing these barriers requires strengthening digital infrastructure, implementing comprehensive policies, and providing continuous, needs-based teacher training (Idiegbeyan-Ose et al., 2019; Mutohar & Hughes, 2016). Moreover, expert ICT support and collaborative learning communities are essential strategies for enhancing educators' preparedness and optimizing Web 2.0 integration in education (Moila, 2024; Aidoo & Chebure, 2024; Pugazh & Jalandharachari, 2024).

Mathematics education in Indonesia remains predominantly reliant on rote learning, despite growing interest in technology integration (Yulianto et al., 2024). Notably, technology is the second most-discussed topic in mathematics education research, accounting for 13.28% of total studies (Nur et al., 2021). However, its implementation in classrooms remains limited due to infrastructure deficits and the underutilization of digital tools, despite strong empirical evidence supporting their effectiveness in enhancing problem-solving and learning experiences (Hidayat & Firmanti, 2024). Furthermore, the use of technology whether individually or collaboratively significantly influences student engagement and attitudes, with gender differences observed in shared device usage (Almusharraf et al., 2023). These challenges underscore the need for strategic improvements in infrastructure and pedagogical alignment to optimize technology-enhanced learning. Web 2.0 technologies have been shown to significantly enhance mathematical comprehension, with tools such as Plickers, Kahoot, and Edmodo demonstrating substantial improvements in primary school students' academic performance (İlknur et al., 2023; Yilmaz et al., 2024). At the secondary level, the integration of Moodle, Edmodo, and Edpuzzle has proven effective in fostering knowledge assimilation and critical thinking (Avila-Pesantez et al., 2019). Given the increasing global engagement of children with Web 2.0 applications (Hossain & Quinn, 2012), optimizing digital potential in Indonesian mathematics education necessitates a strategic approach that balances technological innovation with infrastructural constraints.

Recent studies highlight the significant potential of educational technology (ET) in enhancing early mathematics learning. However, its integration into curricula, particularly in local contexts, remains underexplored. Research-based education (RE) has been shown to improve children's numeracy skills (Verbruggen et al., 2021), yet its classroom implementation remains limited (Haleem et al., 2022; Johnson, 2016). Various RE integration methods have been identified, including hardware, software, and online resources, with PowerPoint being the most commonly used tool (Hidayat & Firmanti, 2024). Furthermore, educational games have demonstrated effectiveness in enhancing children's numerical cognition (Salsabillah & Utami, 2023; Syafdaningsih et al., 2020). Nevertheless, challenges such as inadequate infrastructure and insufficient teacher support persist, hindering the effective adoption of RE (Hidayat & Firmanti, 2024; Verbruggen et al., 2021). Further research is required to examine the characteristics of RE, its implementation strategies, and the child-related factors influencing its effectiveness (Verbruggen et al., 2021). This study investigates statistically significant differences in (1) pre-test scores between the experimental and control groups, (2) changes in pre-test to post-test scores within each group, (3) score improvements in the control group, (4) post-test score differences between groups, and (5) variations in post-test and follow-up test scores across sub-dimensions and the total Numeracy Skills Scale (NSS).

Method

This study utilized a quasi-experimental design with a pre-test, post-test, and follow-up test model to evaluate the effectiveness of a Web 2.0-based Numerical Education Program in enhancing number sense among first-grade students. The independent variable was the "Web 2.0-based Numerical Education Program," while the dependent variable was "Number Sense Development." A pre-test ensured initial equivalence. Following this, the experimental group engaged in a Web 2.0-supported learning program designed to enhance their numerical skills, whereas the control group received conventional mathematics instruction aligned with the National Education Curriculum. Both interventions were directly implemented by the researcher. The study involved first-grade students from Al Wildan International Islamic School 4 Jakarta during the 2023–2024 academic year. A total of 44 students with normal cognitive development and no prior exposure to specialized numerical programs were selected through purposive random sampling from schools with at least 20 first-grade students. Class 1-A (23 students) served as the experimental group, while Class 1-B (21 students) functioned as the control group. Student demographic details are presented in Table 1.

Table 1. The Sample Encompasses the Demographic Details of the Students

Demographic Variables	**Experimental (n = 23)**		**Control (n = 21)**	
Gender	**f**	**%**	**f**	**%**
Female	12	52.2	10	47.6
Male	11	47.8	11	52.4
Number of Children in Family	**f**	**%**	**f**	**%**
Only child	3	13.0	2	9.5
2 children	9	34.8	10	42.9
3+ children	11	43.5	9	38.1
Parents' Age (Years)	**f**	**%**	**f**	**%**
Mother ≤ 29	2	8.7	4	19.0
Mother 30-49	21	91.3	17	81.0
Father ≤ 29	1	4.3	2	9.5
Father 30-49	22	95.7	19	90.5
Parents' Education	**f**	**%**	**f**	**%**
Mother: Primary-Middle	13	56.5	15	71.4
Mother: High School+	10	43.5	6	28.6
Father: Primary-Middle	13	47.8	14	66.7
Father: High School+	10	52.2	7	33.3

Table 1 presents a balanced distribution between the experimental (n = 23) and control (n = 21) groups, with nearly equal gender proportions (52.2% female in the experimental group; 47.6% in the control group). Most students came from families with two or more children, and parents were predominantly aged 30–49. A significant difference was observed in parental education levels, with a higher percentage of parents in the experimental group attaining upper secondary education or higher (mothers: 43.5%; fathers: 52.2%) compared to the control group (mothers: 28.6%; fathers: 33.3%). As this disparity could influence academic support at home, it was controlled to ensure result validity. Demographic data were collected through a General Information Form covering student and parental details (gender, number of siblings, age, education, and occupation), validated against official school records. First-grade students' numerical abilities were assessed using the *Number Sense Screener* (NSS), developed by Jordan et al. (2012) and adapted for Indonesia by Juniarti et al. (2024). This culturally and curriculum-aligned tool evaluates number recognition, quantitative relationships, and basic operations, supporting evidence-based research on Web 2.0's effectiveness in early mathematics learning. Recognized as a key instrument for early numeracy assessment (Aktulun, 2019), NSS comprises six subtests with 30 items measuring number comprehension, operations, estimation, and comparisons (Björklund, 2020; Jordan et al., 2012). Administered individually in 20–25 minutes, it provides a comprehensive evaluation of foundational numerical skills, facilitating early interventions for students with mathematical difficulties.

This study examines a Web 2.0-based *Number Sense* program designed to enhance first-grade students' numerical understanding. Developed through a comprehensive literature review and aligned with the National Mathematics Curriculum, the program was structured with input from three mathematics education experts. Before implementation, an analysis of students' needs, learning environment readiness, and technological infrastructure was conducted. The evaluation focused on learning outcomes across four key curriculum units. The research instrument comprised six numeracy subtests: (1) *Counting Proficiency* (4 items) assessing fundamental numerical concepts, (2) *Number Identification* (4 items) evaluating the ability to identify and name numbers, (3) *Numerical Comparisons* (7 items) measuring skills in comparing values and recognizing numerical patterns, (4) *Nonverbal Computation* (4 items) utilizing visual aids to assess basic arithmetic operations, (5) *Word Problem Solving* (5 items) involving narrative-based tasks to encourage arithmetic problem-solving strategies, and (6) *Number Combinations* (6 items) testing verbal arithmetic proficiency in simple operations.

A 12-week instructional program was developed based on curriculum recommendations and expert input, comprising 11 lesson plans totaling 60 instructional hours. Designed to enhance students' numerical comprehension through Web 2.0 tools, each lesson plan specifies duration, objectives, methods, teaching strategies, and assessment measures across three instructional phases:

1. Introduction → Engaging attention, activating prior knowledge, fostering motivation, and defining learning objectives.
2. Development → Conducting core activities, providing interim summaries, and transitioning to new concepts.
3. Conclusion → Encouraging reflection, reinforcing understanding, and evaluating learning outcomes.

Web 2.0-based activities progress from simple to complex, allowing both guided and independent learning. Each lesson integrates at least three Web 2.0 applications from free online platforms such as Wordwall, LearningApps, Storybird, Canva, and Pixton, with increasing complexity. Three experts in Number Sense and early childhood education evaluated the lesson plans for learning outcome alignment, conceptual coherence, Web 2.0 activity quality, instructional effectiveness, and clarity of learning indicators. Their feedback prompted refinements to enhance alignment with the targeted learning outcomes, resulting in a more structured and effective program.

This study integrates various Web 2.0 tools to enhance early numeracy through interactive learning. In the first week, students are introduced to numbers and patterns via digital stories and interactive quizzes (Digital Story, Wordwall, Derslig) (Nguyen et al., 2016). The second week focuses on basic arithmetic operations using educational comics and visual exercises (Canva, LearningApps, Okulistik) (Davis-Kean et al., 2021). Weeks three and four reinforce arithmetic concepts through virtual characters and interactive fairy tales (Voki, Okulistik, Math Kids) (Ten Braak et al., 2022). In weeks four to five, number recognition is strengthened through educational games (ABCYa, EBA, Primary Games). Weeks five to seven engage students in number concepts and problem-solving through gamified learning (Wordwall, LearningApps, Voki). Weeks eight and nine emphasize number comparison through concept cartoons and visual exercises (Pixton, ABCYa, Okulistik). Finally, weeks ten to twelve focus on applying knowledge through word problems and student-created presentations (Voki, LearningApps, Canva, Wordwall) (Zhang & Holden, 2023).

Over 12 weeks, various Web 2.0 tools were integrated to enhance student engagement through visuals, games, and interactive materials, fostering innovative conceptual understanding. A two-week pilot phase assessed time management, activity suitability, and student responses, yielding positive results. In the experimental study, Web 2.0-based activities were progressively implemented across 11 lesson plans, transitioning from basic to complex concepts using 13 Web 2.0 tools, distinct from conventional methods. To evaluate first-grade students' number sense, the Number Sense Scale (NSS) was administered as a pre-test (October 24, 2023 – January 20, 2024) in both experimental and control groups, ensuring validity and reliability. Parents were informed about the program and the importance of student attendance. The Web 2.0-Based Number Sense Education Program was implemented in the experimental group's mathematics class (60 minutes/day, five days/week), while the control group followed the official curriculum under the same researcher, ensuring methodological consistency. Each session was systematically designed with instructional materials and technological tools (smart boards, computers). A structured schedule was developed with teachers to optimize time and student participation. The lessons followed three phases: (1) Introduction – capturing attention, activating prior knowledge, motivating students, and presenting objectives; (2) Development – conducting activities, providing explanations, and transitioning between tasks; and (3) Closure – summarizing, reinforcing motivation, concluding, and assessing learning outcomes.

The learning materials align with the Grade One Mathematics Curriculum established by the Ministry of National Education. Web 2.0-based content was designed to achieve specific learning objectives, integrating smart boards and computers for student tasks. This approach was applied exclusively to the experimental group, while the control group followed the standard 12-week mathematics curriculum. After the intervention, the Number Sense Screener (NSS) was used as a post-test under the same conditions as the initial pre-test, conducted between October 24, 2023, and January 20, 2024. One week after the post-test, a retention assessment was administered to evaluate lasting effects. The data analysis process began with an examination of demographic characteristics for both students and their parents. Due to the relatively small sample size fewer than 30 participants per group, the Kolmogorov-Smirnov test revealed a non-normal data distribution. As a result, non-parametric statistical methods were applied, including the Mann-Whitney U test for comparing differences between groups and the Wilcoxon Signed-Rank test for assessing changes within groups. A significance threshold of $\alpha = 0.05$ was established, meaning that p-values below 0.05 were considered statistically significant, while values equal to or above 0.05 indicated no meaningful difference.

Results

The quantitative results on the impact of the Web 2.0-enhanced Number Sense Program on children's numerical understanding is detailed in Tables 2–5. Specifically, Table 3 provides an overview of key statistical data, including the number of participants, average scores, and standard deviation for the pre-test results of the Number Sense Screener. These values represent the initial performance levels of first-grade students in both the experimental and control groups before the intervention began.

Table 2. PreTest – PostTest Results of Number Sense Screener for First-Grade Students

Aspects	**PreTest**		**PostTest**	
	Experiment	**Control**	**Experiment**	**Control**
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
Counting Proficiency	5.78 (0.495)	5.56 (0.581)	6.08 (0.458)	5.86 (0.569)
Number Identification	1.36 (0.971)	1.87 (1.222)	1.76 (1.038)	2.07 (1.286)
Numerical Comparisons	7.49 (1.747)	6.93 (1.710)	8.29 (1.644)	7.13 (1.805)
Nonverbal Computation	5.41 (1.046)	3.81 (0.947)	6.01 (1.001)	4.21 (1.084)
Word Problem Solving	2.89 (1.067)	2.73 (1.311)	3.09 (1.299)	3.03 (1.294)
Number Combinations	3.35 (1.862)	2.20 (1.532)	3.65 (1.629)	2.44 (1.728)
NSS Total	26.28 (7.188)	23.10 (7.303)	28.88 (7.069)	24.74 (7.766)

Table 2 presents the PreTest-PostTest results from the Number Sense Screener (NSS), comparing first-grade students in the experimental and control groups. The results indicate that the experimental group consistently outperformed the control group across multiple mathematical aspects, confirming the effectiveness of the instructional intervention. Before the intervention, the experimental group demonstrated a slight advantage in most areas, particularly in nonverbal computation ($M = 5.41$, $SD = 1.046$) compared to the control group ($M = 3.81$, $SD = 0.947$), as well as in number combinations ($M = 3.35$, $SD = 1.862$ vs. $M = 2.20$, $SD = 1.532$). However, the control group exhibited a higher number identification score ($M = 1.87$, $SD = 1.222$ vs. $M = 1.36$, $SD = 0.971$). Following the intervention, the experimental group showed greater improvement across all subdimensions, with notable gains in numerical comparisons ($M = 8.29$, $SD = 1.644$ vs. $M = 7.13$, $SD = 1.805$) and nonverbal computation ($M = 6.01$, $SD = 1.001$ vs. $M = 4.21$, $SD = 1.084$). Additionally, the total NSS score was significantly higher in the experimental group ($M = 28.88$, $SD = 7.069$) than in the control group ($M = 24.74$, $SD = 7.766$), reinforcing the positive impact of the instructional approach.These findings highlight the effectiveness of innovative teaching methods in enhancing mathematical skills, particularly in abstraction, numerical reasoning, and problem-solving. However, the relatively smaller improvement in number identification suggests the need for supplementary strategies to strengthen fundamental numeracy skills.

Table 3. Results of Pre-Test and Post-Test

Aspects	Test	Experiment		Control		U	Z	P
		Mean Rank	**Rank Sum**	**Mean Rank**	**Rank Sum**			
Counting Proficiency	Pretest	23.59	542.50	21.31	447.50	216.500	0.876	0.381
	Posttest	24.12	555.00	20.67	434.00	202.000	1.532	0.126
Number Identification	Pretest	20.91	481.00	24.24	509.00	205.000	0.952	0.341
	Posttest	25.05	576.00	19.38	407.00	177.000	1.687	0.091
Numerical Comparisons	Pretest	23.54	541.50	21.36	448.50	217.5	0.575	0.565
	Posttest	27.31	628.00	17.33	364.00	132.000	2.589	0.010*
Nonverbal Computation	Pretest	22.54	518.50	22.45	471.50	240.5	0.025	0.980
	Posttest	26.95	620.00	17.71	372.00	138.000	2.487	0.013*
Word Problem Solving	Pretest	23.35	537.00	21.57	453.00	222.0	0.479	0.632
	Posttest	28.02	644.50	16.67	350.50	118.500	3.012	0.003*
Number Combinations	Pretest	24.28	558.50	20.55	431.50	200.5	1.014	0.311
	Posttest	27.85	640.50	16.81	354.50	122.500	2.913	0.004*
NSS Total	Pretest	23.52	541.00	21.38	449.00	218.0	0.555	0.579
	Posttest	28.55	656.50	16.19	340.50	110.500	3.176	0.002*

Table 3 presents the results of the pretest, indicating no statistically significant differences between the experimental and control groups across all mathematical ability domains. The Mann-Whitney U test confirmed this equivalence in Counting Proficiency (U = 216.5, Z = 0.876, $p > .05$), Number Identification (U = 205.0, Z = 0.952, $p > .05$), Numerical Comparisons (U = 217.5, Z = 0.575, $p > .05$), Nonverbal Computation (U = 240.5, Z = 0.025, $p > .05$), Word Problem Solving (U = 222.0, Z = 0.479, $p > .05$), Number Combinations (U = 200.5, Z = 1.014, $p > .05$), and the total Number Sense Screener (NSS) score (U = 218.0, Z = 0.555, $p > .05$). These findings confirm comparable numerical proficiency in both groups before the intervention, ensuring that any posttest differences stem from instructional effects rather than initial disparities. In the posttest, no significant differences were observed in Counting Proficiency (U = 202.0, p = 0.126) and Number Identification (U = 177.0, p = 0.091), indicating similar performance in basic numerical skills. However, the experimental group demonstrated significant improvements in Numerical Comparisons (U = 132.0, Z = 2.589, p = .010), Nonverbal Computation (U = 138.0, Z = 2.487, p = .013), Word Problem Solving (U = 118.5, Z = 3.012, p = .003), Number Combinations (U = 122.5, Z = 2.913, p = .004), and total NSS score (U = 110.5, Z = 3.176, p = .002). These results highlight the effectiveness of the instructional approach in enhancing higher-order mathematical skills, particularly in numerical reasoning, problem-solving, and number comparison. However, additional strategies may be required to further strengthen basic arithmetic and number identification skills. Overall, the intervention successfully promoted comprehensive numerical development among elementary students.

Table 4. Wilcoxon Signed-Rank Test Results Pre-Test Score

Number Sense Screener	**Pre / Post-Test**	**Experiment**					**Control**				
		n	**Mean Rank**	**Sum of Rank**	**z**	**p**	**n**	**Mean Rank**	**Sum of Rank**	**z**	**p**
Counting Proficiency	Negative Rank	0	0.00	0.00	1.954	0.051	2	1.50	3.00	0.447	0.655
	Positive Rank	18	9.50	171.00			15	8.00	120.00		
	Ties	5	-	-			4	-	-		
Number Identification	Negative Rank	0	0.00	0.00	3.954	0.000*	0	0.00	0.00	3.411	0.001*
	Positive Rank	21	11.00	231.00			19	10.00	190.00		
	Ties	2	-	-			2	-	-		
Numerical Comparisons	Negative Rank	0	0.00	0.00	3.850	0.000*	0	0.00	0.00	3.810	0.000*
	Positive Rank	19	10.00	190.00			19	10.00	190.00		
	Ties	4	-	-			2	-	-		
Nonverbal Computation	Negative Rank	0	0.00	0.00	3.800	0.000*	3	3.00	9.00	2.217	0.027*
	Positive Rank	18	9.50	171.00			16	9.00	144.00		
	Ties	5	-	-			2	-	-		
Word Problem Solving	Negative Rank	1	3.00	3.00	4.135	0.000*	1	2.00	2.00	3.494	0.000*
	Positive Rank	22	12.41	273.00			18	9.50	171.00		
	Ties	0	-	-			2	-	-		
Number Combinations	Negative Rank	0	0.00	0.00	4.125	0.000*	0	0.00	0.00	3.842	0.000*
	Positive Rank	22	11.50	253.00			19	10.00	190.00		
	Ties	1	-	-			2	-	-		
Number Sense Screener Total	Negative Rank	0	0.00	0.00	4.203	0.000*	0	0.00	0.00	3.933	0.000*
	Positive Rank	23	12.00	276.00			21	10.50	220.50		
	Ties	0	-	-			0	-	-		

Note: $p < 0.05$ indicates statistical significance

Table 4 presents the Wilcoxon Signed-Rank Test results, indicating significant improvements across several Number Sense Screener subdomains in both the experimental and control groups. In the experimental group, notable gains were observed in Number Identification *($z = 3.954$, $p < 0.05$)*, Numerical Comparisons *($z = 3.850$, $p < 0.05$)*, Nonverbal Computation *($z = 3.800$, $p < 0.05$)*, Word problem-solving *($z = 4.135$, $p < 0.05$)*, Number Combinations *($z = 4.125$, $p < 0.05$)*, and the Total Number Sense Screener Score *($z = 4.203$, $p < 0.05$)*. The absence of negative ranks further reinforces the effectiveness of the intervention in enhancing students' mathematical proficiency. However, Counting Proficiency *($z = 1.954$, $p = 0.051$)* did not reach statistical significance, suggesting the need for further instructional refinements.

The control group also demonstrated significant improvements in Number Identification *($z = 3.411$, $p < 0.05$)*, Numerical Comparisons *($z = 3.810$, $p < 0.05$)*, Nonverbal Computation *($z = 2.217$, $p < 0.05$)*, Word Problem Solving *($z = 3.494$, $p < 0.05$)*, Number Combinations *($z = 3.842$, $p < 0.05$)*, and the Total Number Sense Screener Score *($z = 3.933$, $p < 0.05$)*. However, Counting Proficiency *($z = 0.447$, $p > 0.05$)* did not exhibit significant progress, indicating limitations in the control group's instructional approach for foundational numeracy skills. Overall, while both groups showed notable advancements, the experimental group exhibited superior performance in most subdomains. The lack of significant improvement in Counting Proficiency across both groups highlights the necessity for more targeted pedagogical strategies to ensure comprehensive number sense development.

Table 5. Results of Post-Test and Retention Test Scores for First-Grade Students

Number Sense Screener	**Pre-Test / Post-Test**	**n**	**Mean Rank**	**Sum of Rank**	**z**	**p**
Counting Proficiency	Negative Rank	1	1.50	1.50	1.482	0.138
	Positive Rank	2	2.50	5.00		
	Ties	20	-	-		
Number Identification	Negative Rank	2	4.00	8.00	2.231	0.024*
	Positive Rank	10	6.80	68.00		
	Ties	11	-	-		
Numerical Comparisons	Negative Rank	3	5.00	15.00	2.512	0.012*
	Positive Rank	8	7.00	56.00		
	Ties	12	-	-		
Nonverbal Computation	Negative Rank	1	5.00	5.00	2.453	0.014*
	Positive Rank	9	6.20	55.80		
	Ties	13	-	-		
Word Problem Solving	Negative Rank	2	3.50	7.00	0.722	0.471
	Positive Rank	5	4.80	24.00		
	Ties	16	-	-		
Number Combinations	Negative Rank	4	4.20	16.80	1.210	0.226
	Positive Rank	6	6.10	36.60		
	Ties	13	-	-		
Number Sense Screener Total	Negative Rank	3	4.80	14.40	2.972	0.003*
	Positive Rank	12	8.25	99.00		
	Ties	8	-	-		

Notes: *p < .05 indicates statistical significance.

The Wilcoxon Signed-Rank Test (see Table 5) identified significant improvements in key number sense components, including Number Identification (z = 2.231, p = 0.024), Numerical Comparisons (z = 2.512, p = 0.012), Nonverbal Computation (z = 2.453, p = 0.014), and the overall Number Sense Screener score (z = 2.972, p = 0.003), indicating sustained learning effects from post-test to retention test. These results suggest that the instructional approach effectively reinforced students' higher-order numerical skills. However, Counting Proficiency (z = 1.482, p = 0.138), Word Problem Solving (z = 0.722, p = 0.471), and Number Combinations (z = 1.210, p = 0.226) showed no significant differences, highlighting the need for additional reinforcement to enhance long-term retention. The dominance of positive ranks in significantly improved subdomains supports the effectiveness of the intervention, suggesting that while higher-order number sense skills benefit from the instructional method, basic numerical abilities may require extended exposure or alternative pedagogical strategies for lasting impact.

This study evaluates the effectiveness of Web 2.0-based technology in enhancing early childhood number sense skills. The Wilcoxon Signed-Rank Test (Table 5) indicates significant improvements in Number Recognition ($z = 2.231$, $p = 0.024$), Number Comparison ($z = 2.512$, $p = 0.012$), Nonverbal Calculation ($z = 2.453$, $p = 0.014$), and the overall Number Sense Screener (NSS) score ($z = 2.972$, $p = 0.003$), confirming the retention of learning effects. However, no significant differences were observed in Counting Skills ($z = 1.482$, $p = 0.138$), Word Problems ($z = 0.722$, $p = 0.471$), and Number Combination ($z = 1.210$, $p = 0.226$), suggesting the need for extended exposure or alternative pedagogical approaches to reinforce foundational skills. The predominance of positive ranks in significantly improved subdimensions supports the hypothesis that this experimental approach effectively enhances higher-order numerical abilities, while fundamental numerical skills may require more intensive or alternative instructional strategies.

Discussion

The pre-test analysis confirmed that Web 2.0 tools significantly enhance early numeracy. In counting skills, the experimental group outperformed the control group ($M = 5.78$, $SD = 0.495$ vs. $M = 5.56$, $SD = 0.581$), indicating comparable initial competence. Interactive Web 2.0 learning environments improve numeracy, number recognition, and overall mathematical proficiency while enhancing teaching quality (Akbabaoğlu & Aktulun, 2024; Mowafi & Abumuhfouz, 2021; Clements & Sarama, 2014). Although the control group excelled in number recognition ($M = 1.87$, $SD = 1.222$ vs. $M = 1.36$, $SD = 0.971$), the experimental group demonstrated superior number comparison skills ($M = 7.49$, $SD = 1.747$ vs. $M = 6.93$, $SD = 1.710$), reflecting greater cognitive flexibility in quantitative reasoning. Prior research supports the effectiveness of structured mathematical interventions in fostering numeracy and quantitative representation skills (Sterner & Helenius, 2019), with research-based curricula positively impacting mathematical development and classroom dynamics (Clements & Sarama, 2014).

Children with Developmental Dyscalculia (DD) exhibit deficits in numerical magnitude processing, marked by an increased numerical distance effect across various numerical formats (Mussolin et al., 2010). Core competencies predicting long-term mathematical achievement include numerical fluency, number value comprehension, Arabic numeral recognition, and sensitivity to relative quantity, highlighting the importance of early interventions for at-risk children (Geary & vanMarle, 2016). In Nonverbal Calculation, the experimental group demonstrated superior mental arithmetic skills compared to the control group ($M = 5.41$, $SD = 1.046$ vs. $M = 3.81$, $SD = 0.947$). However, Story Problems showed no significant differences between groups ($M = 2.89$, $SD = 1.067$ vs. $M = 2.73$, $SD = 1.311$), indicating that early numerical reasoning abilities remain comparable. Early arithmetic disparities are influenced by socioeconomic status and cognitive ability, with children from low-income backgrounds struggling with verbal calculations but showing similar progress in nonverbal tasks following formal instruction (Jordan et al., 2012). Children with language impairments tend to face difficulties in word problems but excel in nonverbal tasks, whereas those with cognitive delays exhibit challenges across all problem types (Turan & De Smedt, 2024). Additionally, gender differences slightly favor boys in numerical computation and nonverbal calculations (Jordan et al., 2006).

In Number Combinations, the experimental group demonstrated superior basic numerical operations ($M = 3.35$, SD = 1.862 vs. M = 2.20, SD = 1.532). The Total NSS score confirmed greater numerical proficiency in the experimental group (M = 26.28, SD = 7.188 vs. M = 23.10, SD = 7.303). Web 2.0-based number sense interventions significantly improve first-grade numeracy (Akbabaoğlu & Aktulun, 2024) and enhance mathematical competence in preschoolers from low-income backgrounds (Jordan et al., 2012). Integrated Dynamic Representations (IDR) benefit students with low initial mathematical skills (Cueli et al., 2020), while Taiwanese third graders engaging in number sense-integrated learning outperform those relying solely on standard textbooks (Yang & Wu, 2010). These findings confirm that number sense interventions effectively enhance early mathematical skills, particularly among students with lower initial competencies, addressing early numeracy gaps and promoting long-term academic success.

A comparison of pre-test and post-test scores between the experimental and control groups revealed significant differences across various mathematical competencies. Web 2.0 tools played a crucial role in enhancing arithmetic skills and numerical understanding. The experimental group showed greater improvement in arithmetic skills (M = 5.78 → 6.08) than the control group (M = 5.56 → 5.86), confirming that interactive digital tools enhance engagement, motivation, and knowledge retention, thereby accelerating skill acquisition. Additionally, the experimental group outperformed the control group in higher-order cognitive skills, particularly in Number Comparison (M = 8.29 vs. 7.13), Nonverbal Calculation (M = 6.01 vs. 4.21), and Number Combination (M = 3.65 vs. 2.44). The total NSS score also showed a more substantial improvement in the experimental group (M = 26.28 → 28.88) compared to the control group (M = 23.10 → 24.74), reinforcing the effectiveness of Web 2.0 tools in strengthening conceptual understanding. Further analysis confirmed statistically significant improvements in Number Comparison (+0.80 vs. +0.20), Nonverbal Calculation (+0.60 vs. +0.40), and the Total NSS Score (+2.60 vs. +1.64). However, the modest gains in Number Recognition (M = 1.36 → 1.76 in the experimental group vs. M = 1.87 → 2.07 in the control group) suggest that foundational numerical literacy may require supplementary instructional strategies beyond digital interventions.

These findings align with previous studies. Akbabaoğlu & Aktulun (2024) demonstrated that a Web 2.0-based Number Sense Education Program significantly enhanced first-grade students' numerical proficiency. Similarly, Özenç et al. (2020) found that Web 2.0-integrated activities following the 5E learning cycle model improved fourth-grade students' multiplication performance compared to traditional methods. Gündüzalp (2021) also reported notable gains in metacognitive and creative thinking skills among students engaged in Web 2.0-enriched online learning. These studies underscore the role of technology-based interventions in fostering conceptual understanding, cognitive flexibility, and long-term retention. This study reaffirms the effectiveness of Web 2.0 tools in strengthening early numeracy skills, particularly for students with lower initial competencies. Although the improvement in numerical skills within the experimental group was not statistically significant (U = 202.000, Z = 1.532, p = 0.126), the positive trend suggests that interactive digital tools promote meaningful engagement in foundational numeracy development. Longer intervention periods may yield stronger outcomes, reinforcing the importance of integrating technology into early childhood education. Future research should explore adaptive learning models, gamification, and parental involvement to optimize digital interventions, enhance long-term knowledge retention, and refine strategies for mathematical skill acquisition in young learners.

Conclusion

This study highlights the significant impact of Web 2.0-based tools on early mathematics learning, particularly in Number Comparisons, Nonverbal Calculation, Story Problems, and Number Combinations. Statistical analysis confirms that the experimental group outperformed the control group, reinforcing the effectiveness of interactive technology in enhancing mathematical comprehension. In addition to fostering student engagement, technology accelerates the development of fundamental numerical skills. However, no significant differences were found in Counting Skills and Number Recognition, suggesting the need for more tailored pedagogical strategies or refined implementation approaches.

Future research should explore key factors influencing the effectiveness of Web 2.0-based tools, including students' cognitive attributes, teachers' roles, and learning environments. Longitudinal studies are crucial to evaluating the long-term impact of this approach on numerical development. Expanding the research scope to larger populations or higher education levels would improve the generalizability of findings. Despite limitations in participant numbers and activity variations, this study confirms the intervention's efficacy in strengthening number sense. Future studies should investigate large-scale implementation and teacher training through specialized seminars or academic courses at the undergraduate and graduate levels to maximize the potential of Web 2.0 in mathematics education. Additionally, further research into its application in other mathematical domains is recommended to enhance student interest, motivation, and long-term conceptual retention, particularly in more complex topics.

Recommendations

This study confirms the effectiveness of Web 2.0-based instruction in enhancing early numeracy skills, particularly in number comparisons, nonverbal calculations, and problem-solving. However, gaps remain in foundational counting skills, necessitating further exploration. Future research should focus on the long-term retention of learning outcomes through longitudinal studies, adaptive and personalized learning models tailored to individual needs, and expanded implementation across diverse educational settings. Investigating the role of teacher training in optimizing digital pedagogy is essential, alongside exploring the impact of gamification and multimodal learning on student engagement. Additionally, parental involvement in home-based digital learning warrants further examination to strengthen early numeracy development. Comparative analyses with other digital learning frameworks, such as AI-driven tutoring and virtual reality, will provide deeper insights into the relative effectiveness of Web 2.0 methodologies. Addressing these areas will refine digital interventions and ensure their scalability, sustainability, and long-term impact on early childhood mathematics education.

Acknowledgments

The authors express their gratitude to the Institute for Research and Community Service (LPPM), Universitas La Tansa Mashiro, for funding support through the Internal Research Grant Program. Appreciation is also extended to academic advisors, colleagues, research assistants, and technical staff for their valuable contributions. Lastly, sincere thanks go to all individuals and institutions that have supported this research.

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