

The impact of teaching with schemas on structural word challenges



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Abstract Instruction is adapted for students having a specific learning disability (SLD) that focuses on the fundamental structure of maths recommending problems as an evidence-based practice. Additionally, evidence-based schema-based education is viewed as a practical strategy for students with an SLD. This study expanded upon earlier efforts by (a) utilizing the implementer and a teacher, (b) assessing a flexible intervention's efficiency, and (c) assessing the performance of students on integrated and generalized schema structure issues. There were 12 impaired fourth and fifth graders receiving extra maths teaching in a resource room. The intervention package included arithmetic education based on schema and a problem-solving mnemonic. A multiple-probe approach involving different participant a functional connection was done using groups. Students performed better when given straightforward, generic, and integrated schema structures. The aggregate normalized mean difference between cases (BC-SMD) for this study was 3.05 (CI95 [2.54, 3.60]), while aggregate "Tau-U effect size (ES) was 95% (CI90 [83%, 100%])".

Keywords: schema-based instruction, mathematics, problem-solving

1. Introduction

The Common Core Standards strongly emphasize the value of solving structural word challenges following the structural word challenges. Investigating more effective teaching methods, such as modelling and schema-based instruction, is essential since general structural training has yet to successfully educate pupils with learning difficulties or those at risk of developing them. Understanding the requirements of children with difficulty solving mathematical problems is crucial before choosing and assessing educational solutions (Hughes 2020). Student's today need different preparation compared to pupils in past, they must be more prepared for workforce actively participate in their education to be ready for life after the classroom. Graduates must be prepared to enter the workforce with the communication, teamwork, problem-solving, analysing, and application abilities required by the workplace (Skinner and Cuevas 2023). Schema matching, which looks for semantic similarities between elements of two schemata, is a crucial step in data integration. Experts with a solid grasp of the data's semantics have traditionally handled this task. However, as current schemata grow in size and complexity, manual schema matching becomes time-consuming and error-prone (Hättasch et al 2022). Large-scale self-paced online courses typically do not require an instructor to be available at all times. Due to the lack of personal interactions and adequate procedures for reliable learning assessments, learners find it difficult to gain in-depth knowledge and skills in many learning contexts, particularly in self-paced online environments (Jung et al 2022). Despite the various instructional strategies developed children struggle to answer challenging problems, despite efforts throughout the world to improve children' arithmetic skills employing a wealth of procedural and conceptual information. Students have reportedly had trouble comprehending algebraic expressions and equations, a comprehension of dynamic role of variables, use of constants and coefficients to isolate unknowns, and use of algebraic knowledge to solve issues in context (Adeniji and Baker 2023). Both elementary mathematical topics and high school topics like derivatives have linguistic difficulties when it comes to word problems. According to one research, students had trouble understanding language, knowing what information to utilize, or comprehending the text when completing derivative word problems (Fatmanissa et al 2020).

2. Literature Review

The paper Arsenault and Powell (2022) performed on word problems in terms of schemas and position of the unknown, then we evaluated how well kids with Mathematics Difficulty (MD) performed in terms of schemas, role of the unknown, irrelevant information, and charts or graphs. The paper Alghamdi et al (2020) looked into the efficacy of teaching third- and fifth-grade students with arithmetic difficulties to solve multiplicative whole-number word problems using



Schema-Based Instruction (SBI), a research-based intervention. The paper Ovadiya (2023) was utilized as a foundation for instructing high school students with difficulty with mathematics (in a regular-level mathematics classroom) and may provide a framework for task design to promote a problem-solving, thinking classroom. The paper Khatin-Zadeh et al (2023) examined the effects of priming a metaphor through the gestural portrayal of its schema on metaphor interpretation. The paper Vidanaralage et al (2022) investigated participant behaviour when interacting with the flipped learning environment, medium of instruction, and video-based learning resources. The paper Powell et al (2022) focused on the Data-based Individualization (DBI) framework used in a tier-based support system for maths intervention paradigm as children having problems with math. The paper Peltier et al (2020) expanded upon earlier efforts by (a) utilizing the practitioner as a teacher, (b) assessing the effectiveness of a flexible intervention, and (c) assessing the performance of students on integrated and generalized schema structure issues. The paper Polo et al (2021) employed multiple baselines across students' design, looked at three students, two of whom had autism spectrum condition, had modest intellectual difficulties—performed at solving mathematical word problems. The paper Fuchs et al (2022) evaluated the impact of Word Problem (WP) intervention with embedded Language Comprehension (LC) education on those on the WP performance of at-risk first graders. The paper Corral et al (2020) investigated the effects of giving people schema training at the beginning of learning (relative to later stages) on mathematics word problems modelled after problems from the Graduate Record Examination. The paper evaluated an evidence-based classification of Schema-based Instruction (SBI) as an intervention to improve word problem-solving outcomes for students with learning or math problems in Grades K–12. The paper Cox and Root (2020) evaluated the efficacy of Modified Schema-based Instruction (MSBI) on the development and upkeep of social skills in middle school students with Autism Spectrum Disorder (ASD) arithmetic material also practices. The paper Fuchs et al (2020) suggested a contribution of language understanding to Word-Problem Solving (WPS) is given, along with an explanation role of language comprehension in WPS. The paper Peltier et al (2021) diagnosed with a specific learning disability (SLD) struggle to solve mathematical problems. One potential strategy for children with SLDs is Schema-based Instruction (SBI).

2.1. Current Study

By assessing (a) the impact of connected, basic, and simple schema architectures on word problems; (b) the instructor acting as implementer; (c) the viability of a modified intervention technique; and (d) participants' social acceptability, we hoped to further enhance the literature. The following inquiries guided our research (Table 1):

Table 1 Characteristics of Participants.

Name	Age/grade	ALL	Ethnicity	Primary disability	Secondary	IQ	Math achievement
Asher	—/4th	—	—	—	—	—	—
Drake	10/4th	No	Black, Asian, White	SLD	SLI	83 (WISC-V)	87 (KTEA-III Brief)
Andy	10/4th	No	White	OHI	SLI	78 (WISC-III)	88 (KTEA-III Brief)
Joe	—/5th	—	—	—	—	—	—
Jack	11/5th	Yes	Hispanic	ASD	SLI	83 (WISC-V)	77 (KTEA-III Brief)
Javon	11/5th	No	White	ASD	None	None	78 (KTEA-III Brief)

Research Question 1: Exists a relationship between a more significant mean-level shift and SBI in correctly solving word problems in mathematics using basic “schema structures”?

Research Question 2: How does SBI impact students' use of combined and generalized schema structures when solving word problems?

Research Question 3: What is the intervention's social acceptability to students and teachers?

3. Methodology

3.1. Participants

Twelve students in all took part in the research (Table 1). Each student's Individualized Education Program (IEP) required a math-related annual objective, and math general education classroom instruction combined with unique education support settings was needed to be included in our study. According to all participants met with the special education teacher, these requirements. Every interventionist was the special educator. She was a conventional certified teacher with more than dealt with students with unique needs for 20 years. Getting a master's in special education. Dealt with SBI before. She has 13 pupils on her caseload to serve.

3.2. Setting

A public education system in a state's southwest suburb served as the study's setting. Prekindergarten through fifth graders (n = 481) attended the elementary school. White (57.5%) made up the bulk of the registered students, followed by



American Indian (7%), “Hispanic (17.7%), students of two or more races (14%), and Black (3.8%)”. Economically disadvantaged students made up around 50.5% of the total student population. 8.1% of the students were English language learners, and 16.7% needed exceptional education support. In a resource room, research was conducted. The instructor handled students in fourth and five grades. A wide rectangular table and two kidney-shaped tables were in the classroom. Students in general education settings got instruction that aligned with Everyday Mathematics. The students' resource room finished assignments given by an available education teacher or received a refresher on ideas they had yet to learn during general education lessons. The class always included six to ten students, a paraprofessional, and an undergraduate particular education intern while teaching, as given during the research.

3.3. Measures

The current project, they developed nine metrics. One three-word problem was included in each baseline probe's schema structure. The PPW, modify, and comparison probes all had an identical format, each with three-word problems that matched the goal schema. Each problem's missing value was assigned at random. Each search had three-word problems that matched the goal schema, known as generalized PPW, change, and comparison probes. The intervention and maintenance phases both used merged schema probes. Each test had three-word problems. Every syllable puzzle has several steps and two different embedded schema kinds. One problem per schema structure, mixed schemas were only utilized during maintenance and had the same format as baseline probes. The special educator stated the targeted skill area for measurements. Fourth-graders made comprised groups 1 and 2. Calculation was only allowed for double-digit whole numbers for these groupings that did not need to be regrouped. Fifth-grade kids made up Group 3. Only fractions with the same denominator could be calculated.

3.4. Measurement and Experimental Design

The effectiveness of an intervention program that combined SBI with a mnemonic for problem-solving and student performance on mathematical problem-solving using a multi-probe design involving different student groups. This particular design was chosen because (a) Target behaviour could a reversed, and (b) an instrument structure enabled do away with the lengthier standard assignments for Groups 2 and 3. Every WWC Pilot Single-Case Design Standards (2017) were consulted when designing the study to ensure that it adhered to particular requirements for Multiple-probe designs: (a) At the start of the study, three panels simultaneously collected baseline probes and right before intervention was introduced, and (b) a data point as collected when intervention first came up in one panel and across all succeeding panels. Because the teacher preferred to start with the smallest group, Group 1 entered intervention first. Three of four children in Group 2 had a stable baseline when intervention began, but only two of six students in Group 3 had a stable baseline at the time of decision. This difference allowed Group 2 to commence intervention before Group 3.

The ability to solve mathematical puzzles was the dependent variable. Students were awarded points for accurately completing each stage of a mathematical problem to gauge their progress. The following method converted this value to a percentage: $(\text{earned points} / \text{possible points}) \times 100$. The process involved (a) designing an appropriate schematic diagram (s), (b) inserting quantities in the suitable locations inside schematic diagram(s), (c) creating a precise to facilitate a solution, and (d) offering appropriate answers. Every issue carried a 4-point value. Students had to finish twice, earning 8 points when using combined schemas.

3.5. Interobserver Agreement (IOA) and Implementation Fidelity

A doctorate student in a program for special education that is also a “Board Certified Behaviour Analyst (BCBA),” an additional judge for permanent goods for evaluation of IOA. For scoring baseline and intervention probes, the first author offered two training sessions lasting 30 minutes each. 90% agreement on two successive investigations was the threshold to be met before being allowed to leave the course. Every baseline, intervention, and maintenance probe had IOA data collected. IOA was 96.5% for intervention/maintenance and 96% for intergroup comparison.

In a program for special education, two doctorate students assessed implementation faithfulness. The teacher's training session and a second 30-minute session on the fidelity checklist were both attended by evaluators. The fidelity of implementation data was gathered throughout the study in 33% of intervention sessions. Fidelity was 96.7% (variations among groups: 96.5%–96.9%). Each fidelity check included gathering duration. The timer started following stating behavioural expectations also beginning first problem model. After modelling was finished and before the session's probe sheet was created, the timer was stopped. Sessions lasted an average of 18 minutes (from 16 minutes for Group 1 to 20 minutes for Group 3). Combination schemas had an average runtime of slightly more than 25 minutes.

3.6. Procedures

3.6.1. Baseline

The specialist educator had 30- to 40-year teaching career minutes daily during baseline. There was no set curriculum in place, and frequently, students brought completed worksheets to a general education teacher. The instructor summoned the group to kidney-shaped table at room's back for data collection periods and handed them the appropriate sheet for probing. All word puzzles were read out by the teacher, who also provided a calculator.

3.6.2. Teacher training

The intervention was taught for three hours by the first author. The aim based a strategy on a heuristic for solving problems and SBI on boosting students' performance was explained at the beginning of the training. Four steps comprised a problem-solving heuristic: Look into the issue, create a schematic diagram of the problem, Identify the subject, and Review the STAR for the solution. Four steps for effective issue solving are aligned with STAR: Recognise, Plan, Solve, and Reflect. A schema for each was explained, along with the matching diagram of a schematic. The teacher then had an opportunity to classify and record issues that matched the intended schemas. Before letting the trainer's model of teaching, an issue that fits each structure modelled one problem for each schema. The trainer went over each item on the fidelity checklist with the teacher. The binder containing all about intervention materials was given to the instructor at the end of training. The research team swiftly debriefed on any missed steps after giving the teacher the completed fidelity checklist during direct observations.

3.6.3. Intervention

There were 19 intervention sessions overall for each group. The following sessions were part of the intervention: two schema identification sessions and four PPW sessions, four sessions about compare, four sessions at change, three sessions on coupled schemas, and two sessions on combined schema identification. The teaching sequence was created using explicit instruction principles. The teacher would call a limited number of people to a kidney-shaped table in room to begin each session. The teacher started the lecture by reviewing behavioural expectations, restating the goal of becoming a problem solver and outlining the day's aim following the framework for Audience Behaviour Conditions. Depending on the logistical limitations and the intervention order, the teacher modelled between one and three difficulties.

The teacher explained the goal, its reason, and behavioural expectations, reaffirmed a plan, and asked for student input during closure in the schema identification sessions ($n = 4$). Only first two steps—identifying crucial information and structure of problem—were practiced during modelling and guided practice, though. Students sorted around ten issues into the appropriate systems to conclude the lesson. In combining structures, students recognized two structures included into each case.

3.6.4. Maintenance

The special educator provided formal training to participants for 15 to 30 minutes during maintenance. The teacher gave no problem-solving instruction. Groups 1 (2-3, 14-15, 23-24 instructional days), 2 (5-6, 14-15 instructional days), and 3 (7-8 instructional days) all received maintenance probes at various points after the intervention. The baseline and probe techniques were the same.

3.7. Data Analysis Techniques

To ascertain (a) whether a functional relationship and (b) the size of an effect, used visual analysis. Six essential characteristics of data level, trend, variability, immediacy, overlap, and consistency guided decision-making. They followed the procedures outlined 2017 WWC Design Standards to systematize this strategy: Identify any concerns and observe whether reliable data were acquired by (a) analysing the baseline; (b) evaluating each phase's level, trend, and variability independently; (c) examining cross-phase comparisons for overlapping, promptness, and consistency; and (d) determining whether examples of the same phenomenon were seen at three different times.

The BC-SMD measures the degree of change from baseline to intervention, essentially the same as group design metrics. We submitted the modified BC-SMD for the current project, which makes use of it because it provides additional flexibility, Restricted Maximum Likelihood (REML). The results of the visual analysis helped us make the selection of the model. They specified baseline-level trends since fixed effects were absent in most cases because baseline levels were frequently varied because baseline values were consistent across instances and randomly. They chose a steady trend intervention since simplest model and offered the best match. An adjustment in level between intervention and baseline, which varied between cases, led to the specification of a random and fixed intervention effect.

Students responded to a social validity survey, an initial maintenance probe for their group. With emoticons to symbolize the varied levels of satisfaction with the intervention, responses to questions ranging from strongly disagree (1) to strongly agree (5). Students could express their likes and dislikes of the intervention by responding to two open-ended questions. The teacher answered the 21 items on a 7-point Likert scale plus the five open-ended questions that made up the

Treatment Acceptability Rating. Three latent variables' measurement characteristics (a) Appropriateness, (b) Perceived advantage, and (c) convenience supported by research.

4. Result and Discussion

This study examined 12 children with impairments getting more arithmetic education in a resource room. It involved in analysis, which looked at the association between schema education and mathematical problem-solving ability. Figure 1 displays the results for each participant as graphs. Although the effect size varied across cases, overall visual analysis showed a functional relationship between schema training and mathematical problem-solving performance for all participants. Below is a more detailed account of the conclusions from the graphical study. The combined “Tau-U ES was 95% (CI90 [83%, 100%])”, indicating that 95% of intervention data were better after correction than baseline. Standardized units increased it by 3.05 from the baseline to intervention, with an aggregated BC-SMD of 3.05 (CI95 [2.54, 3.60]).

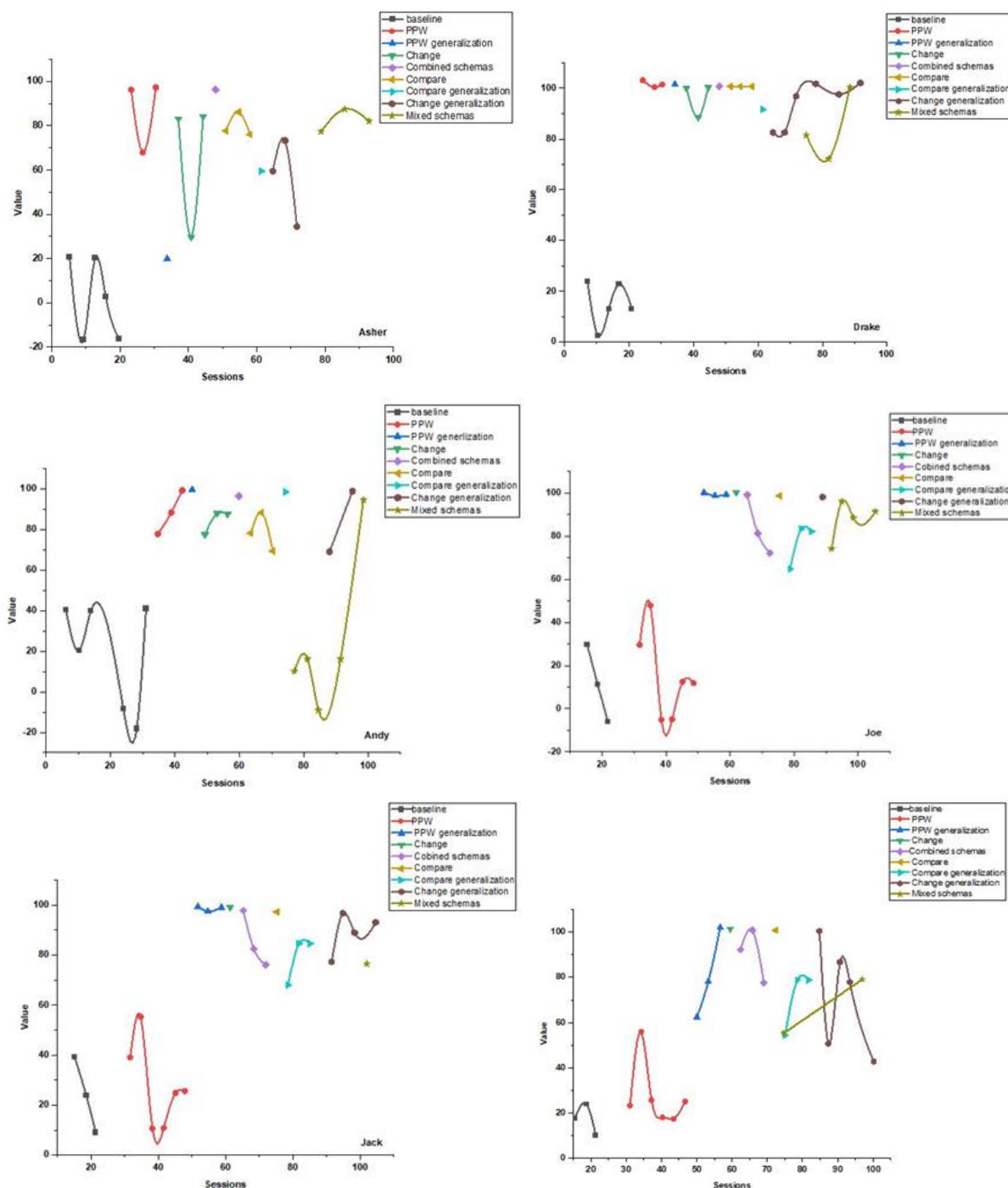


Figure 1 performance at solving problems in mathematics.



4.1. Group 1

The mean values 16.8% and 26.7%, respectively, for Asher's and Drake's baseline. Drake's baseline fluctuated less than Asher's, oscillating between 0% and 33%, and finished on a decreasing trend baseline showed only minor variability, varying between 16.7% and 33%. Asher's intervention data needed to be more consistent. With the exception of coupled schema, Asher was successful with at least two probes during each problem structure. Asher fared worse than simple structures for PPW and modified generalized systems but better than simple structures for comparing generalized searches. All of Drake's intervention data, including generalized structures, except for coupled schemas, had a 90% stability rate or higher. For both students, the immediacy of effect was significant when comparing across stages. For Asher and Drake, baseline and intervention, there was a mean-level difference of 60% and 69.6%, respectively. During an intervention, both students fared worse against main structure probes on mixed schema probes for maintenance data.

4.2. Group 2

The baseline mean level is below acceptable values: 31.9% (Andy). The results showed that baseline data across cases varied greatly: 16.7% to 50% (Andy) and 0% to 50%. Before the intervention, Mike and Andy's statistics showed a tiny upward trend.

Students' performance effectiveness of mixed schema probes during the intervention and their function on specific structures were comparable for maintenance data. Four pupils each received a perfect score on the examination 14 days after teaching. Students achieved or exceeded their performance during the intervention regarding combination structures. Fifteen days after education, all four pupils received 95% or better grades.

4.3. Group 3

The average baseline level in all cases was 18.5% (Joe), below permissible ranges. All subjects, except for Jack, that offered a consistent baseline, showed variation: 0% to 50% (Joe). Ellie, Gabe, and Javon all produced varying baselines. However, Joe's was variable to steady. For this group, intervention data were inconsistent. Except for Joe on change, in each simple structure, every student met criteria of 80% at least once. All students achieved scores equal to or higher than their simple structure performance on generalized issue structures. Only Joe and Javon had completed the 80% requirement for combination structures. Four of the pupils had a significant immediate effect when comparing across stages. On mixed schema probes, students still needed to meet the need for maintenance data. Six pupils received composite schema probe scores ranging from 75% for four to 66% and 33% for the remaining two. Five out of six students performed better on combined schema structures than during the intervention.

4.4. Social validity

The exercise received a passing rating from a teacher, an advantage, and convenience. That pupil used schematics drawings to enhance their capacity for solving mathematical puzzles. Using a word problem mnemonic for addressing issues and schematics for understanding organized information were two aspects of intervention she found most helpful. Given their similarity, the teacher advised changing the compare and change diagrams. Thanks to this adjustment, students may find it easier to differentiate between them. During the implementation, she found two problems. Due to school-wide events and the need to pull pupils from several maths classrooms, scheduling was first a problem.

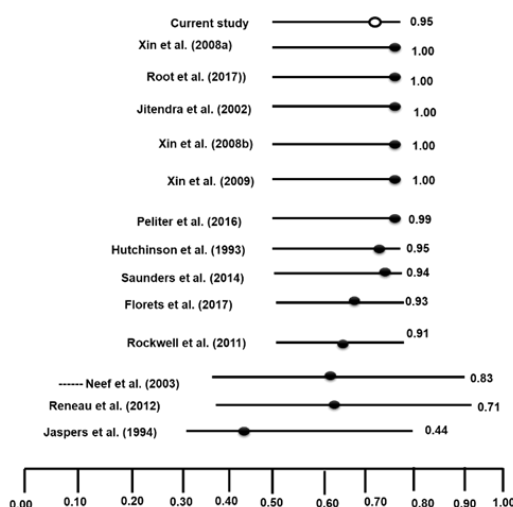


Figure 2 Schema-based instruction forest plot of single-case experimental designs.



5. Discussion

The purpose of this study was to find out if SBI enhanced students' problem-solving skills, when dealing with word problems that included simple, generalized, and mixed schema structures. Another goal is to evaluate the effectiveness of teachers applying for intervention given the logistical limitations of the learning environment. Looking at EBPs used by teachers in realistic settings and circumstances, the nasty detail must be addressed to close the research-to-practice gap. Additionally, they must discover strategies to improve kids' performance on more complicated problems when assisting students with disabilities required for success in general education mathematics courses through problem-solving exercises.

6. Conclusions

Most students reacted favourably to schema instruction and were competent at resolving combined and generalized problem structures. Prior studies assessed student performance on generalized issue structures without teaching, and the results showed that pupils needed to generalize. The present investigation showed that students' performance was comparable to simple structures after instruction in these generalized structures. Only a few studies have examined students' composite schematic structure performance. Most students' performance was similar to basic structures. Specific training with issue structures can give students access to problem-solving abilities to navigate a general education setting more quickly.

Ethical considerations

Not applicable.

Declaration of interest

The authors declare no conflicts of interest.

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