

## Designing AI-Enhanced Interventions for Dysgraphia: An Instructional Framework Integrating Visual, Motor, and Cognitive Scaffolds

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Dysgraphia is a specific learning disability that affects handwriting, written expression, and the cognitive organisation of written tasks. Students with Dysgraphia often face overlapping challenges in visual perception, fine motor coordination, and cognitive load management—factors that are frequently overlooked in general education settings, particularly for undiagnosed learners. This paper presents a conceptual and instructional design-driven framework for developing an AI-based intervention tool that provides personalised support for students with Dysgraphia. The framework integrates three interdependent domains—visual, motor, and cognitive—guided by Gestalt Theory, Motor Learning Theory, and Scaffolding Theory. These domains are visualised as a triangular model to reflect their instructional interplay and mutual reinforcement. The proposed AI tool will incorporate adaptive features such as visual tracing, stroke sequencing, and scaffolded writing prompts, with support tailored to varying severity levels of Dysgraphia. While empirical testing is planned in a future phase of this research, this paper outlines the theoretical foundation, design principles, and inclusive pedagogy informing the intervention. By grounding artificial intelligence in evidence-based instructional strategies, this work contributes to the design of equitable, technology-enhanced learning tools for special education. Feedback from this conference will guide the next stage of prototype development and qualitative inquiry.

**Keywords:**  
Dysgraphia,  
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### Introduction

Dysgraphia is a type of specific learning disability that impacts how a person writes. It often appears as sloppy handwriting, irregular written spacing, misspelling, and production of illegible written material even though normal or above average intelligence and exposure to appropriate instruction. These problems are often result from a failure of visual processing, fine motor coordination and cognitive processes. Dysgraphia affects

7–15% of children in school (Sangalli et al., 2019) but is grossly under-identified with another clear indication being in mainstream classrooms where subtle or mild signs are too often overlooked. As a result, most of the students throughout their studies facing difficulty in writing had no help at all.

The lack of promptly identification and intervention in educational settings for Dysgraphia can result to long-term academic

disadvantage, diminished self-esteem, and disengagement from learning process. Conventional interventions, such as handwriting drills or occupational therapy, frequently do not meet the diverse and dynamic requirements of learners, especially those who do not fit into the established diagnosis systems. A rising demand exists for personalised, scalable, and adaptive support systems that are both pedagogically sound and technologically viable.

Recent advancements in artificial intelligence (AI) present promising opportunities for personalised learning and focused interventions in special education. AI-powered educational tools have demonstrated improvements in attention, writing, and language outcomes in students with learning disabilities (Almahdawi et al., 2024) (Gupta et al., 2023). Nevertheless, most existing tools focus isolated aspects of Dysgraphia such as spelling or grammar and lack an integrated instructional design that encompasses the complete spectrum of visual, motor, and cognitive difficulties.

This research proposes a theoretically grounded instructional design framework for an AI-based intervention tool that aimed to support students with Dysgraphia. Drawing from Gestalt Theory (visual processing), Motor Learning Theory (movement-based skill acquisition), and Scaffolding Theory (cognitive development), the framework is structured around three interdependent domains which are visual, motor, and cognitive. These domains are illustrated as a triangle to reflect their interrelation in writing performance and learning.

This framework seeks to evidence-based learning theories with adaptive AI capabilities in order to offer a comprehensive and practical method for assisting and helping learners with Dysgraphia. The

following section outlines the specific research objectives that guide the development of this framework.

### **Problem Statement**

Dysgraphia is one of the most frequently overlooked learning disabilities, and it significantly impacts on a student's ability to express himself in writing, often due to a combination of visual perception, fine motor, and work memory issues. It impacts basic writing abilities like letter formation, spelling, punctuation and written organisation (Sangalli et al., 2019). Even though it affects 7–15% of school-aged children many cases inevitably go undetected in regular classrooms, especially in students without a formal diagnosis (Akpan et al., 2025).

Current treatments for Dysgraphia, including handwriting practice, occupational therapy, or spelling software, typically target only one aspect of the condition. Full integration of the complex visual, motor, and cognitive requirements of writing is not supported by most digital tools. Additionally, these tools are seldom based on instructions theory or tailored to specific severities (Gupta et al., 2023). While AI has shown promise in support of learners with learning difficulties, such as personalised feedback or adaptive learning experiences (Alsolami, 2025), few tools integrate AI in a way that supports the multi-dimensional nature of Dysgraphia.

Recent review work calls for inclusive Ai-augmented educational technologies that would support neurodiverse learners with scaffolding, dynamic adaptivity, and theory-grounded design principles (Deckker & Sumanasekara, 2025), (Omar et al., 2025). However, there remains a lack in use of this vision to guide treatment approaches for students with Dysgraphia which transcend several domains and severity levels.

This research speaks to this gap by presenting a theoretical instructional design model for an AI-facilitated intervention tool that addresses both visual, motor and cognitive processes contributing to Dysgraphia. Based on learning theory, the framework is designed to inform the development of adaptive, accessible and scalable solutions applicable to children across diverse educational systems.

### Research Objectives

The main objective of this study is to design a conceptual instructional framework that guides the development of AI-based interventions for students with Dysgraphia, emphasizing on three key domains of support: visual, motor, and cognitive scaffolding. Grounded in instructional design principles and learning theories, this study aims to explore how adaptive AI tools can deliver personalised support tailored to varying severity levels of Dysgraphia.

Specifically, this study aims to:

1. To analyse the role of visual, motor, and cognitive challenges in the learning experiences of students with Dysgraphia.
2. To review existing AI-based educational interventions targeting writing or learning disabilities, with attention to their instructional design.
3. To propose an instructional design framework that integrates AI-driven scaffolds aligned to the visual, motor, and cognitive domains.
4. To explore how severity levels of Dysgraphia can moderate the application of AI-based scaffolds in instructional contexts.
5. To outline a future research and development plan for a prototype intervention tool based on the proposed framework.

### Research Questions

Based on the research objectives, the following research questions are proposed:

1. What are the specific visual, motor, and cognitive challenges experienced by students with Dysgraphia that impact their writing performance?
2. To what extent do existing AI-based interventions address the writing needs of students with Dysgraphia, and what instructional design limitations are evident?
3. How can instructional design theories (e.g., Gestalt Theory, Motor Learning Theory, and Scaffolding Theory) inform the development of an AI-based intervention framework for Dysgraphia?
4. In what ways can visual, motor, and cognitive scaffolds be integrated into an adaptive AI tool to support writing development in students with Dysgraphia?
5. How can the severity level of Dysgraphia be used to tailor the type and intensity of AI-based instructional support within the proposed framework?

### Literature Review

The purpose of this literature review was to position the study within the extant literature on Dysgraphia as well as educational interventions and AI in special education. Based on the evidence from previous studies, this section presents gaps in existing interventions and rationalizes the necessity of having an integrative instructional design framework that incorporates visual, motor, and cognitive scaffolding.

### Understanding Dysgraphia

Dysgraphia is a learning disability that affects writing, generally manifesting in the form of very sloppy handwriting, spelling problems,

and disorganised written expression. Between 7% and 15% of school children are estimated to have a writing disorder, increasingly diagnosed in mainstream classrooms and often underdiagnosed or misunderstood (Sangalli et al., 2019). Dysgraphia can either be developmental or acquired, and is associated with visual processing, fine motor skills and executive cognitive functions deficits (Fukushima et al., 2008). Only available for students with a formal diagnosis, the invisibility of Dysgraphia in these settings is a particularly pressing issue, as many students who do not have the diagnosis are left to flounder without targeted help. Failure to recognise can results in the lack of motivation and increased irritation and disengagement, and thus the importance of early intervention and holistic instructional design (Akpan et al., 2025).

### **Educational Interventions for Dysgraphia**

Conventional or Dysgraphia include occupational therapy, handwriting drills, and regimented writing practice. Even though these techniques can improve mechanical handwriting, there often remain unaddressed underlying cognitive and visual processing problems. On top of that, they are usually non-personalised, and, in some cases, they do not scale well in regular classrooms (Sangalli et al., 2019). In recent years, with the development of digital supports (spelling, grammar check), systems have tended to appear. However, many of these tools are dedicated to components of Dysgraphia only. For instance, some emphasise on legibility or spelling and exclude from their implementation motor and developmental scaffolds allowing fragmented solutions (Gupta et al., 2023). This division underscores the need for an all-encompassing paradigm involving various spheres of help, as opposed to taking Dysgraphia as a one-dimensional disorder.

### **AI-Based Interventions in Special Education**

With its personalising, adaptive, and scalable interventions, Artificial Intelligence (AI) has shown significant promise to revolutionise special education. Recent studies show that AI-based solutions are able to improve academic skills, attention control, and writing results for learning-disabled students (Alsolami, 2025) ; (Almahdawi et al., 2024). Several AI-based handwriting analysis and correction (using machine learning models) systems have been designed in the context of Dysgraphia to improve spelling, grammar, and handwriting quality (Gupta et al., 2023). Similarly, cognitive AI screening tools have been utilised for early detection of Dyslexia and Dysgraphia, supporting timely intervention (Rokade et al., 2024). Systematic reviews corroborate the function of AI in improving inclusive education, offering real-time scaffolding, and customising learning experiences to diverse needs (Hussein et al., 2025). Despite these progresses, there are still less work to bridge the gap to implement AI-based supports with visual, motor, and cognitive scaffolds altogether.

### **Instructional Scaffolding and Learning Theory**

Instructional design theory offers a strong foundation for developing AI-based interventions that are not only technologically advanced but also pedagogically effective. Scaffolding Theory, based in Vygotsky's Zone of Proximal Development, emphasises structured assistance that can be gradually diminished as learners gain independence, making it highly relevant for supporting the cognitive demands of writing (Omar et al., 2025). Gestalt Theory enhances the visual domain, highlighting how learners perceive

patterns, organise visual input, and recognise structures-skills essential for letter formation and spatial alignment. Motor Learning Theory underlies the motor domain, emphasising on repetition, feedback, and procedural skill acquisition for handwriting fluency.

Bringing these theories together, instructional design can ensure that AI-based interventions are adaptive, evidence-based, and inclusive, responding to both the complexity of Dysgraphia and the individual needs of learners.

### Conceptual Framework

The proposed model for the AI-based intervention tool for Dysgraphia is presented in this study. The approach also includes three domains of support - visual, motor, and cognitive, all of which are theoretically based and grounded in traditional learning theory, with AI serving as the adaptive scaffolding. The domains are represented as a triangle which may be interpreted as a metaphorical device for showing their relationship in relation to writing.

### Visual Domain (Gestalt Theory)

The emphasis of Gestalt Theory is on a holistic vision and our ability to interpret patterns, structures, and figure-ground

relations (Todorovic, 2008). In Dysgraphia, the difficulty in aligning space and handwriting can be alleviated through visual guidelines, arranged according to the Gestalt principles, such as writing guidance and base-plane order (Kılıç & Parsıl, 2023).

### Motor Domain (Motor Learning Theory)

Handwriting fluency is based on fine motor coordination, practice and feedback, which are principles of motor learning (Al Imam et al., 2025). Students with Dysgraphia often struggle to master stroke sequencing and motor control, all competencies that can be facilitated by AI based handwriting guidance and adaptive practice (Gupta et al., 2023).

### Cognitive Domain (Scaffolding Theory)

Writing also demands planning, memory and focus control, which can be too much to ask some students with Dysgraphia. Scaffolding Theory (Vygotsky) proposed that learners benefit from support which is systematically removed as their skills increase (Pearson & Gallagher, 1983). AI can provide scaffolded writing prompts and adaptive task decompositions to lower cognitive load and promote independence (Omar et al., 2025).

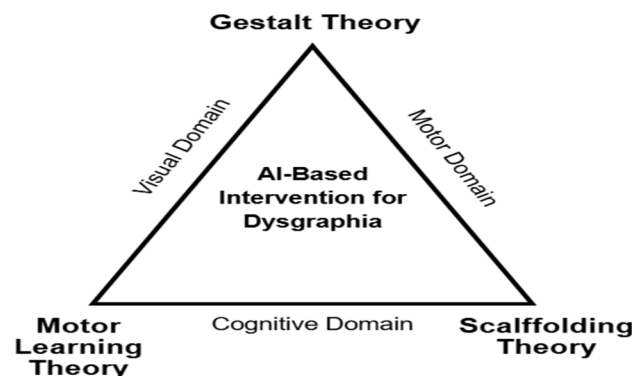


Figure 1. Conceptual framework for AI-based instructional intervention in Dysgraphia, integrating visual, motor, and cognitive scaffolds with adaptive AI support moderated by severity.



As illustrated in Figure 1, the conceptual framework positions visual, motor, and cognitive scaffolds as three interdependent domains, alongside adaptive AI support that integrates support across these areas. The triangular illustrates that writing ability in students with Dysgraphia is not influenced by a single factor, but by the dynamic interaction of visual perception, motor coordination, and cognitive processes. Each domain is based on a specific learning theory which are Gestalt Theory for visual organisation, Motor Learning Theory for fine motor development, and Scaffolding Theory for cognitive regulation, hence ensuring that the framework remains pedagogically sound. Fundamentally, AI functions as a personalised scaffolding engine, providing specific interventions such as tracing tools, stroke guidance, and scaffolded writing prompts. The severity of Dysgraphia functions as a moderating variable, allowing the system to modify the intensity and type of scaffolds, thereby providing inclusivity and differentiation for learners with mild, moderate, or severe requirements.

### Methodology

This study will adopt a mixed-methods research design, combining qualitative and quantitative approaches. Mixed methods are particularly effective in education research because they provide a comprehensive perspective on complex learning challenges, integrating the depth of qualitative inquiry with the generalisability of quantitative data (Creswell & Clark, n.d.). In the context of Dysgraphia, this design allows the study to capture both teachers' and students lived experiences and broader trends in perceptions of AI-based interventions. Participants

Two key groups will participate in the preliminary study:

Teachers – including special education teachers and mainstream classroom teachers with experience supporting students who struggle with writing.

Students – aged 8–14, with either diagnosed or suspected Dysgraphia, representing mild, moderate, and severe cases.

A purposive sampling strategy will be employed to ensure a diverse range of perspectives across different teaching and learning contexts. Such purposeful selection is often recommended in exploratory studies where depth of insight is prioritised.

### Data Collection

The study will begin with semi-structured interviews to capture the nuanced experiences of teachers and students. Semi-structured formats are particularly suited for this research as they allow flexibility while ensuring that core themes such as visual, motor, and cognitive challenges are consistently explored. Classroom observations will complement the interviews by documenting how Dysgraphia manifests during writing activities and how teachers currently scaffold support. Observational methods provide critical insight into actual classroom practices, making them invaluable in special education research. Finally, a short survey will be administered to a broader sample of teachers to capture trends in perceptions of AI-based support for Dysgraphia. This quantitative component will provide complementary evidence to validate and extend findings from the qualitative phase (Creswell & Clark, n.d.).

### Data Analysis

Qualitative data from interviews and observations will be analysed using thematic analysis, a flexible method well-suited for identifying patterns in experiences and

practices. Themes will focus on how visual, motor, and cognitive challenges affect learning and what scaffolds are most effective. Quantitative survey responses will be analysed using descriptive statistics to highlight common perceptions and areas of divergence.

### **Ethical Considerations**

This study will follow established ethical standards for educational research (ETHICAL GUIDELINES FOR EDUCATIONAL RESEARCH, 2018). Informed consent will be obtained from teachers, parents, and students. Participation will be voluntary, and anonymity will be protected. For students, interviews will use age-appropriate questioning, with sensitivity to their learning needs and emotional well-being.

### **Use of Findings**

The findings from the preliminary study will be used to refine the conceptual framework and guide the design of prototype AI features, such as tracing, stroke guidance, and scaffolded writing prompts. By combining theoretical insights with empirical evidence from teachers and students, the intervention will be both pedagogically grounded and practically relevant for inclusive classrooms.

### **Implications and Future Work**

This research enhances the theoretical understanding of technology-enhanced learning in special education by integrating Gestalt Theory, Motor Learning Theory, and Scaffolding Theory into a unified framework for Dysgraphia intervention. Although previous research has utilised these theories independently in education, there is limited study combining them to tackle the multi-dimensional issues of writing disabilities. By doing so, the suggested framework enhances

knowledge on how learning theories can be operationalised in AI-based educational design. Such integration demands for more theory-driven approaches in the use of AI in education (Zawacki-Richter et al., n.d.).

### **Practical Implications for Educators and Students**

For educators, this framework offers a structured model for identifying and supporting the visual, motor, and cognitive needs of students with Dysgraphia. By embedding AI-based scaffolds into instructional design, educators can benefit from real-time feedback, adaptive task design, and personalised learning support, which are otherwise challenging to provide consistently in mainstream classrooms. Evidence from previous studies indicates that AI tools can improve student engagement and provide differentiated instruction in inclusive environments (Bonneton-Botté et al., 2023). For students, especially those undiagnosed, the framework promises more equitable access to customised support, diminishing barriers to academic participation and achievement (Hussein et al., 2025).

### **Technological Implications**

The framework additionally aids to the design of inclusive instructional technologies. Most current digital supports for Dysgraphia are fragmented concentrating only on spelling, grammar, or handwriting mechanics (Gupta et al., 2023). In contrast, this model emphasises multi-domain integration, displaying how AI can simultaneously address visual, motor, and cognitive scaffolds in a unified system. It also highlights the significance of severity as a moderating variable, a characteristic that could inform adaptive learning algorithms capable of customising interventions in real

time. Such personalisation aligns with broader trends in AI-enhanced adaptive learning systems (Fadel et al., 2019).

### **Policy and Inclusive Education Implications**

At the policy level, this research underscores the importance of designing interventions that align with Universal Design for Learning (UDL) principles. UDL emphasises multiple means of representation, activity, and engagement, which correspond directly onto the visual, motor, and cognitive scaffolds of this framework. By integrating AI-driven scaffolding into inclusive classroom environments, policymakers and school leaders can provide equitable learning opportunities for neurodiverse students. This corresponds with international agendas advocating technology-enhanced inclusion in education.

### **Future Work**

The next stage of this research will concentrate on empirical validation and prototype development. A preliminary qualitative study, incorporating interviews and classroom observations, will enhance the framework based on stakeholder insights. The next phase will also involve the development and pilot testing of an AI-based prototype that implements the visual, motor, and cognitive scaffolds. Future studies will evaluate the effectiveness of the intervention in enhancing handwriting fluency, writing organisation, and student engagement, using both qualitative feedback and quantitative performance measures. Iterative testing will guarantee that the tool remains pedagogically valid, technologically viable, and contextually appropriate.

### **Conclusion**

Dysgraphia presents significant challenges for students, particularly in inclusive classrooms where many remain undiagnosed or insufficiently supported. Existing interventions, while valuable, are often fragmented and fail to address the interconnected visual, motor, and cognitive difficulties that underlie the condition. This paper has proposed a conceptual instructional design framework for an AI-based intervention tool that unites these three domains, grounded in Gestalt Theory, Motor Learning Theory, and Scaffolding Theory. By integrating adaptive scaffolding with AI technologies, the framework offers a pathway toward personalised, responsive, and inclusive educational support.

The contribution of this work lies in its theoretical grounding and practical orientation, providing educators, researchers, and designers with a structured model for developing multi-domain interventions. Importantly, the inclusion of severity of Dysgraphia as a moderating factor highlights the framework's potential for differentiated and equitable learning experiences.

As a work-in-progress, the framework will be refined through qualitative inquiry with teachers and students, followed by prototype development and pilot testing. These next phases will ensure that the tool remains not only technologically feasible but also pedagogically sound and aligned with the needs of diverse learners. Ultimately, this study contributes to the broader goal of advancing technology-enhanced learning for inclusion, bridging the gap between theory, design, and practice.



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