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Graphics-Based Strategy Improves Visual Thinking and Problem-Solving in Geometry

Essa Melfi Aldosari [1], *Mohammad A. Tashtoush* [2,3,*], *Amin M. Elfeky* [4], *Mohamad A. Khasawneh* [5], *Mohamed Sayed Abdellatif* [6], *and Sherif Ahmed Ibrahim* [7]

[1] Department of Curriculum and Instruction, College of Education, Prince Sattam Bin Abdulaziz University, Al-Kharj, Saudi Arabia
[2] Department of Basic Sciences, AL-Huson University College, AL-Balqa Applied University, Salt, Jordan
[3] Faculty of Education and Arts, Sohar University, Sohar, Oman
[4] Department of Mathematics, College of Science and Humanities, Prince Sattam Bin Abdulaziz University, Al-Kharj, Saudi Arabia
[5] Special Education Department, King Khalid University, Abha, Saudi Arabia
[6] Department of Psychology, College of Education, Prince Sattam Bin Abdulaziz University, Al-Kharj, Saudi Arabia
[7] Department of Educational Technology, College of Education, University of Bisha, Saudi Arabia

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Abstract: Geometry is an important applied domain of mathematics in which effective Problem Solving requires the integration of spatial relationships, geometric properties, symbolic information, and structured representations. This study investigates the application of a structured graphics-based strategy to mathematical information processing, visual-spatial reasoning, and Geometry Problem Solving among eighth-grade students with learning disabilities. Using an intact-group quasi-experimental design, 40 students enrolled in resource-room mathematics classes in Irbid, Jordan, were assigned to either a graphics-based instructional condition (n=20) or a conventional mathematics instruction condition (n=20). Over six weeks, the experimental group participated in 18 geometry lessons incorporating graphic organizers, diagrams, visual models, and structured representations of mathematical problem-solving procedures. A researcher-developed 34-item assessment was administered before and after the intervention to evaluate visual thinking and geometry problem-solving performance. The displayed post-test results showed higher mean performance for the graphics-based group in visual thinking (M=16.93, SD=2.09) and geometry problem solving (M=35.95, SD=8.25) compared with the conventional instruction group (M=11.68, SD=4.20 and M=20.53, SD=8.64). The findings suggest that structured graphical representations may facilitate the organization and interpretation of geometric information and support sequential mathematical reasoning in multistep geometry problems. From an applied mathematics perspective, the study highlights the potential of representing mathematical information through structured visual models to support the transformation of geometric data into analyzable relationships and solution procedures. However, the non-random intact-group design and the need to verify the reported inferential statistics against participant-level data require cautious interpretation. The study provides preliminary, context-specific evidence for the application of structured graphical representations in mathematics problem solving and inclusive mathematics instruction.

Keywords: Mathematical Information Processing; Geometry; Graphical Representations; Visual-Spatial Reasoning; Mathematical Problem Solving; Structured Visualization; Learning.

1 Introduction

Applied mathematics encompasses the use of mathematical concepts, representations, and reasoning processes to interpret information, analyze relationships, and solve problems arising in structured and practical contexts. Within this broad perspective, geometry represents an important domain in which mathematical information is frequently communicated through diagrams, figures, spatial configurations, symbolic notation, and relationships among measurable and non-measurable properties [1]. Solving a geometric problem therefore involves more than recalling formulas or performing calculations; it requires the effective processing, organization, representation, and transformation of mathematical information into relationships that can be analyzed and used to construct a

* Corresponding author e-mail: tashtoushzz@su.edu.om

solution [2].

Geometry provides a particularly relevant context for examining the application of mathematical representations because geometric information is inherently multidimensional. A learner may need to coordinate the properties of shapes, spatial relationships, numerical data, verbal conditions, and symbolic expressions while simultaneously determining which information is relevant to the solution [3,4]. In this sense, geometric problem solving can be viewed as a structured mathematical information-processing activity in which visual and symbolic representations serve as tools for organizing data, identifying relationships, and supporting logical reasoning. The ability to move systematically between a geometric configuration and its mathematical representation is therefore central to effective problem solving [5].

Mathematical problem solving is a fundamental process through which mathematical knowledge is applied to analyze information, identify relationships, formulate strategies, execute procedures, and evaluate solutions [6,7]. In geometry, this process often involves a sequence of interrelated operations: identifying the relevant properties of a figure, analyzing the information provided, determining the required quantity or relationship, constructing an appropriate representation, developing a solution plan, implementing mathematical procedures, and checking the resulting answer [8]. These operations reflect the applied nature of mathematical reasoning because learners must transform given information into a coherent mathematical structure that can be manipulated and evaluated [9].

Visual thinking plays an important role in this process. It refers to the ability to interpret, organize, and connect information presented through visual representations such as diagrams, geometric figures, and graphical structures [10,11]. In geometry, visual thinking enables learners to recognize shape characteristics, identify spatial relationships, compare geometric configurations, and connect visual information with mathematical properties and symbolic representations. Consequently, visual representations can function as information-processing tools that make mathematical relationships explicit and facilitate the movement from observed configurations to formal mathematical reasoning [12].

From an applied mathematics perspective, the value of a graphical representation lies not simply in its visual appearance but in its capacity to encode, organize, and communicate mathematical information. A well-constructed diagram can externalize relationships among geometric elements, allowing learners to inspect and compare information that may otherwise be difficult to coordinate mentally [13,14]. Similarly, a graphic organizer can structure the information required to solve a mathematical problem by separating the available data, the required result, the representation of the problem, the solution plan, the implementation process, and the verification stage. Such structures may support the systematic processing of mathematical information and reduce unnecessary search for relevant relationships [3, 14].

However, graphical representations are not automatically effective. Their usefulness depends on the extent to which they correspond to the mathematical structure of the problem. Excessive visual detail, decorative elements, or poorly organized information may increase the amount of irrelevant information that learners must process [5,15]. In contrast, schematic and curriculum-aligned representations may highlight essential mathematical relationships and provide a clearer pathway from information interpretation to mathematical reasoning. The present study therefore conceptualizes graphics-based instruction as the structured representation of mathematical information rather than as the use of visual materials for their own sake [2].

This distinction is particularly important in geometry problem solving among students with learning disabilities. Such learners may experience difficulties in processing abstract mathematical information, coordinating multiple pieces of information, or maintaining the sequence of operations required to solve multistep problems [16]. When a geometry problem contains spatial relationships, verbal conditions, geometric properties, and symbolic information simultaneously, the learner must integrate several sources of information before selecting an appropriate solution strategy [17,18]. Structured graphical representations may provide an external framework through which this information can be organized and related, potentially supporting the learner's transition from information interpretation to mathematical analysis and solution construction [3].

The instructional strategy examined in this study is based on the use of graphic organizers, diagrams, visual models, and structured visual problem-solving exercises [19]. These tools were designed to support a sequence of mathematical processes that begins with identifying geometric figures and their relevant features, continues through the analysis and connection of geometric relationships, and extends to representing the problem, planning a solution, implementing mathematical procedures, and checking the correctness of the result [20]. Thus, the intervention can be interpreted as an applied representation framework in which graphical structures are used to organize mathematical information and make the underlying relationships more accessible for analysis.

The theoretical rationale for this approach is consistent with cognitive load theory and perspectives on multiple representations. Geometry problems can impose substantial processing demands because learners must coordinate spatial information, verbal descriptions, mathematical symbols, and multiple solution steps [21]. A structured representation may externalize some of these relationships and reduce unnecessary visual search, thereby allowing greater attention to relevant mathematical information [18]. The proposed mechanism is therefore not that increased visual stimulation automatically improves performance, but that mathematically aligned graphical representations may facilitate the organization and processing of information required for geometric reasoning and problem solving. The present study does not directly measure cognitive load or statistically test mediation; rather, the theoretical framework provides a rationale for the design and interpretation of the intervention [19].

Within this framework, the present study examines the application of a structured graphics-based strategy to geometry learning and mathematical problem solving among eighth-grade students with learning disabilities. The study is positioned at the intersection of applied mathematics, mathematical information processing, geometric representation, and mathematics education. Its central premise is that the effectiveness of mathematical problem solving may be supported when learners are provided with structured representations that help them organize geometric information, identify mathematical relationships, and follow a logical sequence of solution processes.

1.1 Problem Statement and Research Gap

Previous research has established the importance of visual representations and visualization in mathematics learning, but the available evidence remains heterogeneous with respect to mathematical content, learner characteristics, representation formats, and instructional settings. Existing research has examined graphical and visual representations across mathematics learning contexts, including digital mathematical environments, tactile graphics, and other forms of external representation. However, these studies do not necessarily address the specific problem of how structured graphical representations can support the processing of mathematical information during multistep geometry problem solving among students with learning disabilities.

From an applied mathematics perspective, an important unresolved issue concerns the extent to which a structured graphical representation can function as an information-processing framework for mathematical problem solving. Specifically, there is limited evidence concerning whether a sequence of schematic diagrams and graphic organizers embedded in geometry instruction can assist learners in transforming mathematical information into organized representations, identifying relevant geometric relationships, constructing solution plans, implementing mathematical procedures, and verifying the resulting solutions.

The present study addresses this specific and bounded gap by examining a six-week graphics-based instructional strategy among eighth-grade students with formally identified learning disabilities in resource-room mathematics settings. The study focuses on two related outcomes: visual thinking and geometry problem solving. Visual thinking represents the learner's capacity to process and interpret geometric information, whereas geometry problem solving represents the application of that information in a structured mathematical solution process.

The study does not claim that graphical representations universally improve mathematical performance or that all visual formats are equally effective. Instead, it investigates whether a structured, mathematically aligned graphics-based approach is associated with improved performance in the specific context examined. This focus is relevant to applied mathematics because it considers how mathematical information can be represented and organized to facilitate reasoning and problem solving, while also contributing to research on inclusive mathematics education.

1.2 Study Aim, Objectives, and Research Questions

The primary aim of this study is to examine whether a six-week structured graphics-based instructional strategy is associated with improved visual-thinking and geometry problem-solving performance among eighth-grade students with learning disabilities.

The study has two objectives:
Objective 1. To compare the experimental and control groups in post-test visual-thinking performance in geometry, with the four visual-thinking subskills treated as secondary outcomes.
Objective 2. To compare the experimental and control groups in post-test geometry problem-solving performance, with the six problem-solving subskills treated as secondary outcomes.

The study addresses the following research questions:
RQ1. To what extent do the groups differ in post-test visual-thinking performance after the intervention, taking baseline performance into account where the available data permit?

RQ2. To what extent do the groups differ in post-test geometry problem-solving performance after the intervention, taking baseline performance into account where the available data?

1.3 Significance of the Study

The significance of this study is situated primarily within the application of mathematical representations and structured information processing to geometry problem solving. From an applied mathematics perspective, the study examines how graphical structures can be used to organize mathematical information and facilitate the interpretation of relationships embedded in geometric problems. This focus extends beyond the use of graphics as instructional aids by considering representations as tools for organizing mathematical data and supporting sequential reasoning.

Theoretically, the study examines a proposed pathway in which structured graphical representations make geometric relationships more explicit, reduce unnecessary information search, and support the processes of mathematical analysis and solution monitoring. Although the study does not directly measure cognitive load or test mediation, its theoretical framework provides a basis for understanding how external representations may support mathematical reasoning.

Empirically, the study contributes context-specific evidence involving eighth-grade students with learning disabilities, a population that is comparatively less visible in research on structured mathematical representations and geometry problem solving. By examining both visual thinking and geometry problem solving, the study considers the relationship between processing mathematical information and applying that information in multistep mathematical tasks.

From an instructional perspective, the intervention provides a structured sequence through which mathematical information can be processed: identifying geometric features, analyzing relationships, representing the problem, specifying requirements, planning the solution, implementing mathematical procedures, and checking the correctness of the result. This sequence provides a potentially replicable framework for applying structured representations in geometry instruction.

For inclusive mathematics education, the study also considers how structured representations may support learners who experience difficulty with abstract mathematical information and multistep reasoning. The findings may therefore inform the development of mathematics learning environments in which visual, verbal, and symbolic representations are coordinated to improve access to mathematical information and reasoning.

1.4 Scope and Delimitations

The study is limited to the application of a structured graphics-based strategy in geometry instruction and mathematical problem solving among eighth-grade students with learning disabilities. The participants were drawn from two schools in Irbid, Jordan, during the 2022–2023 academic year. The study specifically examines visual thinking and geometry problem solving and does not investigate motivation, social interaction, teacher preference, long-term retention, or transfer to unfamiliar mathematical tasks.

The findings should be interpreted within the boundaries of the mathematical domain, learner population, sample size, instructional context, and quasi-experimental design. The study is intended to provide preliminary evidence concerning the application of structured graphical representations to mathematical information processing and geometry problem solving rather than to establish universal effectiveness across mathematical domains or populations.

2 Literature Review

2.1 Graphic-Based Strategies in Mathematics Education

Graphic strategies are considered to be highly effective teaching instruments in enabling students' comprehension, organization, and synthesis of complex information. In the learning of mathematics, graphic strategies are used in illustrating relationships among concepts and procedures through the aid of graphics such as diagrams, concept maps, graphs, and graphic organizers [18]. Graphic strategies in teaching offer students the opportunity to reason in a nonlinear fashion by presenting information in a way that goes beyond the linear text-centered manner of teaching [3].

It is asserted that graphic organizers help learners to effectively distinguish key ideas, relate previous knowledge, and make sense of the relationships between mathematical ideas [13,15]. In geometry, graphic strategies specifically suit the visual and spatial characteristics of the subject matter to help learners explore ideas, properties, and relationships about shapes in organized visual representations. It has been observed to improve understanding and retention by simplifying complex concepts and lowering cognitive load [21].

Moreover, graphic-based instruction assists learners in problem-solving situations by walking them through steps, visualizing information, and outlining paths for finding solutions. This is even more helpful for math problems that involve analysis, comparison, and logical reasoning. Using graphic-based instruction, students are assisted in making their thinking processes visible while they are trying to understand the problem.

2.2 Visual Thinking and Geometry Learning

Visual thinking represents a cognitive process for the interpretation, organization, and processing of visual information to create meaningful representations in the mind. In the process of mathematics learning, visual thinking takes a crucial position to help the learner in understanding the concepts of geometry, recognizing patterns, and analyzing spatial relationships between objects [10,22]. Geometry learning, in and of itself, is a process that depends mainly on the visual and imaginative capabilities of the human mind to convert visual to symbolic representation.

Many researchers have pointed out the importance of visual thinking in helping students link graphical or pictorial information to the related math concepts [16]. It benefits understanding by enabling the learner to build on the visuals to make meaning rather than on the verbal or symbolic form. Graphics are also cognitive tools that support the learner in analyzing a situation to find the solution [20].

In addition, visual thinking enables the improvement of higher-order cognitive abilities such as analysis, interpretation, and critical reasoning. By engaging geometry problems from a visual point of view, students would be better equipped to identify similarities and differences among shapes and figures, as well as grasp relationships among the parts and components of a shape or figure [15]. For this reason, the teaching strategy that aims to improve visual thinking abilities becomes a crucial aspect of effective geometry learning, especially among students who face challenges associated with abstract mathematical reasoning.

2.3 Instructional Strategies for Students with Learning Disabilities

Students with learning disabilities often face challenges related to the processing of abstract information and the attention needed to follow the process of problem-solving during the teaching of mathematical concepts. It is on this point that the importance of utilizing teaching techniques that are clear and provide structure and directions becomes imperative [2]. Visual teaching techniques have also come out as effective teaching tools suitable for such groups.

There is evidence that teaching methodologies using pictorial forms of representation can lower levels of cognitive overload and improve the focus of learning on key details for students with learning disabilities [15]. Graphic organizer tools have been shown to be helpful in enabling students with learning disabilities to break down difficult learning tasks into bite-sized pieces and identify the systematic steps of problem solving in mathematics.

In inclusive and resource-room classrooms, research has indicated a positive correlation between visually and graphically based approaches and increased engagement, understanding, and achievement outcomes for students with learning disabilities [18]. These approaches emphasize principles associated with differentiated instruction in that they support diverse learning needs and present information in various forms. Thus, there is a growing acceptance of the value in incorporating visually based approaches to instruction in mathematics for students with learning disabilities, especially in visually intense content areas like geometry [23].

Recent evidence supports the value of visual scaffolding but also shows that its effects are conditional. [15], in a meta-analysis of 41 studies involving 10,562 learners, reported a medium average effect of visualization interventions together with substantial heterogeneity. [24] Found that schematic chunking improved geometry performance among students with geometry learning difficulties, but benefit depended on learners' prerequisite knowledge and their ability to recognize meaningful geometric chunks. [3] Likewise emphasize that visualizations should be integrated with explicit problem-solving instruction rather than treated as self-explanatory.

2.4 Previous Studies

[4] Conducted a study where a total of forty students who have visual impairments performed tasks consisting of multiple-choice questions for five different kinds of images that were given in their preferred medium. They also offered assessments of the level of difficulty. Several aspects were taken into consideration when the instructors of pupils with vision impairments evaluated the students. To evaluate the association between disparities in performance and characteristics that were judged by teachers, statistical analyses were conducted. For the bar graph, the map, and the total correct replies on all activities, it was discovered that users of print graphics and users of tactile graphics performed significantly differently relative to one another. It was shown that the perceived difficulty of some activities among users of tactile graphics did not correspond with their actual

performance. Significant differences in performance were found between total correct and most individual graphic results. These differences were attributed to the ratings that teachers gave to students who had Individualized Education Program goals for graphics, independence in using graphics, problem-solving ability, mathematics ability, and frequency of engaging with graphics.

[25] Sought to fill a gap in our understanding by examining the intellectual framework of innovative assessment techniques for students with mental disabilities and autism disorders. Specifically, it sought to define the philosophy, objectives, justifications, and types of these techniques as they pertain to students with special needs in the context of the twenty-first century. Utilizing both a descriptive and forward-looking approach, the researcher adhered to research best practices. The research ultimately met some of the requirements for improving the effectiveness of these techniques in the context of the twenty-first century, to ensure their stability.

[26] Examined how elementary school students' performance with mathematical applets was affected by the visual design's appropriateness. Two sets of mathematical applets are compared in this quantitative study; the only difference between them is the visual style, namely the level of detail and the quantity of distraction. The mathematical problems are identical, however. Matific is a library of mathematical applets; the first applet uses its ideas for animated images. For this study, we created a second applet that replicates the first but in a more simplified, schematic form. The students in the group using schematic graphics were more efficient and finished the task faster than their animated graphics counterparts. Furthermore, the schematic group had more success than the other, even among pupils with inferior mathematical abilities. In terms of how much fun the kids had, there was no discernible difference between the two sets of data.

[12] Compared the effectiveness of MG learning with video-based learning to draw any conclusions about the relative merits of the two approaches to teaching English. Students from Bina Nusantara University made up the study's population in a quasi-experimental design. Two classes, each with forty students, served as the sample for this in-class experiment and control, respectively. According to the results, students' English proficiency was significantly enhanced by motion graphics-based learning due to its accessibility, motivation, stimulation, encouragement, informational content, and entertainment value. In addition, compared to video-based learning (VBL), motion graphic learning significantly improved students' English proficiency.

[19] Sought to improve our understanding of visual thinking strategies and how graphic designers may better convey information to their audiences. This study investigates the spatial thinking of graphic designers and the information-receiving public via the lens of visual semiotics, combining Li Siqu's DIMT thinking style with Morris's symbolic context. At the formal level, you'll find things like important academic thinking and visual symbol research elements; at the entity level, you'll find things like the three-dimensional grasp of its theoretical concepts, a sketch of the interaction with the audience, and visual graphics. This article highlights the concepts of innovative graphic design and audience acceptability of information, and it uses semiotic theory to explore the connection between various graphics and ideographic approaches.

The previous studies are not equally comparable to the present investigation. Research involving visual impairments, intellectual disabilities, autism, English-language learning, or graphic design contributes useful principles about accessibility and representation, but the populations, sensory demands, subjects, and outcomes differ from those of eighth-grade students with learning disabilities studying geometry. The most relevant unresolved issue is therefore not whether visualization can ever help, but whether a structured sequence of diagrams and graphic organizers embedded in ordinary geometry lessons improves both visual-thinking performance and multistep problem solving in resource-room settings.

The existing body of evidence highlights the importance of graphic strategies in mathematics instruction, the significance of visual thinking in geometry learning, and the importance of organized visual instruction for students with learning disabilities. Even though previous studies have indicated that visual and graphic approaches most often have a positive effect, there is a gap in empirical studies that investigate their combination in regard to visual thinking and geometry skills in middle school students with learning disabilities.

In particular, there are only a few experimental studies that focus on eighth-grade students in resource room classrooms or employ valid measures to examine the simultaneous outcomes of visual thinking and problem solving. In an attempt to fill this research void, the present study investigates the impact of a graphic-based approach to instruction regarding the promotion of visual thinking and geometry problem-solving competencies of eighth-grade learning disabled students in Irbid, Jordan. Through the provision of research insights in the abovementioned specific setting, the present study can contribute to the body of knowledge for inclusive mathematics education and the implementation of graphic-based approaches in geometry education for learning disabled students.

2.5 Theoretical Framework and Design Logic

Cognitive Load Theory provides the principal explanatory framework [27]. Geometry tasks require students to coordinate spatial relations, verbal conditions, symbols, and several solution steps. For students with learning disabilities, keeping these elements active while deciding what to do next may create substantial working-memory demands. A well-designed diagram or organizer can externalize relationships, segment a task, and reduce unnecessary visual search. The framework does not imply that more imagery is always better; irrelevant detail and poorly aligned graphics may impose additional extraneous load.

The intervention therefore used visual organizers to highlight shape attributes, comparison structures, and the sequence of information analysis, requirement identification, representation, planning, implementation, and checking. These features map directly onto the assessed visual-thinking and problem-solving skills. The proposed pathway is: structured representation $->$ more visible relations and lower unnecessary search $->$ improved analysis and monitoring $->$ stronger performance. The study tests group differences consistent with this pathway; it does not establish cognitive load as a measured mediator.

3 Methodology

3.1 Design of the Study

The study used a non-randomized, pre-test-post-test, intact-group quasi-experimental design. Two existing resource-room classes were allocated to graphics-based or conventional instruction. This design is appropriate when individual randomization is not feasible, but it requires cautious causal interpretation because pre-existing class, school, or teacher differences may remain.

3.2 Participants

The participants were 40 eighth-grade students with learning disabilities enrolled in resource rooms at Shafiq Irsheidat Secondary School for Boys and Saad bin Abi Waqqas Secondary School for Boys in Irbid Governorate, Jordan. The students had been formally diagnosed with learning disabilities according to school records and Ministry of Education procedures. Because both participating institutions were boys' secondary schools, the sample was male; age, diagnostic subtype, prior achievement, and accommodation details were not reported in the available manuscript record.

Two intact classes were purposively selected and allocated to the experimental group (n=20) or control group (n=20). Documented inclusion criteria were enrollment in eighth grade, placement in a participating resource room, and formal identification of a learning disability in school records under Ministry procedures. A pre-test was administered before the intervention, and the manuscript reports no statistically significant baseline differences. Additional exclusion criteria, the exact allocation procedure, attrition, and the mapping of school and teacher to condition were not documented in the supplied file and should be confirmed from the original study records.

3.3 Instructional Procedures

This instructional intervention was done for a period of six weeks, with three instruction sessions held in a week, taking an approximate period of 45 minutes for each, similar to the regular mathematics timetables.

- The experimental group received instruction in geometry using a graphic-based instructional approach. This approach used graphic organizers, visual models, diagrams, and visual problem-solving exercises. This instructional approach was intended to help students analyze graphic shapes, make comparisons, and think about solution steps in visual terms.
- In contrast, the control group was taught through the conventional teaching method described within the math curriculum, through verbal explanations, textbook illustrations, and exercises designed for problem-solving with less use of graphic organizers.

To support treatment fidelity, the researcher provided the resource-room mathematics teachers with instructions for the assigned method and observed implementation. The available manuscript does not report the observation schedule, a formal fidelity checklist, or a quantitative fidelity score; these details should be added from the study records if they were documented.

3.4 Instrumentation

The researcher developed a 34-item assessment to measure visual-thinking and geometry problem-solving performance at pre-test and post-test. Ten specialists in mathematics education, curriculum and instruction, and mathematics teaching reviewed the draft for content alignment and clarity, and items were revised in response to their comments. The available manuscript does not specify the item format, allocation of items to the two domains, scoring rules, possible score ranges, or administration time; these details are required for full replication.

The coefficients in Table 1 range from 0.558 to 0.889 and were reported as significant at the 0.01 level. Their exact meaning—such as item-to-total, subscale-to-total,

Table 1: Reported Correlations Among the Intended Skills of the Researcher-Developed 34-Item Assessment

Skill	Correlation Coefficient	Sig.
Visual Thinking Skill		
Identifying the shape and its features	0.574	0.01
Shape analysis	0.775	0.01
Connecting relations to the shape	0.759	0.01
Recognizing vagueness and its analysis	0.713	0.01
Problem-Solving Skill		
Information analysis	0.734	0.01
Specifying requirement	0.560	0.01
Drawing the question and identifying the requirement	0.728	0.01
Putting a solving plan	0.750	0.01
Implementing the solving plan	0.558	0.01
Checking the correctness of the solution	0.889	0.01

or domain-to-total correlation—must be specified before they can be interpreted accurately. They are treated here as preliminary evidence concerning internal structure rather than as a stand-alone reliability coefficient.

3.5 Validity and Reliability

The review by ten specialists provides evidence of content relevance and clarity, but it does not by itself establish construct or criterion validity. A complete validity account should identify the review criteria, revision rules, and any content-validity index calculated.

The manuscript does not provide Cronbach's alpha, McDonald's omega, or another verified score-reliability coefficient. These values should be calculated from the item-level responses for the total assessment and, where the scoring structure supports them, the visual-thinking and problem-solving scores. Until then, the instrument should be described as researcher-developed with preliminary content and internal-structure evidence rather than as fully validated.

3.6 Data Analysis

Data analysis proceeded from descriptive to inferential reporting. Means and standard deviations were summarized for the groups, and the two total scores—visual thinking and geometry problem solving—were treated as primary outcomes; the subskills were secondary. The original analysis used independent-samples t tests after examining normality and equality of variance and reported eta-squared and Cohen's d. The final revision should state the actual diagnostic results, degrees of freedom, exact p values, 95% confidence intervals, missing-data handling, and any multiplicity adjustment. Importantly, the reported t values are not fully consistent with the displayed means, standard deviations, and n=20 per group. All inferential values and standardized effects therefore require verification against the participant-level dataset before submission.

4 Results and Discussion

4.1 Results: Visual Thinking

The experimental group obtained a higher total post-test visual-thinking mean (M = 16.93, SD = 2.09) than the control group (M = 11.68, SD = 4.20), a descriptive difference of 5.25 points. The experimental group also had higher displayed means on identifying shape features, shape analysis, connecting relations, and recognizing vagueness. The inferential values in the original table require verification from the participant-level dataset.

The displayed pattern favors the graphics-based group across the four visual-thinking skills. Because the design used intact classes and the inferential statistics require rechecking, the result is described as a between-group performance difference in the sampled classes rather than definitive causal proof.

The original manuscript classifies the reported visual-thinking effects as large. Those estimates should not be treated as final until the t statistics and standardized effects have been recalculated from the raw data and accompanied by confidence intervals.

4.2 Results: Geometry Problem Solving

The experimental group obtained a higher total post-test problem-solving mean (M = 35.95, SD = 8.25) than the control group (M = 20.53, SD = 8.64), a descriptive difference of 15.43 points. Higher experimental-group means were also displayed for information analysis, requirement identification, representation of the problem,

Table 2: Post-Test Visual-Thinking Scores by Instructional Group (n=20 Per Group)

Skill	Group	Mean Score	Standard Deviation	T-Value	Sig.
Identifying the Shape and its Features	Experimental Control	4.525 3.275	0.716 1.320	5.264	0.01
Shape analysis	Experimental Control	4.125 2.750	1.042 1.316	5.181	0.01
Connecting Relations to the shape	Experimental Control	4.425 3.075	1.279 1.774	3.904	0.01
Recognizing Vagueness and its Analysis	Experimental Control	3.850 2.575	1.189 1.466	4.273	0.01
Total	Experimental Control	16.925 11.675	2.093 4.202	7.073	0.01

Table 3: Reported Standardized Effect Estimates for Post-Test Visual-Thinking Outcomes

Skill	T-Value	ET-Square	D-Value	Effect Size
Identifying the Shape and its Features	5.264	0.262	1.192	Large
Shape analysis	5.181	0.256	1.173	Large
Connecting Relations to the shape	3.904	0.163	0.884	Large
Recognizing Vagueness and its Analysis	4.273	0.190	0.968	Large
Total	7.073	0.391	0.391	Large

Table 4: Post-Test Geometry Problem-Solving Scores by Instructional Group (n=20 Per Group)

Skill	Group	Mean Score	Standard Deviation	T-Value	Sig.
Information analysis	Experimental Control	7.825 5.050	2.286 2.591	5.079	0.01
Specifying requirement	Experimental Control	3.275 1.925	2.136 1.803	3.054	0.01
Drawing the question and identifying the requirement	Experimental Control	5.675 3.150	2.635 2.627	4.292	0.01
Putting a solving plan	Experimental Control	3.450 2.550	0.959 1.552	3.120	0.01
Implementing the solving plan	Experimental Control	5.175 2.150	1.647 2.704	6.043	0.01
Checking the correctness of the solution	Experimental Control	10.550 5.700	3.273 3.473	6.427	0.01
Total	Experimental Control	35.950 20.525	8.249 8.641	8.166	0.01

planning, implementation, and checking. The inferential values require verification from the participant-level dataset.

The original manuscript reports medium-to-large effects across the problem-solving subskills and a large total effect. These estimates should be recalculated and accompanied by confidence intervals before they are used to support claims about educational magnitude. Claims about ease, hesitation, or teacher feedback were removed because those outcomes were not measured.

4.3 Discussion

The higher displayed visual-thinking means are consistent with the proposed role of structured graphics in making shape attributes and spatial relationships easier to inspect. Rather than requiring students to hold every relation mentally, the diagrams and organizers may have externalized some of the information needed for comparison and analysis. This interpretation is theoretically plausible, but the study did not measure cognitive load directly and therefore cannot establish the

Table 5: Reported Standardized Effect Estimates for Post-Test Geometry Problem-Solving Outcomes

Skill	T-Value	ET-Square	D-Value	Effect Size
Information analysis	5.079	0.249	1.150	Large
Specifying requirement	3.054	0.107	0.692	Medium
Drawing the question and identifying the requirement	4.292	0.191	0.972	Large
Putting a solving plan	3.120	0.111	0.707	Medium
Implementing the solving plan	6.043	0.319	1.368	Large
Checking the correctness of the solution	6.427	0.346	1.455	Large
Total	8.166	0.461	1.849	Large

Table 6: Descriptive summary of the two primary post-test outcomes. Note. Values are reproduced from the manuscript tables; inferential statistics, confidence intervals, and standardized effects require raw-data verification

Primary Outcome	Experimental M (SD)	Control M (SD)	Descriptive Difference
Visual-Thinking Total	16.93 (2.09)	11.68 (4.20)	5.25
Geometry Problem-Solving Total	35.95 (8.25)	20.53 (8.64)	15.43

proposed mechanism.

The problem-solving pattern suggests that the visual sequence may also have supported the organization of multistep work. The experimental group showed higher displayed means for analyzing information, identifying the requirement, representing the problem, planning, implementing, and checking. These outcomes align with the intervention sequence, although the bundled design cannot identify which component—organizers, diagrams, visual models, guided practice, or teacher support—was responsible for the difference.

The direction of the findings is consistent with the broader visualization literature, but that literature does not justify an unconditional conclusion that graphics always improve learning. Schematic and task-aligned representations may be more effective than crowded or decorative displays, and students need sufficient prior knowledge to connect a visual configuration to a relevant theorem or procedure. The present findings therefore concern a structured instructional package in the sampled setting, not every possible graphic format.

The participants were students with formally identified learning disabilities, not students with visual impairments. Research on tactile or multimodal graphics can inform accessibility principles, but it is adjacent rather than directly equivalent evidence. The present results should not be generalized to learners with visual impairments or to all students without additional comparative research.

Because the groups were intact and non-randomly allocated, alternative explanations remain possible. Similar pre-test performance does not establish equivalence on unmeasured characteristics, and the supplied file does not clarify whether school, class, teacher, and condition were confounded. The short intervention captures immediate performance only; use of the same assessment may create familiarity effects; the instrument has limited reported psychometric evidence; and the numerous subskill tests increase the risk of false-positive interpretation. These constraints limit causal inference and generalizability.

4.4 Responses to the Research Questions

RQ 1. What is the effect of using a graphics-based strategy on visual-thinking performance among eighth-grade students with learning disabilities in Irbid?

According to the reported post-test data, the experimental group achieved a higher total visual-thinking mean ($M = 16.925$, $SD = 2.093$) than the control group ($M = 11.675$, $SD = 4.202$), a descriptive difference of 5.250 points. Higher experimental-group means were also reported for identifying shape features, shape analysis, connecting relations to a shape, and recognizing and analyzing vagueness. This pattern supports an association between the graphics-based instructional package and stronger visual-thinking performance in the two sampled classes. The result should not be treated as definitive causal proof because the groups were intact and non-randomly allocated, and the inferential statistics require raw-data verification.

RQ 2. What is the effect of using a graphics-based strategy on geometry problem-solving performance among eighth-grade students with learning disabilities in Irbid?

The reported post-test data show a higher total geometry problem-solving mean for the experimental group (M = 35.950, SD = 8.249) than for the control group (M = 20.525, SD = 8.641), a descriptive difference of 15.425 points. The experimental group also had higher displayed means for information analysis, identifying the requirement, drawing and representing the problem, planning a solution, implementing the plan, and checking the solution. The pattern is consistent with the possibility that structured diagrams and organizers helped students make multistep solution processes more visible and manageable. This interpretation remains context-bound because the intervention bundled several supports, the design was non-random, and the reported inferential values require verification.

4.5 Internal Validity and Limitations

Future research should use larger multi-school samples, include female students, randomize classes or schools where feasible, balance teacher effects, report fidelity systematically, and include delayed and transfer measures. Comparative studies should isolate schematic versus decorative graphics, static versus interactive representations, and teacher-generated versus student-generated diagrams. Observation, think-aloud protocols, and student work samples could clarify how visual supports influence the actual problem-solving process.

4.6 Future Research

Future research should use larger multi-school samples, include female students, randomize classes or schools where feasible, balance teacher effects, report fidelity systematically, and include delayed and transfer measures. Comparative studies should isolate schematic versus decorative graphics, static versus interactive representations, and teacher-generated versus student-generated diagrams. Observation, think-aloud protocols, and student work samples could clarify how visual supports influence the actual problem-solving process.

5 Conclusion

This intact-group quasi-experimental study found higher displayed post-test means for the graphics-based group on total visual-thinking and geometry problem-solving performance. The pattern is consistent with the view that structured diagrams and organizers can make geometric relations and solution steps more visible. It does not establish effects on motivation, social interaction, teacher preference, or long-term learning, and it does not show that all graphic formats are equally effective. Because the sample was small, the groups were not randomly formed, and the inferential statistics require verification, the conclusion is limited to promising evidence from the sampled classes and supports larger, better-controlled replication.

6 Practical Implications and Recommendations

For teachers, graphics should be uncluttered, directly aligned with the geometric relation being taught, and accompanied by explicit modeling of how to read and use the representation. For curriculum developers, geometry units can include sequenced organizers, comparison matrices, and worked diagrams, together with accessible alternatives and teacher guidance. For school leaders and policymakers, the findings support pilot-based professional development, provision of adaptable visual materials in resource rooms, and careful implementation monitoring. They do not justify immediate system-wide adoption without replication, cost analysis, and evidence of sustained learning.

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Contribution of the Study

This study provides context-specific evidence concerning a structured graphics-based instructional package in eighth-grade resource rooms. It also clarifies the theory-to-design logic of the intervention and identifies measurement, design, and implementation issues that future replications should address. The findings support cautious instructional piloting rather than universal or system-wide claims.

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Essa Melfi Aldosari is a Saudi national and a lecturer in mathematics education. He holds a Bachelor's degree in Mathematics and a Master's degree in Mathematics Teaching Methods, and he is currently a doctoral researcher at Imam University. His professional journey in education began as a secondary school mathematics teacher, after which he served as a teaching assistant at King Saud University and later at Salman bin Abdulaziz University, both at the College of Arts and Sciences in Wadi Al-Dawasir, within the Department of Mathematics. He currently works as a lecturer at Prince Sattam bin Abdulaziz University, College of Education. In addition to his teaching roles, he has held administrative positions, including Director of the College of Arts and Sciences at Wadi Al-Dawasir, King Saud University, and Statistics Coordinator for the university branches. His teaching portfolio covers courses such as Principles of Calculus, Foundations of Mathematics, Linear Algebra, Introduction to Topology, and Mathematics Teaching Strategies and Methods, as well as an Introduction to Teaching. His research interests include a published study on the effect of a developed algorithm on fourth-grade mathematics students' performance, and an unpublished comparative study of the fifth-grade mathematics curricula in Saudi Arabia, the UAE, and Qatar based on the McGraw-Hill series.

Mohammad A. Tashtoush received the PhD in Mathematics Curriculum & Instruction. Assistant Professor with +20 years of teaching experience in mathematics, statistics, and education at Jordanian and Omani universities. Currently Lecturer at AL-Balqa Applied University (Jordan) and Adjunct Assistant Professor at Sohar University (Oman). Authored +120 Scopus/WOS-indexed publications, with research focusing on self-regulated learning, AI in education, mathematics achievement, and NHPP reliability modeling. Serves as Editor for +8 and Editorial Board Member for +10 international journals and peer reviewer for +75 journals. Secured numerous funded research grants from Saudi and Omani institutions. Experienced in curriculum development, program accreditation, quality assurance, and student supervision. Former Assistant Dean for Quality Assurance and Scientific Research at AL-Huson University College. Published two academic books.

Amin M. Elfeky is an Assistant Professor in the Department of Mathematics at the College of Science and Humanities in Al-Kharj, Prince Sattam bin Abdulaziz University, Al-Kharj, Saudi Arabia (a.elfeky@psau.edu.sa). His academic work focuses on research and applications within the Saudi higher education system.

Mohamad A. Khasawneh hold a PhD in Special Education from Amman Arab University, 2009. He is currently working as an Assistant Professor in Special Education at King Khalid University from 1/9/2015 until now. He worked as an assistant professor of special education at the University of Hail from 1/9/2009 to 1/9/2014. He is a licensed Photosensitivity Syndrome (SSS) screener by the Irlen Helen Center. And a licensed examiner to measure and diagnose learning difficulties from the Jordanian National Institute for Learning Difficulties. He is also a scientific advisor to Dar Al-Fikr for Publishing and Distribution, Amman. He is an academic scholar in Wasit University Journal.

Mohamed Sayed Abdellatif is an Assistant Professor of the Department of Psychology at the College of Education in Al-Kharj, Prince Sattam Bin Abdulaziz University, Alkharj, Saudi Arabia (m.heby@psau.edu.sa). His academic work focuses on psychological research and education within the Saudi higher education system. Dr. Abdellatif contributes to understanding psychological processes and their applications in educational settings. His research addresses contemporary challenges in psychological education and practice.

Sherif Ahmed Ibrahim is a specialist in Educational Technologies and E-Learning, with a strong focus on enhancing digital learning environments. His research interests center on the effectiveness of e-learning platforms, blended learning strategies, and the quality of online education. He is particularly interested in how technology can be integrated into educational settings to improve learner outcomes and institutional performance. Shreef is affiliated with the University of Bisha, where he contributes to the development of innovative teaching and learning practices. His academic contributions are documented through his ORCID profile (0000-0002-6581-9290) and Scopus ID (58182170000), reflecting his active engagement in the field of educational research and technology.