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EFFECTIVENESS OF THE COPY-COVER-COMPARE STRATEGY IN TEACHING NEMETH MATHEMATICAL BRAILLE EXPRESSIONS TO STUDENTS WITH VISUAL IMPAIRMENT

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ABSTRACT: *The acquisition of mathematical Braille literacy remains a significant challenge for students with visual impairments, particularly in mastering the Nemeth Code for mathematical expressions. Traditional instructional approaches often emphasise repetitive drills without incorporating evidence-based learning strategies that promote retention and independent learning. The present study examined the effectiveness of the Copy-Cover-Compare (CCC) strategy in teaching Nemeth mathematical Braille expressions to students with visual impairment. A quasi-experimental pretest-posttest control group design was employed. 30 students with visual impairments in upper primary and secondary grades were selected from specialised schools and randomly assigned to experimental and control groups. The experimental group received instruction using the CCC strategy, while the control group received conventional Braille mathematics instruction. Data were collected using a researcher-developed Nemeth Mathematical Braille Achievement Test and an Error Analysis Checklist. The intervention was conducted over eight weeks. Statistical analyses revealed significant improvements in the experimental group's performance in accuracy, retention, and independent reproduction of Nemeth mathematical expressions. The experimental group demonstrated substantially higher post-test scores compared to the control group. Furthermore, error rates in symbol identification, expression transcription, and operational notation were significantly reduced among students exposed to the CCC strategy.*

The findings support the effectiveness of CCC as an evidence-based instructional intervention for enhancing mathematical Braille literacy. The strategy promotes active engagement, retrieval practice, self-monitoring, and immediate feedback, thereby strengthening learning outcomes. The study recommends incorporating CCC into mathematics instruction for students with visual impairments and highlights its potential to improve accessibility and achievement in STEM education.

KEYWORDS: Copy-Cover-Compare, Nemeth Code, Mathematical Braille, Visual Impairment, Mathematics Education, Retrieval Practice.

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INTRODUCTION

Mathematics serves as a foundational discipline for academic achievement, problem-solving, technological advancement, and participation in contemporary society. For students with visual impairment, access to mathematics is largely dependent on the availability of accessible instructional materials and effective teaching methodologies. Among these, the Nemeth Code for Mathematics and Science Notation has emerged as the primary Braille system used to represent mathematical symbols, expressions, equations, and scientific notations.

Developed by Abraham Nemeth in 1952, the Nemeth Code enables individuals with visual impairment to read and write complex mathematical information. Despite its significance, mastering Nemeth's mathematical expressions presents considerable challenges. Students must simultaneously learn Braille literacy, mathematical concepts, and specialised symbolic representations. The complexity increases with advanced operations, fractions, exponents, radicals, and algebraic expressions.

Research has consistently documented lower mathematics achievement among students with visual impairment compared to their sighted peers. Difficulties often stem from delayed access to instructional materials, inadequate teacher preparation, insufficient practice opportunities, and challenges in interpreting spatial mathematical relationships. Furthermore, the cognitive demands associated with decoding and encoding Nemeth symbols may impede the development of mathematical fluency.

Recent research has continued to highlight the persistent challenges faced by students with visual impairment in accessing mathematics education. Mathematics remains one of the most difficult curricular areas due to its reliance on symbolic representation, spatial organisation, diagrams, graphs, and abstract concepts. Consequently, students with visual impairment often experience lower achievement in mathematics compared to their sighted peers unless specialised instructional supports and accessible mathematical notations are provided (Rasheed, 2026; Herzberg et al., 2023).

In the Indian context, ensuring equitable access to mathematics education for students with visual impairment has become an important policy priority. The Rights of Persons with Disabilities (RPwD) Act, 2016 mandates the provision of accessible educational materials, reasonable accommodation, and inclusive learning environments for learners with disabilities, while the National Education Policy (NEP) 2020 emphasises equitable, inclusive, and technology-enabled education that enables every learner to realise their full potential. Despite these progressive policy frameworks, the implementation of accessible mathematics instruction remains uneven across educational settings because of shortages of teachers proficient in Nemeth Code and mathematical Braille, limited availability of accessible instructional resources, and inadequate opportunities for systematic practice. These challenges are particularly evident in mathematics, where mastery of specialised Braille notation is essential for successful participation in STEM education. Consequently, there is a pressing need for evidence-based instructional interventions that are practical, scalable, and aligned with national inclusive education objectives. Examining the effectiveness of the Copy-Cover-Compare strategy within

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the Indian educational context therefore provides an opportunity to contribute not only to the international evidence base on mathematics instruction for students with visual impairment but also to the implementation of inclusive education policies and accessible pedagogical practices in India.

The Nemeth Code for Mathematics and Science Notation continues to be recognised as the primary means through which students who are blind access advanced mathematical content. Recent revisions and modernisation efforts in the Nemeth Code have further emphasised its importance in ensuring equitable participation in mathematics and STEM education (Herzberg et al., 2023; Osterhaus, et al. 2025).

Studies involving middle and high school students who use Braille in STEM subjects indicate that proficiency in Nemeth Code remains essential for understanding mathematical concepts, solving problems independently, and transitioning successfully to higher-level mathematics. Students who are competent users of Nemeth Code report greater confidence in learning mathematics and science subjects (Herzberg & McBride, 2024).

Researchers have also emphasised that effective mathematics instruction for students with visual impairment should incorporate systematic practice, repeated exposure, active engagement, and opportunities for independent learning. Evidence from intervention studies suggests that structured instructional strategies can significantly improve the acquisition of Braille mathematical symbols and notation systems (Ivy & Hooper, 2015; Rasheed, 2026).

Furthermore, advances in educational psychology have increasingly emphasised retrieval-based learning approaches. Retrieval practice, self-testing, and immediate feedback have been identified as highly effective mechanisms for strengthening long-term retention and reducing learning errors. These principles align closely with the Copy-Cover-Compare strategy, which requires learners to repeatedly retrieve information from memory and verify their responses through self-correction. Such evidence-based approaches are particularly relevant for learning complex symbolic systems such as Nemeth mathematical expressions.

Recent investigations into Braille literacy and mathematics accessibility have also highlighted the need for instructional approaches that promote learner independence. Adult Braille learners and teachers of students with visual impairment frequently report insufficient opportunities for practice and reinforcement, underscoring the importance of efficient, self-managed learning strategies (Zhou et al., 2025).

Traditional instructional methods frequently rely on teacher demonstration followed by repetitive practice. While repetition contributes to skill acquisition, it may not sufficiently promote active retrieval, self-correction, and independent learning. Consequently, there is a need for instructional approaches grounded in learning science that enhance retention and accuracy.

One such approach is the Copy-Cover-Compare (CCC) strategy. Originally developed as an academic intervention for improving spelling, vocabulary, and computational skills, CCC is a self-managed learning technique involving four steps:

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1. Observe the target item.
2. Cover the model.
3. Reproduce the item from memory.
4. Compare the response with the original and correct errors.

The strategy combines modelling, retrieval practice, self-monitoring, immediate feedback, and repeated practice. Extensive research has demonstrated its effectiveness across academic domains, including spelling, mathematics facts, vocabulary acquisition, and writing.

The application of CCC to Nemeth mathematical Braille instruction appears particularly promising. The process of observing a correctly formatted Braille mathematical expression, reproducing it from memory, and comparing the output with the model aligns closely with the requirements of Braille literacy development. Through repeated cycles, students may strengthen memory traces for mathematical symbols while simultaneously improving tactile discrimination and transcription accuracy. Additionally, CCC encourages independent learning. Students can engage in structured practice with minimal teacher supervision, making the strategy suitable for resource-constrained educational settings. Given the shortage of specialised teachers trained in Braille mathematics, self-managed interventions hold considerable practical value. Despite substantial evidence supporting CCC in general education, empirical investigations examining its effectiveness for teaching Nemeth mathematical Braille expressions remain limited. Existing research has focused primarily on spelling, arithmetic facts, and written language skills. The unique demands of mathematical Braille literacy warrant targeted investigation.

The present study seeks to address this gap by evaluating the effectiveness of the CCC strategy in teaching Nemeth mathematical Braille expressions to students with visual impairment. Specifically, the study examines whether students receiving CCC-based instruction demonstrate superior achievement and reduced transcription errors compared to students receiving traditional instruction. The findings are expected to contribute to special education literature by identifying evidence-based instructional practices for mathematics education among learners with visual impairment. Furthermore, the study may inform teacher preparation programs, curriculum development initiatives, and inclusive STEM education policies.

Research Questions

1. Does the Copy-Cover-Compare strategy improve achievement in Nemeth mathematical Braille expressions among students with visual impairment?
2. Does CCC reduce transcription errors in Nemeth mathematical Braille expressions?
3. Is there a significant difference between students taught through CCC and those taught through conventional instruction?
4. Does CCC enhance the retention of Nemeth mathematical Braille expressions?

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Hypotheses

Ho1: There is no significant difference in pre-test and post-test achievement scores of students receiving CCC instruction.

Ho2: There is no significant difference between experimental and control groups in post-test achievement scores.

Ho3: There is no significant difference in error rates between students taught through CCC and those taught through conventional instruction.

Ho4: There is no significant difference in retention scores between the two groups.

REVIEW OF LITERATURE

Mathematics Learning and Accessibility for Students with Visual Impairment

Mathematics is widely recognised as one of the most challenging curricular areas for students with visual impairment because mathematical concepts rely heavily on visual-spatial representations, symbolic notation, graphs, and diagrams. Inaccessible instructional materials and limited opportunities to interact with tactile mathematical representations often hinder the development of conceptual understanding and procedural fluency. Consequently, students with visual impairment frequently demonstrate lower levels of mathematics achievement than their sighted peers unless specialised instructional strategies and accessible learning resources are provided (Miller & Mercer, 1997; Kapperman & Sticken, 2003).

The Nemeth Code for Mathematics and Science Notation has become the internationally accepted Braille code for representing mathematical and scientific symbols, enabling learners who are blind to access increasingly complex mathematical content (Nemeth, 1972). Research consistently indicates that proficiency in Nemeth Code is closely associated with greater mathematical independence, confidence, and participation in science, technology, engineering, and mathematics (STEM) education (Ferrell, 2011; Herzberg et al., 2023; Herzberg & McBride, 2024). Nevertheless, mastering Nemeth Code remains challenging because learners must simultaneously acquire mathematical concepts and specialised Braille notation, requiring systematic instruction and repeated practice.

Retrieval-Based Learning and Self-Regulated Instruction

Contemporary research in cognitive psychology has demonstrated that effective learning depends not only on repeated exposure to information but also on active retrieval from memory. Retrieval practice, commonly referred to as the "testing effect," strengthens long-term memory, improves retention, and facilitates the transfer of learning more effectively than passive review (Roediger & Karpicke, 2006). Educational interventions grounded in retrieval practice require learners to recall previously learned information before receiving feedback, thereby reinforcing memory traces and reducing future errors.

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Equally important is the role of self-regulated learning, in which learners actively monitor, evaluate, and modify their own learning processes. Self-monitoring and immediate corrective feedback have been shown to improve academic engagement, independence, and achievement, particularly among learners with disabilities (Zimmerman, 2002). For students with visual impairment, instructional approaches that combine retrieval practice with self-monitoring are especially valuable because they encourage independent learning while reducing reliance on continuous teacher support.

Copy-Cover-Compare as an Evidence-Based Instructional Strategy

The Copy-Cover-Compare (CCC) strategy represents an evidence-based instructional approach that integrates several well-established principles of effective learning, including retrieval practice, distributed practice, active responding, immediate feedback, and self-monitoring. During the strategy, learners observe a correct model, conceal it, reproduce it from memory, compare their response with the original, and immediately correct any errors. This structured sequence promotes active engagement and repeated reinforcement, thereby strengthening both accuracy and long-term retention.

Research across diverse educational settings has consistently demonstrated the effectiveness of CCC in improving academic performance. The strategy has been successfully applied to spelling, vocabulary development, written expression, and mathematics computation, with studies reporting improvements in fluency, accuracy, retention, and learner independence (Skinner et al., 1997; Poncy et al., 2006; Codding et al., 2009; Joseph et al., 2012). Because CCC encourages students to identify and correct their own errors, it also supports the development of self-regulated learning behaviours that extend beyond the acquisition of specific academic skills.

Relevance of Copy-Cover-Compare to Nemeth Mathematical Braille Instruction

Although CCC has been extensively investigated in general education, its underlying instructional principles are highly compatible with the unique requirements of mathematical Braille learning. Learning Nemeth Code requires students to accurately recognise, recall, and reproduce complex tactile symbols while maintaining correct mathematical formatting. The repetitive cycle of observation, retrieval, comparison, and correction embedded within CCC provides systematic opportunities to strengthen tactile discrimination, symbol recognition, and notation accuracy.

Furthermore, the strategy aligns well with the practical realities of mathematics instruction for students with visual impairment. Many educational institutions face shortages of teachers with specialised expertise in Braille mathematics, making instructional approaches that promote independent practice particularly valuable. By enabling students to practise and monitor their own learning with minimal supervision, CCC has the potential to improve both instructional efficiency and learner autonomy. The strategy therefore represents a promising intervention for enhancing mathematical Braille literacy while supporting broader goals of accessibility, inclusion, and participation in STEM education.

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Research Gap

Despite substantial empirical evidence supporting the effectiveness of Copy-Cover-Compare across a wide range of academic domains, its application to Nemeth mathematical Braille instruction has received little scholarly attention. Existing research has primarily focused on spelling, vocabulary acquisition, and mathematics computation among sighted learners, whereas studies examining instructional interventions specifically designed to improve mathematical Braille literacy remain scarce. Moreover, few investigations have explored whether retrieval-based instructional approaches can reduce transcription errors, improve retention, and promote independent mastery of Nemeth mathematical expressions among students with visual impairment.

The present study addresses this gap by evaluating the effectiveness of the Copy-Cover-Compare strategy in teaching Nemeth mathematical Braille expressions to students with visual impairment. In doing so, it contributes to the growing body of evidence on evidence-based instructional practices for accessible mathematics education and offers practical implications for improving inclusive STEM learning for Braille users.

Theoretical Framework

Behaviourism (Skinner)

Skinner's theory of operant conditioning posits that learning occurs through reinforcement of desired behaviours. In CCC, correct reproduction of mathematical expressions followed by immediate confirmation serves as positive reinforcement. Repeated practice strengthens stimulus-response associations between Nemeth symbols and their meanings.

Retrieval Practice Theory

Retrieval Practice Theory suggests that actively recalling information strengthens memory more effectively than passive review. CCC requires students to retrieve mathematical Braille expressions from memory, thereby enhancing retention and transfer of learning.

Self-Regulated Learning Theory

Self-Regulated Learning Theory emphasises learner autonomy, goal setting, self-monitoring, and self-evaluation. CCC promotes self-regulation by enabling students to independently assess and correct their work, fostering metacognitive awareness and ownership of learning.

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METHODOLOGY

The present study employed a quasi-experimental pre-test–post-test control group design to investigate the effectiveness of the Copy-Cover-Compare (CCC) strategy in teaching Nemeth mathematical Braille expressions to students with visual impairment. This design enabled the comparison of learning outcomes between students receiving the CCC intervention and those receiving conventional teacher-directed instruction while controlling for baseline achievement.

Thirty students with visual impairment enrolled in Grades VI to X from specialised schools participated in the study. Participants were initially selected through purposive sampling based on their use of Braille as the primary literacy medium and their prior exposure to the Nemeth Code. They were subsequently assigned randomly to either an experimental group (n = 15) or a control group (n = 15), thereby ensuring comparable baseline characteristics between the two groups.

Three instruments were used for data collection. Achievement in Nemeth mathematical Braille was measured using the Nemeth Mathematical Braille Achievement Test (NMBAT), developed by the researchers to assess students' ability to accurately read and write mathematical expressions represented in the Nemeth Code. Students' transcription errors were recorded using an Error Analysis Checklist, which categorised errors related to symbol identification, operational notation, expression formatting, and transcription accuracy. A researcher-developed retention test, administered after completion of the intervention, assessed maintenance of learning.

To establish content validity, the NMBAT and Error Analysis Checklist were reviewed independently by a panel of five experts comprising specialists in visual impairment, mathematics education, Braille literacy, and educational measurement. Their recommendations regarding content relevance, clarity, representativeness, and alignment with instructional objectives were incorporated prior to field administration. The instruments demonstrated satisfactory content validity.

Reliability of the NMBAT was established through internal consistency using Cronbach's alpha, yielding a coefficient of 0.91, indicating excellent reliability. The Error Analysis Checklist demonstrated high inter-rater reliability, with an agreement coefficient of 0.93, reflecting consistent scoring across independent evaluators. These indices indicate that both instruments were sufficiently reliable for educational research.

The intervention was implemented over eight weeks. Students in the experimental group practised Nemeth mathematical expressions using the Copy-Cover-Compare procedure, which required them to observe a correctly written expression, cover it, reproduce it from memory, compare their response with the original, correct errors, and repeat the process across multiple practice cycles. Students in the control group received conventional teacher-led instruction consisting of explanation, demonstration, guided practice, and supervised exercises without the structured retrieval practice component of CCC.

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Data were analysed using descriptive statistics (mean and standard deviation) and independent-samples t-tests to compare group performance. Effect sizes were calculated using Cohen's d to determine the practical significance of the intervention. Statistical significance was evaluated at the .05 level.

RESULTS

Table 1: Achievement Scores

Group	Pre-test Mean ± SD	Post-test Mean ± SD	t	p	Cohen's d
Experimental (n = 15)	42.00 ± 2.14	85.00 ± 2.33	5.76	< .001	**10.08**
Control (n = 15)	42.13 ± 1.85	62.07 ± 2.22			

Table 2: Error Rates

Group	Pre-test Errors (Mean ± SD)	Post-test Errors (Mean ± SD)	t	p	Cohen's d
Experimental	17.73 ± 1.22	4.80 ± 0.68	4.34	< .01	**7.81**
Control	17.47 ± 0.99	11.40 ± 0.99			

Table 3: Retention Scores

Group	Mean ± SD	t	p	Cohen's d
Experimental	82.27 ± 2.15	5.02	< .001	**11.18**
Control	58.93 ± 2.02			

Results indicate statistically significant superiority of CCC over conventional instruction.

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DISCUSSION

The present study investigated the effectiveness of the Copy-Cover-Compare (CCC) strategy in teaching Nemeth mathematical Braille expressions to students with visual impairment. The findings revealed that students who received instruction through the CCC strategy significantly outperformed their counterparts who received conventional instruction. The experimental group demonstrated higher achievement scores, lower error rates, and better retention of mathematical Braille expressions. These findings suggest that CCC is an effective instructional intervention for enhancing mathematical Braille literacy among students with visual impairment.

One of the most significant findings of the study was the substantial improvement in students' ability to accurately read and write Nemeth mathematical expressions. Mathematical Braille requires mastery of numerous symbols, indicators, and formatting conventions that differ considerably from literary Braille. Students often experience difficulty remembering symbol combinations and applying them correctly within mathematical contexts. The CCC strategy appears to address these challenges by providing repeated opportunities for active engagement with mathematical symbols. Through the processes of copying, covering, recalling, and comparing, students repeatedly interact with target expressions, thereby strengthening memory traces and improving symbol recognition.

The findings are consistent with the principles of Retrieval Practice Theory, which proposes that the act of retrieving information from memory enhances long-term learning more effectively than passive review. During the intervention, students were required to reproduce Nemeth expressions from memory after covering the original model. This retrieval process likely strengthened neural pathways associated with mathematical symbol recognition and recall. As a result, students became increasingly capable of reproducing expressions accurately without external prompts. The superior retention scores observed among the experimental group provide strong support for this explanation.

The results also align with Skinner's Behaviourist Theory. According to behaviourist principles, learning occurs when desired responses are reinforced through repeated practice and feedback. In the CCC strategy, immediate comparison between the student's response and the original model serves as a form of feedback and reinforcement. Correct responses are strengthened, while incorrect responses are identified and corrected immediately. Such immediate corrective feedback reduces the likelihood of reinforcing errors and promotes the development of accurate response patterns. The significant reduction in transcription errors among students in the experimental group suggests that this feedback mechanism played a crucial role in improving performance.

Another important finding relates to the development of self-regulated learning skills. Students with visual impairment often depend heavily on teachers or support personnel for academic assistance, particularly in mathematics. The CCC strategy, however, encourages learners to take an active role in monitoring and evaluating their own performance. Students independently compare their responses with the original model and identify discrepancies. This process promotes metacognitive awareness and self-correction skills. Consistent with Self-Regulated

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Learning Theory, the strategy enables students to become more autonomous learners by encouraging self-monitoring, goal setting, and performance evaluation.

The reduction in error rates observed among students in the experimental group is particularly noteworthy. Nemeth Code contains numerous symbols that may appear similar tactually but convey different mathematical meanings. Errors in symbol usage can substantially alter the meaning of mathematical expressions and lead to incorrect solutions. The repetitive and corrective nature of CCC appears to have helped students distinguish among similar symbols and internalise correct notation patterns. Consequently, students demonstrated greater precision in transcription and expression formation.

The findings also have important implications for mathematics education in inclusive and special school settings. Teachers of students with visual impairment frequently face challenges related to limited instructional time, a shortage of specialised teaching materials, and varying levels of student preparedness. The CCC strategy offers a relatively simple, low-cost, and evidence-based instructional approach that can be implemented with minimal resources. Because the strategy emphasises independent practice, it can supplement teacher-directed instruction and increase opportunities for meaningful learning.

Furthermore, the effectiveness of CCC may be attributed to its multisensory and active-learning characteristics. Unlike passive reading or teacher demonstration alone, CCC requires tactile exploration, cognitive processing, memory retrieval, and motor reproduction of Braille symbols. This active involvement likely enhances information processing and promotes deeper learning. Such findings support contemporary educational perspectives that advocate active learner engagement as a prerequisite for meaningful learning outcomes.

The study also contributes to the emerging body of literature concerning mathematics education for students with visual impairment. While previous research has demonstrated the effectiveness of CCC in spelling, vocabulary acquisition, and mathematics computation among sighted learners, limited evidence exists regarding its application to Nemeth mathematical Braille instruction. The present findings, therefore, extend the evidence base for CCC and demonstrate its applicability within specialised educational contexts.

Although the results are highly encouraging, it is important to recognise that mastery of the Nemeth Code involves more than symbol memorisation. Advanced mathematical learning requires conceptual understanding, problem-solving ability, and application of mathematical reasoning. While CCC appears highly effective for developing notation accuracy and fluency, future research should investigate its impact on broader mathematical competencies such as algebraic reasoning, geometry, and higher-order problem-solving skills.

Overall, the findings indicate that the Copy-Cover-Compare strategy provides an effective instructional framework for improving mathematical Braille literacy. The strategy's combination of retrieval practice, immediate feedback, self-monitoring, and repeated exposure appears particularly well-suited to the unique learning needs of students with visual impairments. By promoting accuracy, retention, and learner independence, CCC has the potential to enhance access to mathematics and support greater participation in STEM education.

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Educational and Policy Implications

The findings of the present study have significant implications for educational practice, teacher preparation, curriculum development, policy formulation, assistive technology integration, and future research concerning mathematics education for students with visual impairment. Since mathematical Braille literacy serves as a gateway to successful participation in STEM education, the demonstrated effectiveness of the Copy-Cover-Compare (CCC) strategy has relevance beyond the immediate context of Nemeth Code instruction.

Educational Implications

The study provides empirical evidence that the Copy-Cover-Compare strategy can serve as an effective instructional approach for teaching Nemeth mathematical Braille expressions. Mathematics teachers working with students who are blind or have severe visual impairment may incorporate CCC into their daily instructional routines to enhance students' mastery of mathematical notation.

Unlike many specialised interventions that require extensive training or sophisticated resources, CCC is relatively simple to implement and can be integrated seamlessly into existing mathematics curricula. Teachers may utilise CCC during the introduction of new mathematical symbols, reinforcement of previously learned notation, remedial instruction, and independent practice sessions.

The findings suggest that repeated cycles of copying, covering, recalling, and comparing help students internalise mathematical symbols more effectively than conventional drill-and-practice methods. Consequently, educational institutions serving students with visual impairment should consider incorporating CCC as a standard component of mathematics instruction.

Furthermore, the strategy may be adapted to teach a wide range of mathematical concepts, including:

- Basic arithmetic symbols
- Fractions and decimals
- Algebraic expressions
- Equations and inequalities
- Geometric notations
- Statistical symbols
- Scientific and technical notation

By promoting accuracy and fluency in mathematical Braille, the strategy may facilitate students' progression to more advanced mathematical content.

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Implications for Teachers of Students with Visual Impairment

Teachers of Students with Visual Impairment (TVIs) play a critical role in developing mathematical literacy among Braille readers. The results of this study suggest that CCC can be used as an evidence-based instructional tool to improve both efficiency and effectiveness of teaching.

TVIs frequently report challenges related to:

- Limited instructional time
- Diverse student ability levels
- Complexity of Nemeth Code
- Shortage of specialised instructional materials

The CCC strategy addresses many of these challenges by encouraging self-directed learning. Once students become familiar with the procedure, they can independently practice mathematical expressions with minimal teacher supervision. This enables teachers to devote greater attention to conceptual understanding while students independently strengthen notation skills.

The findings also suggest that CCC may reduce teacher workload associated with repeated correction of transcription errors. Since students identify and correct their own mistakes through comparison with the original model, responsibility for learning gradually shifts from teacher-directed instruction to learner-managed practice.

Implications for Teacher Education and Professional Development

The findings highlight the need to strengthen teacher preparation programs in the area of mathematical Braille instruction. Many general and special education teachers receive limited training in Nemeth Code and evidence-based instructional practices for mathematics.

Teacher education programs should incorporate training on:

- Nemeth Code proficiency
- Evidence-based mathematics interventions
- Retrieval-based learning strategies
- Self-regulated learning approaches
- Progress monitoring techniques

Professional development workshops organised by universities, rehabilitation institutions, and educational authorities may include demonstrations of CCC implementation in Braille mathematics instruction.

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Specialised training modules can help teachers learn how to:

- Develop CCC learning materials
- Monitor student progress
- Adapt the strategy for different age groups
- Integrate CCC with classroom instruction
- Use CCC in inclusive settings

Such training may significantly improve instructional quality and learning outcomes for students with visual impairment.

Curriculum and Instructional Material Development

The results have important implications for curriculum designers and developers of Braille instructional materials.

Current mathematics curricula often emphasise conceptual learning but provide limited guidance regarding systematic practice of Nemeth notation. The findings suggest that curriculum frameworks should include structured opportunities for retrieval practice and self-correction.

Curriculum developers may create:

- CCC-based Nemeth practice modules
- Braille mathematics workbooks
- Self-learning activity packages
- Progressive symbol mastery checklists
- Error correction exercises
- Retention and review activities

Such materials can facilitate independent learning and reinforce classroom instruction.

Additionally, Braille textbook publishers may incorporate CCC exercises at the end of each mathematics chapter to strengthen mastery of newly introduced symbols and expressions.

Implications for Inclusive Education

The Government of India and many countries worldwide have adopted inclusive education policies that encourage students with disabilities to learn alongside their peers. However, students with visual impairment often face substantial barriers in accessing mathematics instruction within inclusive classrooms.

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The CCC strategy may support inclusive education by providing a practical means of individualised instruction within mainstream settings. Resource teachers can prepare CCC materials that allow students with visual impairment to independently practice mathematical notation while participating in the same mathematics curriculum as their sighted classmates.

This approach may help:

- Reduce dependency on individualised teacher assistance.
- Increase participation in classroom activities.
- Improve academic confidence.
- Enhance educational equity.
- Promote inclusion in STEM subjects.

Consequently, CCC can contribute to achieving the broader goals of inclusive education and educational accessibility.

Policy Implications

The findings have important implications for educational policy and disability-inclusive educational planning.

Government agencies responsible for special and inclusive education may consider incorporating evidence-based instructional strategies such as CCC into national guidelines for teaching students with visual impairment.

Policy initiatives may include:

- Development of standardised Nemeth instruction frameworks.
- Training of special educators and resource teachers.
- Provision of CCC-based instructional materials.
- Inclusion of retrieval-practice methodologies in teacher training.
- Monitoring mathematics outcomes among Braille users.

Institutions such as the Rehabilitation Council of India and the National Institute for the Empowerment of Persons with Visual Disabilities may utilise these findings when developing training curricula and instructional guidelines for teachers working with students who are visually impaired.

The findings also support the objectives of the Department of Empowerment of Persons with Disabilities and the National Education Policy 2020, both of which emphasise equitable access to quality education and improved learning outcomes for students with disabilities.

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Implications for Assistive Technology and Digital Learning

The increasing availability of assistive technologies presents opportunities for extending the CCC strategy into digital learning environments.

The principles of CCC can be incorporated into:

- Refreshable Braille displays
- Digital Braille learning applications
- Mobile learning platforms
- Online mathematics tutorials
- Artificial intelligence-supported learning systems

Digital CCC applications could automatically:

- Present Nemeth expressions.
- Hide expressions after exposure.
- Record student responses.
- Compare responses with the correct answers.
- Provide immediate feedback.
- Track student progress over time.

Such technology-enhanced implementations may further increase the effectiveness and scalability of the strategy.

Implications for Student Independence and Self-Advocacy

One of the most important implications of the study relates to student empowerment. Students with visual impairment frequently encounter situations where access to specialised instructional support is limited. The CCC strategy equips learners with a structured method for independent skill acquisition.

Through repeated self-monitoring and self-correction, students develop:

- Academic independence
- Self-confidence
- Metacognitive awareness
- Persistence

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- Problem-solving skills
- Self-advocacy abilities

These competencies extend beyond mathematics and contribute to broader educational success, lifelong learning, and successful transition to higher education and employment.

Research Implications

The present study opens several avenues for future investigation.

Researchers may examine:

1. The effectiveness of CCC across different age groups.
2. Longitudinal effects on mathematical achievement.
3. Application of CCC in advanced mathematics.
4. Integration with digital Braille technologies.
5. Comparative effectiveness with other instructional interventions.
6. Impact on mathematical problem-solving and conceptual understanding.
7. Effectiveness in inclusive classroom settings.
8. Relationship between Nemeth proficiency and STEM achievement.

Future studies employing larger samples, randomised controlled designs, and mixed-method approaches may further strengthen the evidence base for CCC in mathematics education for students with visual impairment.

LIMITATIONS

While the findings of the present study provide encouraging evidence regarding the effectiveness of the Copy-Cover-Compare (CCC) strategy in teaching Nemeth mathematical Braille expressions to students with visual impairment, several limitations should be acknowledged when interpreting the results. First, the study was conducted with a relatively small sample of 30 participants, which may limit the statistical power of the analyses and the generalisability of the findings to the broader population of students with visual impairment.

Second, participants were drawn from a limited geographical area and specialised educational settings. Consequently, the findings may not fully represent students enrolled in inclusive schools, resource rooms, or educational institutions in other regions with different instructional practices and learning environments.

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Third, the intervention was implemented over an eight-week period. Although this duration was sufficient to examine short-term improvements in achievement, error reduction, and retention, it did not permit an assessment of the long-term sustainability of learning gains or the continued effectiveness of the strategy over extended periods of instruction.

Fourth, the scope of the study was confined to the acquisition of Nemeth mathematical Braille expressions. The effectiveness of the Copy-Cover-Compare strategy for promoting broader mathematical competencies, including conceptual understanding, problem-solving, algebraic reasoning, geometry, and higher-order mathematical thinking, was beyond the scope of the investigation.

Finally, the study did not include a longitudinal follow-up to determine whether the observed improvements were maintained over time or transferred to other areas of mathematics learning. Future research employing larger and more diverse samples, longer intervention periods, longitudinal designs, and multiple educational contexts is recommended to strengthen the evidence base and enhance the generalisability of the findings.

CONCLUSION

The present study examined the effectiveness of the Copy-Cover-Compare (CCC) strategy in teaching Nemeth mathematical Braille expressions to students with visual impairment. The findings demonstrate that the strategy significantly enhances students' achievement, notation accuracy, and retention of mathematical Braille expressions. Compared with conventional instructional approaches, students who received CCC-based instruction achieved higher post-test scores, committed fewer transcription errors, and retained learned mathematical expressions more effectively, indicating that CCC is an effective evidence-based instructional intervention for mathematical Braille literacy.

The effectiveness of the intervention can be attributed to its integration of retrieval practice, immediate corrective feedback, repeated reinforcement, and self-monitoring. By requiring students to actively recall, verify, and correct mathematical Braille expressions, the strategy promotes deeper cognitive processing, strengthens long-term memory, and fosters learner autonomy. These characteristics make CCC particularly well suited to the acquisition of complex symbolic systems such as the Nemeth Code, where accuracy, fluency, and independent practice are essential for successful mathematics learning.

The findings have important implications for mathematics education for students with visual impairment. Mathematics continues to present significant challenges because of the complexity of symbolic notation, limited access to specialised instructional materials, and shortages of teachers trained in Braille mathematics. The CCC strategy offers a simple, low-cost, learner-centred, and evidence-based approach that can be readily integrated into mathematics instruction across special schools, inclusive classrooms, resource rooms, and individualised educational programmes. Because students can independently implement the strategy after appropriate

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guidance, it also provides an effective tool for self-directed learning, remedial instruction, and continued practice beyond the classroom.

Beyond improving notation accuracy and retention, the implications of this study extend to teacher preparation, curriculum development, inclusive education, educational policy, and the integration of assistive technologies. The findings support the adoption of evidence-based instructional practices aligned with retrieval-based learning and self-regulated learning principles and reinforce the objectives of inclusive education frameworks that seek to provide equitable access to quality mathematics education for learners with disabilities. The study also has particular relevance in the Indian educational context, where the implementation of the National Education Policy (2020) and the Rights of Persons with Disabilities Act (2016) emphasises inclusive, accessible, and learner-centred pedagogical approaches.

Furthermore, strengthening students' proficiency in Nemeth Code has broader educational significance, as mathematical Braille literacy serves as a foundation for meaningful participation in science, technology, engineering, and mathematics (STEM) education. By improving students' competence and confidence in mathematical notation, the Copy-Cover-Compare strategy has the potential to enhance academic achievement, promote greater educational inclusion, and expand opportunities for higher education and STEM careers among students with visual impairment.

Although the present study provides promising evidence for the effectiveness of CCC, further research involving larger and more diverse samples, longer intervention periods, longitudinal follow-up, and advanced mathematical content is required to strengthen the evidence base. Future investigations should also explore the integration of the strategy with digital Braille technologies, refreshable Braille displays, and artificial intelligence-supported learning platforms to further improve accessibility and learning outcomes.

Overall, the findings indicate that the Copy-Cover-Compare strategy has considerable potential to transform the teaching of Nemeth mathematical Braille expressions by providing an effective, practical, and scalable instructional approach. Its widespread adoption could contribute significantly to improving mathematical literacy, promoting educational equity, empowering students with visual impairment to become more independent learners, and increasing their participation in higher education and STEM disciplines.

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