

THE DEVELOPMENT OF PAPER GRAPH MEDIA TO REDUCE STUDENT'S MATHEMATICAL DYSGRAPHIA

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ARTICLE INFO

Article history:

Received Jan 17, 2026

Revised Jan 19, 2026

Accepted Jan 20, 2026

Keywords:

Mathematical Dysgraphia
Paper Graph
Elementary School

ABSTRACT

Students with mathematical dysgraphia frequently experience procedural errors in column-based arithmetic due to difficulties in visual-motor integration and spatial organization. These difficulties often result in misaligned digits, incorrect column placement, digit misreading, and improper regrouping, which are commonly categorized as Watson Errors. This study aims to develop Papergraph media as a visual structural learning medium to reduce mathematical errors in students with mathematical dysgraphia. This study employed a Research and Development (R&D) approach using the ADDIE model, consisting of analysis, design, development, implementation, and evaluation stages. The media were developed based on a needs analysis focusing on students' visual-motor characteristics and common procedural error patterns in arithmetic operations. Papergraph was designed as a grid-based medium to support accurate digit placement, place-value alignment, and vertical operational structure. The implementation of the developed media was evaluated using a Single Subject Research (SSR) design with an A-B-A pattern involving a fourth-grade elementary school student identified as having characteristics of mathematical dysgraphia. Data were collected through repeated measurement of arithmetic performance and analysis of Watson-type errors across baseline, intervention, and withdrawal phases. The results showed a significant reduction in mathematical errors during the intervention phase, particularly in digit misreading, column misplacement, incorrect digit combination, and regrouping errors. Performance improvements were maintained during the baseline-2 phase, indicating the internalization of spatial organization strategies facilitated by the Papergraph media. In conclusion, Papergraph demonstrates strong potential as an effective visual-structural learning medium to improve procedural accuracy and reduce Watson Errors in students with mathematical dysgraphia.

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How to Cite:

Amarulloh, S. I., Lestari, P., & Yulianto, E. (2026). The Development of Paper Graph Media to Reduce Students' Mathematical Dysgraphia. *JIMML*, 9(1), 177-190.

INTRODUCTION

Watson Error is one of the most frequently occurring forms of procedural error among students when solving column-based arithmetic operations, particularly in children with visual–motor impairments such as dysgraphia. Watson Error is characterized by misreading digits, incorrect column placement, improper grouping of unrelated numbers, and skipping algorithmic steps during problem solving (Watson, 1980; Clements & Ellerton, 2018). These errors do not stem from a lack of conceptual understanding but rather from an inability to maintain spatial structure throughout the calculation process (Barnes & Smiley, 2020). Therefore, Watson Error is closely associated with visual organization, symbol stability, and fine motor control.

Dysgraphia, as a neurological disorder, affects writing ability, symbol accuracy, and spatial organization (Berninger & Richards, 2011). Children with dysgraphia experience difficulties in maintaining digit alignment, organizing columns consistently, and preserving stable numerical forms (Rosenblum, 2016). As a result, they are particularly vulnerable to Watson Error. According to Meltzer (2018), weaknesses in visual–motor coordination hinder individuals' ability to integrate written information with mathematical cognitive processes that require precision. In the context of arithmetic operations, students with dysgraphia often exhibit error patterns such as misaligned columns, digit misreading, irregular regrouping, and incorrect digit combination (Pramuditya & Kartini, 2019; Fuchs et al., 2020).

These errors are further exacerbated by high working memory demands. Sweller's (1988) cognitive load theory states that tasks involving complex spatial components increase extraneous cognitive load, especially for students with visual–motor difficulties. When attention must be divided between organizing digits and executing algorithmic steps, the likelihood of Watson Error increases substantially (Paas & Ayres, 2014). Lee and Al Otaiba (2019) emphasize that students with writing disorders require explicit visual support to maintain consistency in the form and position of mathematical symbols.

In the context of elementary mathematics education, the need for such visual support is particularly critical. The National Mathematics Advisory Panel (2008) highlighted that clear visual structure enhances procedural stability and reduces errors in basic operations. Consequently, numerous studies have recommended the use of grid-based media to improve spatial organization (Rahayu & Fadillah, 2021; Jones & Dyson, 2019). Grids or paper graph tools serve as simple yet effective aids in helping students maintain column positions, align digits, and understand vertical representations in arithmetic operations (Kim & Lambert, 2020).

Papergraph functions as a visual anchor that reduces working memory load by providing clear spatial boundaries (Sweller, 1988; Van Merriënboer & Kirschner, 2017). When numerical organization is automatically supported by the grid, students can allocate more cognitive resources to processing algorithmic steps accurately. Furthermore, grid-based learning aligns with the principles of Universal Design for Learning (Meyer, Rose, & Gordon, 2014), which emphasize the importance of varied visual representations to support diverse learning needs.

Previous research has demonstrated that the use of grids can reduce procedural error rates among students with mathematical learning difficulties (Rosenblum & Livneh-Zirinski, 2018; Bryant et al., 2015). Box-based media help students develop systematic digit alignment habits, thereby reducing the risk of Watson Error, particularly errors related to regrouping and vertical alignment (Cohen, 2020). Moreover, repeated use of grids can facilitate the formation of internalized spatial schemas, allowing learned strategies to persist even after the media is no longer used (Newell & Rosenbloom, 1981; Siegler, 2017).

For students with dysgraphia, Papergraph serves not only as a visual aid but also as scaffolding that enables predictable numerical organization (Vaughn & Bos, 2020). This structured support

provides spatial clarity, thereby reducing digit misreading, column misplacement, and incorrect digit combination—three primary indicators of Watson Error. In elementary education, such support is essential, as column-based arithmetic operations form the foundation for more advanced mathematical learning (Kilpatrick, Swafford, & Findell, 2001).

Based on these findings, Watson Error should not be viewed merely as a procedural issue but as a manifestation of difficulties in organizing spatial information, which are strongly influenced by dysgraphia. Papergraph, as a simple instructional medium, holds strong potential for reducing Watson Error by providing structured visual support that facilitates the development of procedural organization.

One medium that addresses this need is Papergraph, a grid-based instructional tool designed to help students place digits and mathematical symbols in an orderly manner. Papergraph provides clear visual boundaries for each place value, thereby supporting digit alignment and the vertical structure of arithmetic operations. Through the use of this medium, students are expected to develop more stable and consistent spatial organization patterns. Accordingly, this study focuses on the development of Papergraph as a visual-structural learning medium and its implementation in mathematics instruction to reduce mathematical errors among elementary school students with mathematical dysgraphia.

METHOD

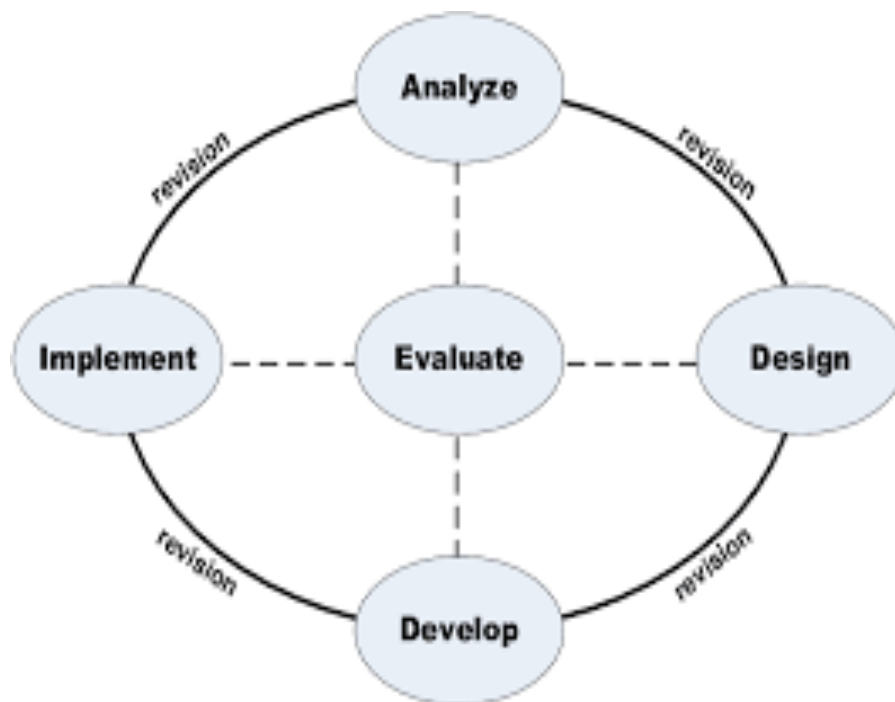


Figure 1. ADDIE Research Model

This study employed a Research and Development (R&D) approach using the ADDIE model, which consists of the stages of Analysis, Design, Development, Implementation, and Evaluation. The ADDIE model was selected because it provides a systematic and learner-centered framework for instructional media development while allowing continuous evaluation of effectiveness. In this study, ADDIE was used to ensure that the developed Papergraph media was aligned with the characteristics of students with mathematical dysgraphia and effectively addressed spatial and procedural difficulties in column-based arithmetic operations. The analysis stage focused on identifying students' learning needs, learner characteristics, and dominant types of mathematical errors. This stage was conducted through classroom observations and analysis of students' written work on addition and subtraction tasks. The

analysis revealed that the primary difficulties were not related to conceptual understanding, but rather to visual–motor and spatial organization problems, such as digit misalignment, incorrect place-value positioning, digit misreading, and irregular regrouping, which are commonly classified as Watson-type errors. These findings served as the basis for determining the design specifications of the Papergraph media.

Based on the results of the analysis, the design stage emphasized planning Papergraph as a visual–structural medium in the form of grid-based worksheets. The grid structure was designed to provide clear visual boundaries for each digit and place-value column, thereby supporting orderly number writing and reducing spatial errors. Usage procedures and learning tasks were designed progressively, starting from basic number writing activities to column-based arithmetic operations. At this stage, research instruments such as arithmetic worksheets, Watson Error observation sheets, and performance recording formats were also prepared. During the development stage, the Papergraph media was produced according to the predetermined design specifications, with particular attention to grid size, spacing, and visual clarity. The media and research instruments were reviewed and refined to ensure alignment with instructional objectives and learner characteristics. This stage ensured that the Papergraph media was ready for instructional implementation.

The implementation stage applied the developed Papergraph media using a Single Subject Research (SSR) design with an A–B–A pattern. The research subject was a fourth-grade elementary school student identified as having characteristics of mathematical dysgraphia. Subject identification was based on classroom observation, academic task analysis, teacher recommendations, and a researcher-developed mathematical dysgraphia detection instrument validated by experts. The study consisted of three phases: Baseline-1 (A1), Intervention (B), and Baseline-2 (A2), conducted over 18 sessions under controlled instructional conditions. The evaluation stage assessed the effectiveness of the Papergraph media through visual graph analysis, which is commonly used in SSR designs. Data analysis focused on trend direction, level changes between phases, data stability, and performance comparisons across conditions. The reduction of Watson-type mathematical errors during the intervention phase and the maintenance of performance during the baseline-2 phase were used as indicators of the effectiveness of the developed media.

RESULTS AND DISCUSSION

Results

This section presents a comprehensive analysis of the empirical findings obtained from the implementation of Papergraph media in reducing Watson-type mathematical errors in a student with mathematical dysgraphia. The data were collected using a Single Subject Research (SSR) design with an A–B–A pattern, consisting of Baseline-1 (A1), Intervention (B), and Baseline-2 (A2) phases. The results are organized systematically to address the research objective, namely to examine changes in procedural accuracy, spatial organization, and error reduction across instructional conditions. Quantitative performance data are presented through session-by-session scores, percentage levels, and descriptive statistical indicators, including trend direction, data stability, mean level, score range, level change, and overlap analysis. This structured presentation enables a clear visualization of learning progression, intervention effectiveness, and maintenance of outcomes after the withdrawal of the media.

This section presents detailed quantitative findings of the implementation of Papergraph media in reducing Watson-type mathematical errors using a Single Subject Research (SSR) A–B–A design. Results are organized by phase: Baseline-1 (A1), Intervention (B), and Baseline-2 (A2), supported by descriptive statistics and trend analysis.

Analysis in Conditions of SSR Implementation

Analysis in conditions aims to examine the characteristics of the data in each SSR phase, including condition length, directional trend, data stability, data trace, score range, and level changes. A summary of the analysis results in each condition is presented in Table 1.

Table 1. Analysis Under SSR Conditions

| Analysis Aspects | A1 (Baseline-1) | B (Intervention) | A2 (Baseline-2) |
|-------------------------|----------------------------|-----------------------------|----------------------------|
| Condition Length | 5 | 8 | 5 |
| Directional Tendency | Horizontal | Increase | Horizontal |
| Data Stability | Stable | Stable | Very stable |
| Data Trace | Horizontal | Increase | Horizontal |
| Score Range | 2.22 | 26.67 | 0 |
| Mean Level (%) | 36.89 | 88.33 | 100 |
| Level Change | 0 | 26.67 | 0 |

Based on Table 1, the Baseline-1 (A1) phase shows relatively stable data with a flat trend and a low percentage. This condition reflects the subject's initial ability before the intervention and serves as a comparative reference. In the Intervention (B) phase, there was a consistent and significant increase in the percentage score. The data trended upward with a wider score range compared to phase A1, indicating a positive response from the subject to the use of Paper Graph media.

Despite the sharp increase, the data remained stable maintained, indicating that performance changes occur consistently between sessions. Furthermore, in the Baseline-2 (A2) phase, the data showed very stable conditions at the maximum performance level (100%). The absence of a decrease in scores during this phase indicates that the skills acquired during the intervention persisted even after treatment was discontinued. Thus, the within-condition analysis demonstrated both immediate and sustained effects of the intervention.

Analysis of Inter-Conditions in SSR Implementation

In addition to the analysis of conditions, the effectiveness of SSR implementation is also strengthened through inter-condition analysis, namely a comparison of subject performance when moving from one phase to the next. The results of the inter-condition analysis are presented in Table 2.

Table 2. Analysis of SSR Conditions

| Analysis Aspects | A1 → B | B → A2 |
|--------------------------------|-----------------|----------------------|
| Number of Variables | 1 | 1 |
| Change in Directional Tendency | Flat → Up | Increase → Flat |
| Stability Changes | Stable → Stable | Stable → very stabil |
| Level Change | 35,44 | 0 |
| Overlap Percentage | 0% | 0% |

Based on Table 2, the comparison between phases A1 and B shows a clear change in direction from flat to increasing, accompanied by a change in level of +35.44. The absence of overlapping data (0%) between the two phases confirms that the increase that occurred was not a natural variation, but rather a direct result of the intervention using the Paper Graph media.

A comparison between phases B and A2 shows that subjects' performance remained high and stable even after the intervention was discontinued. The consistent 0% overlap and the absence

of a decline in scores indicate that the acquired skills have been well-internalized. This reinforces the finding that the intervention is not only temporarily effective but also has a lasting impact.

The results of the analysis within and between conditions indicate that the A1–B–A2 SSR design in this study was implemented in accordance with the methodological principles of SSR. The presence of a stable initial baseline, clear performance improvements during the intervention phase, and data stability in the final baseline phase are strong indicators that changes in the subjects' abilities are a result of the intervention provided.

Thus, the use of Paper Graph media has proven effective in improving the ability of MPG subjects in writing addition and subtraction operations and reducing Watson-type mathematical errors. The integration between quantitative data in the table and qualitative discussion strengthens the conclusion that the intervention has a direct, consistent, and lasting effect, making it worthy of being recommended as an alternative learning medium for students with similar characteristics.

Profile Watson Error on Baseline-1 (A1)

During the Baseline-1 phase, the subject consistently exhibited high frequencies of Watson-type errors across five consecutive sessions. The observed errors included digit misalignment across place-value columns, digit reversals, inconsistent placement of operational symbols, incorrect regrouping, and inappropriate combination of digits from different columns. Written outputs showed irregular spacing, overlapping digits, and unstable vertical alignment.

Table 3. Results of the Addition and Subtraction Operations Test for Students with Dysgraphia Phase Baseline-1 (A1)

| Day/Date | Session | Acquisition Score | Maximum Score | Level Percentage |
|----------------------------|---------|-------------------|---------------|------------------|
| Monday, October 6, 2025 | 1 | 17 | 45 | 37,78% |
| Tuesday, October 7, 2025 | 2 | 17 | 45 | 37,78% |
| Wednesday, October 8, 2025 | 3 | 16 | 45 | 35,56% |
| Thursday, October 9, 2025 | 4 | 16 | 45 | 35,56% |
| Saturday, October 11, 2025 | 5 | 17 | 45 | 37,78% |

To clarify the changes in the results of addition and subtraction operation skills in the following conditions: Baseline-1 (A1), the data in the table above is visualized in the following graph. This visualization aims to show the trend of the data and the level of stability of the subject's abilities.

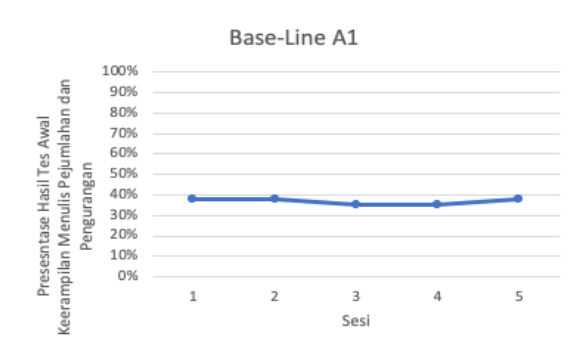


Figure 2. Score Baseline-1 (A1)

Based on the table and graph, the results of the addition and subtraction skills test for MPG subjects show a relatively stagnant score pattern, with a tendency for the graph to flatten in

each session. There was no significant improvement from the first to the fifth session. The subjects' scores were only in the range of 16 to 17 out of a maximum score of 45, with the percentage of achievement ranging from 35.56% to 37.78%. The results of the data analysis showed that the average score achieved was 36.89% with a stability range of $\pm 15\%$, namely between 31.36% and 42.42%. All data from the five measurement sessions fell within this stability range, resulting in a data stability level of 100%. This finding indicates that the subject's performance in the Baseline-1 is very stable and does not show a significant tendency to increase or decrease.

Therefore, the phase Baseline-1 (A1) was stopped in the fifth session because it had meets the criteria for data stability of more than 80% with a relatively flat graph direction. This condition indicates that the subject's ability to complete addition and subtraction operations is still in the low category and has not shown significant development. In this phase, frequent errors include misalignment of digit placement, errors in copying numbers, and inconsistent use of operation signs. This situation indicates that the subject requires special intervention that can help organize written numbers and clarify the position of place values so that the calculation process becomes more precise and systematic. Thus, the results in the phase Baseline-1 serves as an important initial basis for evaluating the effectiveness of media use Paper Graphin the next intervention phase.

Strategy Transformation through Paper graph on Intervention (B)

During the intervention phase, a progressive reduction in Watson-type errors was observed. Minor spatial and notational errors were still detected during Sessions 1–3; however, these errors decreased substantially from Session 4 onward. From Sessions 5 to 8, no observable Watson-type errors were recorded. The subject consistently demonstrated accurate digit placement, stable column alignment, and correct procedural execution.

Table 4. Results of Arithmetic Operations Phase Intervention(B)

| Day | Session | Acquisition Score | Percentage Level |
|-----------------------------|---------|-------------------|------------------|
| Monday, October 13, 2025 | 1 | 32 | 71,1% |
| Tuesday, October 14, 2025 | 2 | 40 | 88,9% |
| Wednesday, October 15, 2025 | 3 | 43 | 95,6% |
| Thursday, October 16, 2025 | 4 | 44 | 97,8% |
| Friday, October 17, 2025 | 5 | 45 | 100% |
| Monday, October 20, 2025 | 6 | 45 | 100% |
| Tuesday, October 21, 2025 | 7 | 45 | 100% |
| Wednesday, October 22, 2025 | 8 | 45 | 100% |

To clarify the changes in the results of addition and subtraction operation skills in the following conditions: *Intervensi* (B), the data in the table above is visualized in the following graph. This visualization aims to show the trend of the data and the level of stability of the subject's abilities.

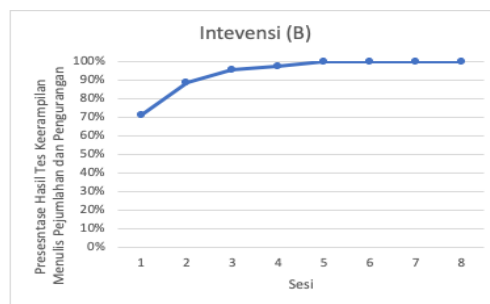


Figure 3. Intervention Score (B)

The intervention phase demonstrated a clear and substantial improvement in the subject's arithmetic performance following the introduction of Papergraph media. The level change from the last Baseline-1 session (37.78%) to the first Intervention session (71.10%) showed an immediate increase of +33.32 percentage points, indicating a strong intervention effect. The data trend during the intervention phase exhibited a consistently increasing direction from Session 1 to Session 5, followed by a stable plateau at 100% from Sessions 5 to 8. This pattern reflects rapid skill acquisition and consolidation of correct numerical writing strategies. The mean performance increased significantly to 94.19%, compared to 36.89% in Baseline-1.

Regarding stability, performance stabilized at a high level beginning in Session 5, where all subsequent scores remained within a narrow range (100%), demonstrating high data stability (>80%). No performance regression was observed during the intervention phase. In terms of overlap analysis, there was 0% overlap between Baseline-1 data (maximum = 37.78%) and Intervention data (minimum = 71.10%), confirming a strong functional relationship between the introduction of Papergraph and performance improvement.

Qualitatively, Watson-type errors—including digit reversal, column misalignment, procedural inconsistency, and place-value confusion—decreased progressively and were completely eliminated by Session 5. The subject developed consistent visual-spatial strategies, such as aligning digits within grid boundaries, verifying column positions before writing results, and maintaining structured vertical layouts. These findings indicate that Papergraph functioned effectively as an external visual organizer that supported spatial regulation and procedural accuracy.

Internality of Strategy in Baseline-2 (A2)

Following the withdrawal of Papergraph media, the subject maintained perfect performance across all five sessions. No Watson-type errors re-emerged. Digit placement remained consistent, operational symbols were written accurately, and calculation procedures were executed correctly without external visual support.

Table 5. Results of Subjects' Arithmetic Operations Test in Phase Baseline 2 (A2)

| Day/Date | Score Acquisition | Score Maximum | Level Percentage | Day/Date |
|------------------------------|-------------------|---------------|------------------|----------|
| Monday, November 10, 2025 | 1 | 45 | 45 | 100 % |
| Tuesday, November 11, 2025 | 2 | 45 | 45 | 100 % |
| Wednesday, November 12, 2025 | 3 | 45 | 45 | 100 % |
| Thursday, November 13, 2025 | 4 | 45 | 45 | 100 % |
| Friday, November 14, 2025 | 5 | 45 | 45 | 100 % |

Based on the results table Baseline-2, it is seen that the subjects were able to maintain very stable performance after the intervention using Papergraph discontinued. In five measurement sessions conducted from November 10–14, 2025, the subject obtained a perfect score, namely 45 out of 45 questions in each session with a percentage level of 100% consistently.

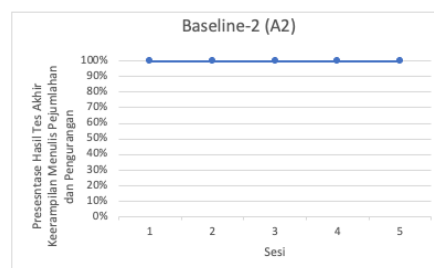


Figure 4. Score Baseline-2 (A2)

The Baseline-2 phase was conducted to evaluate the maintenance and internalization of skills after the withdrawal of Papergraph media. Across five consecutive sessions, the subject consistently achieved 100% accuracy, indicating full retention of acquired skills and absence of performance deterioration. The level change from the last Intervention session (100%) to the first Baseline-2 session (100%) showed no decline (0%), confirming strong maintenance effects. The trend direction remained stable and flat at the optimal level, with no variability across sessions.

Data stability in this phase reached 100%, as all data points fell within a narrow and identical performance range. Overlap analysis showed complete overlap between late Intervention data and Baseline-2 data; however, this overlap represents positive maintenance, not loss of treatment effect. No re-emergence of Watson-type errors was observed during Baseline-2. The subject maintained accurate digit formation, consistent column alignment, and correct procedural execution without external visual support. This indicates that the spatial scaffolding initially provided by Papergraph had been internalized into an autonomous cognitive strategy.

These findings demonstrate that the intervention effect was not temporary but transferred into independent performance, supporting the durability and generalization of the acquired numerical writing skills.

Discussions

The findings of this study demonstrate that Papergraph media effectively reduced Watson-type mathematical errors and significantly improved procedural accuracy in a student with mathematical dysgraphia. The sharp increase in performance observed during the intervention phase, followed by sustained accuracy during the withdrawal phase, confirms that structured visual scaffolding plays a critical role in supporting spatial organization, procedural consistency, and cognitive regulation in arithmetic tasks for learners with graphomotor and visual-spatial challenges.

First, the results strongly align with Kim and Lambert (2020), who reported that visual-spatial scaffolds significantly improve written mathematical accuracy among students with handwriting difficulties by reducing working memory demands and stabilizing digit alignment. In their study, structured grids functioned as external organizers that guided learners in maintaining consistent column structure and symbol placement. Similarly, the Papergraph media provided clear spatial boundaries that enabled the subject in this study to regulate digit positioning, maintain vertical alignment, and minimize column shifting errors. This finding reinforces the notion that external visual cues can compensate for underdeveloped internal spatial representations (Kim & Lambert, 2020; Alloway & Alloway, 2010).

Second, the present findings support the work of Rosenblum and Livneh-Zirinski (2018), who demonstrated that grid-based writing interventions significantly improve visual organization and reduce computational errors in elementary students with handwriting impairments. Their results indicated improvements in letter and digit spacing, alignment consistency, and reduced reversal errors. The elimination of digit misalignment, overlapping numbers, and column displacement observed in this study mirrors the improvements reported in their intervention research, suggesting that grid-based spatial constraints function as perceptual anchors that stabilize motor execution (Rosenblum & Livneh-Zirinski, 2018; Feder & Majnemer, 2007).

Third, the reduction of procedural errors during the intervention phase corresponds closely with Bryant et al. (2015), who emphasized that structured visual supports enhance procedural fluency among learners with learning disabilities. Their findings demonstrated that learners who received explicit visual scaffolding exhibited more stable algorithm execution and fewer operational sequencing errors. In the present study, consistent grid alignment supported

accurate regrouping, symbol placement, and step sequencing, thereby minimizing Watson-type procedural breakdowns. Similar conclusions have been reported by Gersten et al. (2009) and Montague (2008), who highlighted the role of visual representations in strengthening algorithmic stability and strategic self-monitoring.

Fourth, the sustained performance during the Baseline-2 phase confirms the internalization effect described by Newell and Rosenbloom (1981) and further elaborated by Siegler (2017), which explain that repeated exposure to structured patterns promotes the formation of automatic procedural schemas. Once learners repeatedly engage with stable visual structures, these patterns gradually become internalized and no longer require external mediation. The subject in this study continued to apply spatial organization strategies even after the removal of Papergraph media, indicating that the visual scaffolding had transformed into an internal cognitive schema. This finding aligns with Anderson's (1996) ACT-R theory of skill acquisition, which posits that procedural knowledge becomes automatized through repeated practice and pattern consolidation.

Fifth, the results are consistent with Mulligan and Mitchelmore (2009), who reported that explicit visual structures enhance pattern awareness and reduce spatial confusion in early numeracy learning. Their work demonstrated that structured spatial representations improve children's understanding of number relationships, place value, and grouping patterns. The checkerboard layout of Papergraph enabled the subject to visualize place-value boundaries more clearly, thereby reducing digit transposition and grouping errors. Comparable outcomes were also documented by Clements and Sarama (2011), who emphasized that spatial structuring supports conceptual grounding in numerical cognition.

Additionally, the findings provide empirical support for Sweller's (1988) cognitive load theory and subsequent refinements by Sweller, Ayres, and Kalyuga (2011). According to this framework, external supports reduce extraneous cognitive load, allowing working memory resources to be allocated more efficiently toward intrinsic task processing. In the present study, Papergraph minimized the need for the subject to simultaneously manage spatial layout, motor execution, and computational reasoning. By externalizing spatial organization, the media freed cognitive capacity for arithmetic processing, thereby increasing accuracy and consistency. Similar benefits of visual load reduction have been reported by Paas, Renkl, and Sweller (2003) and Mayer (2014).

In the specific context of dysgraphia and visual-motor impairments, the results also reinforce the findings of Lee and Al Otaiba (2019), who found that students with graphomotor difficulties benefit significantly from explicit spatial guidance during mathematical tasks. Their research highlighted that compensatory visual scaffolds reduce handwriting-related interference and support mathematical fluency. The present findings similarly demonstrate that Papergraph functioned as compensatory scaffolding, mitigating fine motor instability while strengthening procedural reliability. This conclusion is consistent with Berninger and Richards (2010), who emphasized the importance of environmental adaptations in supporting learners with transcription difficulties.

Moreover, the observed decline in Watson-type errors aligns with Watson's (1980) error classification framework, which emphasizes that procedural and spatial errors often emerge from weak perceptual-motor integration and unstable visual referencing. By stabilizing spatial references, Papergraph reduced error categories such as miscopying digits, incorrect column alignment, and symbol displacement. Comparable improvements in error reduction through visual structuring have also been reported by Ashlock (2010) and Riccomini and Witzel (2010) in mathematics intervention studies.

From a neurocognitive perspective, the findings also resonate with research on visuomotor integration and executive functioning. Studies by Carlson et al. (2004) and Diamond (2013) indicate that structured environments support inhibitory control, sustained attention, and spatial planning in learners with developmental difficulties. The structured grid likely supported attentional anchoring and reduced impulsive spatial errors, enabling the subject to sustain consistent procedural execution.

The strong maintenance effect observed during the withdrawal phase further supports the principle of learning transfer and generalization. According to Perkins and Salomon (1992), effective instructional scaffolds promote not only immediate performance gains but also long-term transfer when learners internalize the underlying structure of the task. The subject's ability to maintain perfect accuracy without external aids demonstrates successful far transfer of spatial strategies into independent problem-solving behavior.

Overall, this study contributes empirical evidence that grid-based visual media not only improve short-term procedural accuracy but also foster long-term independence in numerical organization for students with mathematical dysgraphia. By integrating spatial scaffolding, cognitive load management, procedural stabilization, and strategy internalization, Papergraph represents a pedagogically effective and theoretically grounded intervention. These findings extend prior literature by demonstrating that even single-subject interventions can produce durable cognitive restructuring when visual supports are systematically embedded and gradually withdrawn.

CONCLUSION

This study aimed to investigate whether the use of Papergraph media could reduce Watson-type mathematical errors and improve procedural accuracy in a student with mathematical dysgraphia. The findings clearly answer the research question by demonstrating that Papergraph produced a substantial and consistent improvement in arithmetic performance. During the baseline phase, the subject exhibited persistent spatial, notational, and procedural errors, reflected in low and stable accuracy levels. Following the introduction of Papergraph, performance increased sharply, Watson-type errors were progressively eliminated, and procedural accuracy reached optimal levels. Importantly, the withdrawal phase showed that the subject maintained perfect performance even without the visual aid, indicating successful internalization of spatial strategies and long-term learning transfer. These results confirm that structured visual scaffolding is highly effective in supporting numerical organization and reducing error patterns associated with dysgraphia.

From a practical perspective, the study suggests that grid-based visual media such as Papergraph can serve as an accessible instructional strategy for teachers to support students with visual-motor and writing difficulties in mathematics classrooms. The media helps stabilize digit placement, clarify place-value structure, and reduce cognitive load, thereby enabling learners to focus more effectively on computational processes rather than mechanical writing demands. For future research, several directions are recommended. First, further studies should involve larger samples and multiple participants to strengthen external validity and generalizability beyond single-subject contexts. Second, longitudinal designs are needed to examine the durability of strategy internalization over longer time intervals and across different mathematical topics, such as multiplication, division, and multi-step problem solving. Third, comparative studies should evaluate the effectiveness of Papergraph relative to other visual scaffolding interventions or digital tools to determine optimal instructional conditions. Fourth, future research may integrate qualitative measures, including student metacognitive responses and teacher implementation fidelity, to deepen understanding of how visual scaffolds influence

learning processes. Finally, neurocognitive and visual–motor assessments could be incorporated to explore individual differences in responsiveness to spatial interventions.

Overall, this study provides empirical evidence that structured visual scaffolding through Papergraph not only improves immediate procedural accuracy but also promotes sustainable independence in numerical organization for students with mathematical dysgraphia, thereby contributing to inclusive and evidence-based mathematics instruction.

ACKNOWLEDGMENTS

The author would like to express appreciation to the elementary school where the research was conducted, particularly the principal and classroom teachers, for granting permission, support, and opportunities to carry out this research. Gratitude is also conveyed to the student who participated as the research subject for their cooperation and active involvement throughout the research process. It is hoped that the findings of this study will contribute positively to the development of inclusive and adaptive mathematics learning for students with special educational needs.

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