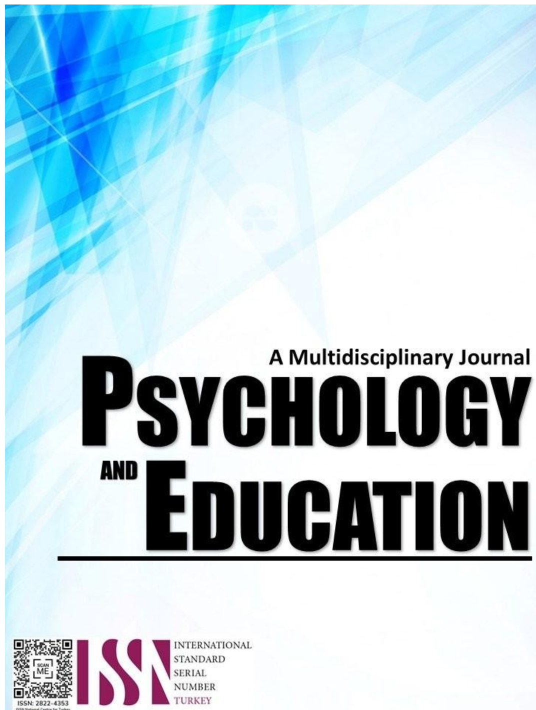
TEXT-TO-SPEECH TECHNOLOGY: EFFECTS ON BASIC MATH CONCEPTS PERFORMANCE AMONG LEARNERS WITH SPECIFIC LEARNING DISABILITIES



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Research Article

Text-To-Speech Technology: Effects on Basic Math Concepts Performance Among Learners with Specific Learning Disabilities

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Abstract

This study examined the effects of Text-to-Speech (TTS) technology on the mathematics performance of learners with Specific Learning Disabilities (SLDs) in a resource-room setting. A quasi-experimental pretest–posttest non-equivalent groups design was employed, involving 20 elementary learners divided into an experimental group (TTS-assisted instruction) and a control group (conventional instruction). A researcher-developed Mathematics Achievement Test was used to measure performance in number recognition, counting, and shapes and patterns before and after a four-week intervention. Descriptive statistics, paired samples t-tests, and Analysis of Covariance (ANCOVA) were utilized to analyze the data. Results revealed a significant improvement in the performance of learners exposed to TTS, with mean scores increasing from 12.50 to 18.70 ($p < .001$). In contrast, the control group showed only minimal and non-significant gains. ANCOVA results further confirmed a significant difference in posttest scores between groups, favoring the TTS intervention ($p < .001$), even after controlling for pretest performance. The findings indicate that TTS technology effectively enhances comprehension and engagement by reducing decoding demands and enabling learners to focus on mathematical reasoning. The integration of auditory support aligns with assistive technology principles and promotes inclusive learning by addressing language-related barriers in mathematics. This study concludes that TTS is a valuable instructional tool for improving basic math performance among learners with SLDs. It is recommended that schools integrate TTS within instructional practices, supported by appropriate training and infrastructure. Future research may explore its long-term impact and integration with other digital interventions to further strengthen inclusive education outcomes.

Keywords: *text-to-speech technology method, conventional method, basic math concepts, number recognition, counting, shapes, and patterns*

Introduction

Mathematics serves as one of the foundational pillars of a child's education, fostering logical reasoning, problem-solving, and analytical thinking. For learners in Grades 1 to 5, early mastery of basic math concepts such as number recognition, counting, and shapes is essential for academic success in higher-level math and daily life tasks. However, many elementary students, especially those with specific learning disabilities (SLDs), struggle to keep pace with these expectations. Difficulties in reading, decoding instructions, and maintaining focus often hinder their ability to engage with math content effectively, particularly when it is presented in traditional, text-heavy formats.

In recent years, the integration of educational technology in elementary schools has opened new possibilities for enhancing instruction and inclusivity. Among these innovations, Text-to-Speech (TTS) technology has gained attention as a promising assistive tool. TTS converts written text into spoken words, thereby reducing the cognitive demands of reading and allowing students to focus more on understanding instructional content. For learners with SLDs in Grades 1 to 5, this tool is particularly beneficial as it helps bridge gaps in literacy that interfere with math learning. By hearing instructions, questions, and explanations read aloud, these students are more likely to comprehend mathematical tasks and respond accurately. TTS also supports learner autonomy, increases engagement, and contributes to a more inclusive learning environment where students with learning differences can participate meaningfully in classroom activities. As such, TTS technology presents a strategic opportunity to support the development of basic math concepts among elementary learners with specific learning disabilities.

Despite the integration of educational technology across various settings, challenges persist in effectively supporting students with Specific Learning Disabilities, particularly in mastering foundational math skills. Globally, many students with learning disabilities continue to perform below grade level in mathematics due to barriers in reading and comprehension (Haberstroh et al., 2019). In the United States, the National Center for Learning Disabilities (2020) reports persistent achievement gaps between students with specific learning disabilities and their general education peers, especially in subjects like math, where reading is required to interpret problems. In Colorado, recent assessments reflect a similar trend, where students with learning disabilities demonstrate limited proficiency in core math competencies (Colorado Department of Education, 2023). At the local level, within Morgan County School District RE-3 and specifically at Pioneer Elementary School, educators have observed that students with specific learning disabilities often struggle with basic math tasks when instructions and problem-solving steps are text-heavy. These difficulties not only hinder academic success but also contribute to low confidence and classroom disengagement among these learners.

While previous studies have examined the effectiveness of TTS in supporting literacy development and reading comprehension for students with learning disabilities (Wood et al., 2018), limited research has focused on its potential to improve understanding in mathematics—especially in the context of basic concepts. Much of the existing literature is concentrated on reading fluency or writing support, leaving a gap in how such technology may influence mathematical thinking and problem-solving (Marino et al., 2014). This study aims to bridge that gap by investigating how text-to-speech technology impacts the learning of basic math concepts in a real-world, resource room setting at Pioneer Elementary School. The purpose of the study is to determine whether the use of TTS can significantly enhance the mathematical performance of students with specific learning disabilities compared to traditional instruction without TTS.

Research Questions

This study aimed to examine the effectiveness of text-to-speech (TTS) technology in improving the academic performance of students with specific learning disabilities (SLDs) in basic mathematics within a resource room setting. It specifically investigated how TTS supports learners in understanding math word problems, instructions, and number operations compared to traditional instructional approaches. Specifically, this study sought to answer the following research questions:

1. What is the level of basic math concepts performance of the learners with specific learning disabilities before and after the text-to-speech (TTS) technology intervention?
2. What is the level of basic math concepts performance of the learners with specific learning disabilities before and after the conventional strategies intervention?
3. Is there a significant difference between the pretest and posttest scores within each group of participants (TTS and conventional)?
4. Is there a significant difference in the posttest scores between the experimental group (TTS) and the control group (conventional)?

Methodology

Research Design

This study adopted a quasi-experimental pretest–posttest non-equivalent groups design to examine the effects of text-to-speech (TTS) technology on the mathematics performance of learners with Specific Learning Disabilities (SLDs). This design is appropriate in educational contexts where random assignment is not feasible, particularly in special education settings where learners are grouped based on Individualized Education Programs (IEPs). By utilizing intact classroom groupings, the design preserves ecological validity while allowing for meaningful comparison between an experimental group exposed to TTS-supported instruction and a control group receiving conventional instruction.

Both groups were assessed using pretest and posttest measures to evaluate learning gains over a four-week intervention period. The non-equivalent groups structure enabled the examination of causal inferences under natural classroom conditions, balancing methodological rigor with ethical and practical constraints. This approach is widely recognized in intervention-based educational research, particularly in studies involving assistive technologies and inclusive practices.

Participants

The participants consisted of 20 elementary learners diagnosed with SLDs and enrolled in a resource-room program in a public elementary school during the academic year 2025–2026. Purposive sampling was employed to select learners who met specific inclusion criteria, including formal SLD classification, enrollment in Grades 1–5, and participation in pull-out mathematics instruction. This ensured that participants were directly relevant to the study's objectives.

The sample was divided into two comparable groups of ten learners each, matched based on grade level, instructional level, and baseline performance to minimize initial group differences. Recruitment was conducted in collaboration with school administrators and special education personnel, with parental consent and learner assent obtained prior to participation. While the sample size was limited due to the population of eligible learners, efforts were made to ensure comparability, consistency in instruction, and adherence to ethical standards. Participants who did not meet attendance requirements or consent conditions were excluded to maintain data integrity.

Instrument

Data were collected using a researcher-developed Mathematics Achievement Test designed to assess foundational skills in number recognition, counting, and shapes and patterns. The 22-item multiple-choice instrument was aligned with the study's learning domains and structured to accommodate the cognitive and accessibility needs of learners with SLDs. The same instrument was administered as both pretest and posttest to ensure consistency in measuring learning gains.

The intervention utilized NaturalReader AI as the TTS tool, selected for its accessibility and compatibility with classroom devices. The application converted written mathematical content into audio, enabling learners to process instructions and problem statements through multimodal input. This aligns with assistive technology principles and Universal Design for Learning (UDL), as it reduces decoding barriers and supports comprehension. The standardized use of TTS across instructional sessions ensured uniformity in intervention delivery and strengthened internal validity.

Procedure

The study followed a structured three-phase procedure: preparation, intervention, and assessment. Ethical and administrative approvals were secured prior to implementation. Participants were recruited through coordination with school personnel, and informed consent and assent were obtained.

During the baseline phase, both groups completed a pretest to establish initial performance levels. This was followed by a four-week intervention period in which the experimental group received TTS-supported instruction, while the control group received conventional teaching. Instructional content, duration, and learning objectives were held constant across groups to control extraneous variables. Fidelity of implementation was monitored through observation and checklists to ensure consistency.

Post-intervention, both groups completed the same assessment to measure learning gains. Data collection procedures were designed to minimize disruption to regular instruction while maintaining methodological rigor. Confidentiality and data security were upheld throughout the process, and all results were reported in aggregate form.

Data Analysis

The study employed both descriptive and inferential statistics to analyze learners' performance. Descriptive statistics, including mean and standard deviation, were used to summarize pretest and posttest scores, providing an overview of performance levels and variability across groups.

Paired samples t-tests were conducted to examine within-group differences between pretest and posttest scores, determining whether each instructional approach produced significant learning gains. To compare posttest outcomes between groups while controlling for baseline differences, Analysis of Covariance (ANCOVA) was applied, thereby enhancing the validity of comparisons in the quasi-experimental design.

Effect sizes, including Cohen's d and partial eta squared (η^2), were computed to assess the magnitude of observed differences, ensuring that findings were interpreted beyond statistical significance. All analyses were conducted at a 0.05 level of significance, providing a robust and comprehensive evaluation of the intervention's effectiveness.

Ethical Considerations

This study adhered to established ethical standards for research involving human participants, particularly minors and learners with disabilities. Ethical clearance was obtained from the institutional research ethics committee, and permissions were secured from relevant school authorities prior to data collection.

Participation was voluntary, with informed consent obtained from parents or guardians and assent from learners. Participants were fully informed of the study's purpose, procedures, potential risks, and benefits, as well as their right to withdraw at any time without penalty. Measures were in place to minimize potential discomfort, including limiting test duration and allowing breaks during sessions.

Confidentiality and data privacy were strictly maintained through the use of anonymized codes and secure data storage systems. All data were used solely for research purposes and reported in aggregate form. The study ensured transparency, integrity, and respect for participants, with no conflicts of interest declared and no disruption to mandated educational services.

Results and Discussion

This section presents and interprets the data gathered from the study participants. Statistical tools such as the mean, standard deviation, paired samples t-test, and analysis of covariance (ANCOVA) were used to examine learners' performance and group differences. The section explains how Text-to-Speech (TTS) technology influenced the basic math concepts performance of learners with Specific Learning Disabilities compared to conventional instruction.

What is the level of basic math concepts performance of the learners with specific learning disabilities before and after the text-to-speech (TTS) technology intervention?

Table 1. *Level of Basic Math Concepts Performance of the Learners with Specific Learning Disabilities Before and After the Text-To-Speech (TTS) Technology Intervention*

Type of Test	*N*	*Mean*	*SD*	*Description*	*Interpretation*
Pretest	10	12.50	2.36	Fair	Shows limited understanding; frequent errors observed
Posttest	10	18.70	1.94	Excellent	Demonstrates complete and accurate understanding; solves all problems correctly

Legend: Range—18–22.00: Excellent (Demonstrates complete and accurate understanding; solves all problems correctly); 13–17.99: Good (Demonstrates partial understanding; some errors but grasps key concepts); 8–12.99: Fair (Shows limited understanding; frequent errors observed); 0–7.99: Poor (Demonstrates little to no understanding; unable to solve problems).

As shown in Table 1, learners with specific learning disabilities obtained a mean pretest score of 12.50 (SD = 2.36), categorized as Fair. This indicates that prior to the intervention, students had a limited understanding of basic math concepts and often committed frequent errors when solving problems. During pretesting, several learners finished answering too quickly without fully reading the items. Some appeared restless and expressed difficulty with longer worded questions, even saying statements such as "it's too hard."

These behaviors reflected their struggles with decoding and sustaining attention during text-based tasks.

After the implementation of the Text-to-Speech (TTS) technology, the posttest mean score significantly increased to 18.70 (SD = 1.94), which falls under the Excellent category. During the intervention, noticeable behavioral and cognitive improvements were observed. Students appeared more relaxed, attentive, and confident. They listened carefully to the text being read aloud, followed along with greater comprehension, and were more engaged in answering each question. The audio support provided by TTS appeared to reduce their anxiety toward reading-heavy items and allowed them to focus more on understanding mathematical content.

These findings are supported by previous research showing that text-to-speech (TTS) and other assistive technologies improve academic performance and comprehension among learners with specific learning disabilities. Bouck and Long (2021) emphasized that TTS helps students overcome reading barriers by converting text into auditory input, promoting task completion and understanding. Likewise, Cullen et al. (2019) found that TTS increases access to grade-level materials and fosters greater independence. Knoop-van Campen et al. (2020) confirmed that audio support allows learners to focus on meaning rather than decoding text, improving retention and performance. Similarly, Sulaimon and Schaefer (2023) reported that consistent TTS use enhances comprehension and engagement across subjects. In line with these, Stultz (2017) noted that computer-assisted math instruction with auditory feedback strengthens fluency and problem-solving skills. Collectively, these studies affirm the present result showing that TTS effectively enhanced learners' understanding of basic math concepts, as reflected in the posttest improvement from 12.50 (Fair) to 18.70 (Excellent).

What is the level of basic math concepts performance of the learners with specific learning disabilities before and after the conventional strategies intervention?

Table 2. *Level of Basic Math Concepts Performance Of The Learners with Specific Learning Disabilities Before and After the Conventional Strategies Intervention*

Type of Test	*N*	*Mean*	*SD*	*Description*	*Interpretation*
Pretest	10	7.90	2.88	Poor	Shows limited understanding; frequent errors observed
Posttest	10	8.60	2.79	Fair	Shows limited understanding; frequent errors observed

Legend: Range—18–22.00: Excellent (Demonstrates complete and accurate understanding; solves all problems correctly); 13–17.99: Good (Demonstrates partial understanding; some errors but grasps key concepts); 8–12.99: Fair (Shows limited understanding; frequent errors observed); 0–7.99: Poor (Demonstrates little to no understanding; unable to solve problems).

As shown in Table 2, learners in the control group obtained a mean pretest score of 7.90 (SD = 2.88), interpreted as Poor. Before the intervention, several learners exhibited clear signs of struggle. Many appeared restless, fidgety, and easily frustrated while answering the pretest. Some frowned, sighed, or stopped midway, expressing that the test felt "too long." Others frequently checked the time, demonstrating limited persistence and low engagement in completing the task. These behaviors indicated both academic and emotional challenges, particularly in sustaining focus and coping with written mathematical tasks without additional support.

After four weeks of instruction using conventional methods, the group's posttest mean score slightly increased to 8.60 (SD = 2.79), which falls under the Fair category. Although the students appeared more confident during the posttest, many still displayed difficulty comprehending the worded problems. Several mentioned that they could recall the visual illustrations used in lessons, but not the accompanying questions. A few expressed frustration, saying that "the words were too hard," which suggested that decoding and comprehension barriers persisted despite repeated practice. Observable signs of confusion and disengagement were still present, including hesitant responses and prolonged pauses before answering.

During the intervention, conventional instruction followed a teacher-directed, print-based approach without the use of assistive or audio-supported technology. Lessons were delivered using an I Do–We Do–You Do format, beginning with explicit teacher explanation and modeling of basic math concepts through the whiteboard, printed worksheets, number charts, and visual illustrations. Learners engaged in guided practice with verbal feedback and completed independent paper-based tasks that required reading and interpreting instructions on their own. Instruction relied on repetition, teacher explanation, and independent seatwork, reflecting standard elementary mathematics practices.

These classroom observations align with prior studies emphasizing the limitations of conventional instruction for students with learning disabilities. The Institute of Education Sciences (2021) reported that systematic and explicit instruction yields stronger outcomes for students struggling in mathematics compared to traditional teaching approaches. Similarly, Stockard et al. (2018) found that Direct or Explicit Instruction produces significantly higher achievement than standard classroom methods. In the current study, the control group's reliance on teacher-directed, text-heavy activities without assistive supports mirrored these traditional practices, explaining the minimal growth observed.

Powell, Bouck, and Sutherland (2023) highlighted that structured modeling, guided practice, and cumulative review are critical for learners with disabilities—components often absent in routine classroom instruction. This observation was evident during the intervention, where the control group required repeated reminders and clarifications but still struggled to apply learned strategies independently. Consistent with Powell, McCoy, and Richman (2022), the findings suggest that individualized, data-based instruction is more effective than uniform, whole-class methods, particularly for students needing targeted scaffolding.

Moreover, Kim and Xin (2022) and Stultz (2017) demonstrated that integrating digital and interactive tools enhances comprehension, problem-solving accuracy, and conceptual reasoning among learners with disabilities. In the present study, digital and interactive tools were operationalized through the use of the Naturalreader AI text-to-speech application in the experimental group. Naturalreader AI functioned as an audio-supported digital tool that read aloud mathematical instructions, word problems, and assessment items while students simultaneously viewed the on-screen text. This interactive feature allowed learners to pause, replay, and control the pace of instruction, thereby reducing decoding demands and supporting comprehension during mathematics tasks. The researcher observed that the absence of such supports in the control group contributed to persistent decoding difficulties and low engagement. Learners often appeared disengaged when reading complex word problems independently, confirming that conventional print-based instruction imposed heavy cognitive demands that impeded their mathematical processing.

Collectively, these findings affirm that the learners' slight improvement from 7.90 (Poor) to 8.60 (Fair) reflected the limited impact of conventional strategies. The combination of low engagement, persistent comprehension barriers, and minimal instructional scaffolding highlighted the need for more explicit and technology-supported approaches, such as text-to-speech integration, to enhance mathematics performance and engagement among students with specific learning disabilities.

Is there a significant difference between the pretest and posttest scores within each group of participants (TTS and conventional)?

Table 3. *Significant Difference between the Students' Pretest and Posttest Scores within the Conventional Strategy Group*

Variables		*Mean*	*SD*	*T*	*P-value*	*Interpretation*
Pair 1	Pretest	7.90	2.88	-1.56	.153	Not Significant
	Posttest	8.60	2.79			

Table 3 presents the results of the paired samples t-test conducted to examine the significant difference between the pretest and posttest scores of students in the Conventional Strategy Group. The findings show that the pretest mean score was 7.90 (SD = 2.88), while the posttest mean score slightly increased to 8.60 (SD = 2.79). Despite this numerical improvement, the computed t-value of –1.56 with a p-value of .153 indicates that the difference between the two scores was not statistically significant.

This result suggests that the use of conventional teaching strategies did not bring about a meaningful improvement in the learners' performance in basic math concepts. Although a minor gain in scores was observed, the lack of statistical significance implies that traditional methods alone may not sufficiently address the learning needs of students with specific learning disabilities. Therefore, it highlights the need to explore more effective, adaptive, and technology-driven interventions, such as Text-to-Speech (TTS), to achieve significant and sustained learning progress.

The non-significant result may be attributed to the continued reliance on print-based instruction and independent reading of mathematical instructions, which placed substantial cognitive and decoding demands on learners with Specific Learning Disabilities. When students are required to decode text and process mathematical concepts simultaneously, their limited working memory capacity may be overextended, resulting in minimal learning gains. Consequently, learners may demonstrate surface-level familiarity with content without achieving measurable conceptual understanding.

Consistent with Cognitive Load Theory, instruction that does not reduce extraneous cognitive load—such as text-heavy tasks without auditory or assistive support—limits students' ability to focus on essential learning processes. In the present study, the absence of alternative modes of representation and individualized scaffolds likely constrained learners' opportunities to fully engage with and internalize mathematical concepts, contributing to the non-significant difference observed between pretest and posttest scores.

Collectively, the results indicate that maintaining the same conventional instructional approach before and after the intervention period resulted in minimal improvement for learners with Specific Learning Disabilities. The non-significant difference observed suggests that the instructional conditions experienced by the conventional strategy group did not sufficiently alter students' learning outcomes during the study.

These findings are supported by the claim of the Institute of Education Sciences (2021), which noted that conventional or undifferentiated instruction often fails to yield significant learning gains for students with math difficulties unless teaching is explicit, scaffolded, and data-driven. Similarly, Stockard et al. (2018) found that Direct or Explicit Instruction produces stronger and statistically significant outcomes than traditional methods. Powell, Bouck, and Sutherland (2023) also emphasized that explicit modeling and guided practice are essential in supporting learners with disabilities, while Powell, McCoy, and Richman (2022) highlighted that individualized, data-based adjustments are critical for measurable progress. In contrast, Kim and Xin (2022) and Stultz (2017) demonstrated that computer-assisted and technology-supported mathematics interventions significantly enhance problem-solving skills and comprehension for students with learning disabilities. The synthesis by Kim and Xin (2022) revealed that technology-based scaffolds—such as multimedia presentations, step-by-step guided prompts, and audio-visual supports—help students decode and solve mathematical word problems more effectively. These strategies promote independent learning and engagement, yielding stronger gains in both accuracy and conceptual understanding compared to conventional instruction.

Since the computed p-value (.153) was greater than 0.05, the null hypothesis (Ho_1) was not rejected. This indicated that there was no significant difference between the pretest and posttest scores of learners taught through the conventional strategy.

Table 4 shows the results of the paired samples t-test conducted to assess the significant difference between the pretest and posttest scores of students in the TTS Strategy Group. The mean score before the intervention was M=12.50 (SD = 2.88), while the mean score after the intervention substantially increased to M=18.70 (SD = 2.79). The analysis yielded a t-value of –7.61 with a p-value of .000, which is statistically significant at the .05 level. This indicates a meaningful improvement in the students' performance following the implementation of the TTS Strategy.

Table 4. *Significant Difference between the Students' Pretest and Posttest Scores within the TTS Strategy Group*

Variables		*Mean*	*SD*	*T*	*P-value*	*Interpretation*
Pair 1	Pretest	12.50	2.88	-7.61	.000	Significant
	Posttest	18.70	2.79			

The significant increase in scores demonstrates that the TTS Strategy effectively enhanced learners' understanding of basic math concepts compared to their initial performance. This finding suggests that integrating TTS as an instructional tool can be a powerful support mechanism for students with specific learning disabilities, as it provides them with more accessible and engaging learning opportunities. The results highlight the potential of TTS to address learning gaps that traditional methods may not fully overcome, making it a valuable approach in promoting academic progress and inclusivity in education.

In the present study, the Text-to-Speech (TTS) strategy was implemented through the consistent use of the Naturalreader AI application, which read aloud mathematical instructions, word problems, and assessment items while learners simultaneously viewed the written text. This audio-supported delivery reduced reading and decoding demands, allowing students to focus more on understanding mathematical concepts rather than interpreting written language. Learners were able to pause, replay, and control the pacing of the audio, which supported individualized learning and accommodated differences in processing speed. The use of TTS throughout instruction and assessment provided continuous scaffolding, contributing to improved engagement, confidence, and accuracy in completing mathematical tasks.

Together, these studies affirm the current finding that the TTS Strategy Group showed a significant improvement from 12.50 to 18.70 (p = .000), indicating that TTS effectively enhanced learners' understanding of basic math concepts by providing accessible, engaging, and auditory-supported instruction that traditional strategies often fail to achieve.

These findings are supported by the claim of Bouck and Long (2021), who emphasized that assistive technologies like text-to-speech (TTS) reduce learning barriers and improve comprehension for students with disabilities. Likewise, Cullen, Keesey, Alber-Morgan, and Wheaton (2019) found that integrating assistive technology enhances academic performance and learner independence. Knoop-van Campen, Segers, and Verhoeven (2020) further demonstrated that audio-supported instruction helps students shift cognitive effort from decoding to understanding, leading to stronger learning outcomes. Similarly, Sulaimon and Schaefer (2023) reported that consistent use of TTS promotes comprehension and retention through multimodal input, while Stultz (2017) confirmed that computer-assisted math instruction with auditory feedback improves fluency and conceptual understanding among students with learning disabilities.

Since the computed p-value (.000) was less than 0.05, the null hypothesis (Ho_1) was rejected. This meant that there was a significant difference between the pretest and posttest scores of learners taught using text-to-speech (TTS) technology, indicating its effectiveness in improving performance.

Is there a significant difference in the posttest scores between the experimental group (TTS) and the control group (conventional)?

Table 5. *Posttest Scores by Group*

Group	*M*	*SD*	*n*
Conventional Strategy	8.60	2.80	10
TTS Strategy	18.70	1.95	10
Total	13.65	5.69	20

Table 5 presents the descriptive statistics of the posttest scores of the two groups. Results indicate that students exposed to the TTS Strategy obtained a higher mean score (M = 18.70, SD = 1.95) compared to students exposed to the Conventional Strategy (M = 8.60, SD = 2.80). The overall mean score across groups was M=13.65 (SD = 5.69). These findings suggest that students who were taught using the TTS Strategy performed better in the posttest compared to those who were taught using the Conventional Strategy, implying that the TTS Strategy may be more effective in enhancing student performance.

Table 6. *ANCOVA: Tests of Between-Subjects Effects*

Source	*SS*	*df*	*MS*	*F*	*p*	*Partial η²*
Corrected Model	556.232	2	278.116	81.072	.000	.905
Intercept	63.265	1	63.265	18.442	.000	.520
Pretest	46.182	1	46.182	13.462	.002	.442
Group	144.854	1	144.854	42.226	.000	.713
Error	58.318	17	3.430			
Total	4341.000	20				
Corrected Total	614.550	19				

Note. R^2 = .905, Adjusted R^2 = .894.

Table 6 shows the results of the Analysis of Covariance (ANCOVA) conducted to compare the posttest scores of the Text-to-Speech (TTS) group and the Conventional Strategy group while controlling for pretest scores. This analysis was used to ensure that any difference in posttest performance was not simply due to students' starting levels before the intervention.

The results indicated that students' pretest scores significantly influenced their posttest performance, showing that prior knowledge played a role in learning outcomes. However, even after considering these starting differences, the instructional strategy used had a strong and significant effect on students' posttest scores.

Specifically, learners who received the Text-to-Speech (TTS) strategy achieved significantly higher adjusted posttest scores than those who received the Conventional Strategy. This means that the TTS group performed much better than the conventional group even when their initial performance levels were taken into account. These findings clearly show that Text-to-Speech technology had a strong positive impact on students' learning in basic math concepts.

Since the computed p-value (.000) was less than 0.05, the null hypothesis (Ho_2) was rejected. This signified a significant difference in posttest performance between learners exposed to TTS technology and those taught using conventional methods, favoring the TTS group.

These findings are supported by the claim of Bouck and Long (2021), who emphasized that assistive technologies like text-to-speech (TTS) improve accessibility and comprehension for students with disabilities by reducing learning barriers. Likewise, Sulaimon and Schaefer (2023) and Knoop-van Campen, Segers, and Verhoeven (2020) found that audio-supported learning strengthens comprehension, retention, and problem-solving by allowing students to focus on understanding rather than decoding text. In support, Kim and Choi (2021) found that data-based instructional models significantly enhance academic outcomes among students with learning difficulties by enabling teachers to modify instruction according to ongoing performance data. Their meta-analysis demonstrated that individualized, adaptive instruction yields strong positive effects on learning, an approach reflected in the present study's use of text-to-speech (TTS) technology. Similar to DBI, TTS provides individualized support that accommodates learners' diverse processing needs, thereby improving engagement and comprehension. Similarly, Shin et al. (2023) emphasized that technology-enhanced mathematics instruction significantly improves conceptual understanding, engagement, and achievement among students with disabilities. Their content analysis revealed that effective technology-based interventions incorporate multimodal supports such as text-to-speech, visual scaffolds, and adaptive feedback to promote accessibility and individualized learning. These findings align with the current study's results, demonstrating that text-to-speech technology supports improved performance by reducing cognitive barriers and fostering inclusive learning experiences.

Collectively, these studies affirm the current finding that the TTS Strategy Group achieved significantly higher posttest scores than the Conventional Strategy Group ($p < .001$, $\eta^2 = .713$), demonstrating that TTS is a more effective, inclusive, and adaptive instructional approach for enhancing mathematical understanding and performance among learners with specific learning disabilities.

Conclusions

This study highlights the instructional value of Text-to-Speech (TTS) technology as an effective support for improving mathematics learning among students with Specific Learning Disabilities (SLDs). By converting written mathematical instructions and word problems into auditory input, TTS reduces decoding demands and enables learners to access content more efficiently. This enhanced accessibility allows students to engage more confidently with mathematical tasks, thereby supporting improved comprehension and participation in learning activities.

The findings further demonstrate that TTS functions as a meaningful assistive intervention that promotes inclusive education by addressing language-related barriers in mathematics. By shifting learners' cognitive focus from reading to problem-solving, TTS facilitates deeper engagement with mathematical concepts. As such, the integration of TTS aligns with inclusive and equitable teaching practices, ensuring that learners with SLDs are provided with appropriate support to achieve meaningful academic progress.

Overall, the study affirms the potential of TTS technology to enhance instructional delivery and learning experiences in mathematics. When implemented systematically, TTS contributes to improved engagement, comprehension, and learning outcomes, particularly in resource-room and inclusive classroom settings. These findings reinforce the role of assistive technologies as essential tools in advancing differentiated instruction and supporting diverse learner needs.

In light of these findings, it is recommended that policymakers and educational leaders prioritize the integration of assistive technologies within instructional frameworks. This includes establishing policies that support funding, infrastructure development, and capacity-building initiatives for TTS implementation. School administrators and technology units should ensure the availability of appropriate digital tools and provide continuous technical and pedagogical support. Teachers and special education providers are encouraged to incorporate TTS into instructional planning, align its use with individualized education goals, and adopt strategies that reduce cognitive overload and enhance student engagement.

Finally, teacher education institutions and future educators should strengthen competencies in assistive technology integration to support inclusive teaching practices. Students with SLDs should be encouraged to use TTS tools to foster independence and confidence in learning. Future research may extend this work by examining TTS across different contexts, integrating it with other digital interventions, and employing longitudinal or mixed-method designs to better understand its sustained impact on academic performance and learner development.

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