# Effectiveness Schema Based Instruction of Mathematical Problem Solving: Literature Review

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**ABSTRACT**
Problem-solving is the main goal of learning mathematics for decades. By the time problem-solving skill development became an important target from primary school to higher education. The research aimed to analyze the effectiveness of the Schema Based Instruction model to improve the problem-solving ability of elementary school students. The research uses a literature review design using articles. SBI has sufficient evidence to warrant its use by teachers and is likely more effective than current problem-solving strategies common in classrooms. The findings of this review build and extend the findings of previous analyses on SBI and provide additional confidence in the application of SBI by those responsible for providing students with LD high-quality mathematics programs and support.

***Keywords:*** Problem solving, Schema Based Instruction

## 1. INTRODUCTION

Since Polya initiated the problem-solving strategy in 1945, the development of problem-solving skills has been a concern at all levels of education until now. In fact, problem-solving is still the main goal of mathematics learning in the 21st century (Vale et al., 2018).[2] In addition, in the 21st century the development of science is accelerating with the follow-up of technological developments. Humans are required to be able to adjust to keep up with the changes that occur, so as to be able to solve new problems they face.

This has been responded to in the world of education, especially mathematics. The main goal of mathematics is to make students become individuals who can solve problems (Takahashi, 2016). A mathematical problem is having a background of situations/conditions in an abstract or contextual form, where individuals try not knowing how to find solutions (Dossey, 2017). Problem-solving requires that students look for a solution after understanding what the problem itself is. In order to be able to find a solution, students must know the relevant concepts. Next, the student compiles mathematical generalizations and representations in such a way as to communicate his understanding and problem-solving strategies. Problem-solving skills become generic abilities that can be implemented in other subjects or in the face of everyday problems.

Some recent studies report students' difficulties in solving mathematical problems spread over several aspects. In the aspect of mathematics, elementary school students have difficulty solving problems in ratio and comparison materials (Kusuma et al., 2018) . Fitria et al., 2021) In the aspect of problem-solving, elementary school students have difficulty devising strategies for solving them (difficulty finding keywords in the problem and making representations of the problem and consequently unable to find the answer to the problem (Kusumadewi and Retnawati, 2017). Putri and Widjajanti (2019) concluded that grade VI elementary school students have difficulty in completing schemes and making irrelevant procedures.

Such conditions require situations that make it easier for students to solve the mathematical problems they face. The role of the teacher during student problem-solving is to help students find solutions by providing efficient strategies, since the main purpose of this lesson is for students to solve problems. However, to develop problem-solving skills and strategies, and teachers focus only on problem-solving strategies and do not develop mathematical concepts and skills.

One of the efforts that can be applied to overcome these problems is to apply the *Schema-based Instruction* (SBI) learning strategy. The advantages of SBI engage students to build rich schemes for different word problem

structures by identifying similarities and differences between structures and identifying how different levels of information related to problems can vary but not change the structure of the problem.

SBI has advantages including 1) overcoming these difficulties by using explicit instruction to provide students with the conceptual understanding necessary to solve problems (Cook et al., 2020) positively affecting students (different levels of ability), at all levels of education (elementary to high school), in all types of mathematical problems (Peltier et al., 2018).

Several studies on the application of SBI have been carried out from elementary schools to universities and spread across various countries. Therefore, it is necessary to conduct a literature review research to find out the specific effect of SBI on learning outcomes.

This study aims to determine the effect of SBI on problem-solving ability. Previously, Cook et al., 2019 concluded that SBI has potential for students who have learning difficulties. This study resulted in a synthesis of SBI influences to answer the following research questions:

## 2. METHOD

This research was carried out in three stages: initial database search, screening of titles and abstracts, and evaluation of articles for inclusion (Cook et al., 2019). The initial data search was carried out using the Publish or Perish search and searching for articles on the Scopus database published between 2017-2022.

In the initial search using the keyword "Schema based Learning" obtained 57 articles. Searches with the keywords "schema-based instruction" AND "word problem" obtained 35 articles. Last search with the keywords "schema based instruction" AND "word problem" AND Mathematics in 26 articles. After setting aside articles in the form of reviews, 20 articles were obtained for analysis (Table 1).

**Table 1.** Articles Involved In The Research

| No | Author ID | Material | Method and treatmen | Participants | Purpose | Findings |
|---|---|---|---|---|---|---|
| 1 | Desmarais, 2019 | Whole number addition | SBI protocol by breaking the problem-solving process into smaller units for instruction | intellectual disabilities and autism spectrum disorders, performing poorly relative to their peers, average performers | Increase mathematical word problem solving in inclusive classrooms. | able to develop both conceptual and procedural knowledge |
| 2 | Im et al., 2019 | ratio and proportion situations—ratio, fraction | Experiments group by SBI and control group by business-as-usual | 338 of 7 Grades studentas MLD | Effects of schema-based instruction (SBI) on the mathematical outcomes | significant effect size of 0.50 *SD* for the four open-ended items on the PPS posttest |
| 3 | Peltier, 2019 | computation was limited to double-digit whole numbers not requiring regrouping | Experiments groups by<br><br>a problem-solving mnemonic and schema-based | 12 fourth- and fifth-grade students a specific learning disability (SLD) | evaluating student performance on schema structure problems | The aggregated Tau-U effect size (ES) for this study was 95% ($CI_{90}$ [83%, 100%]) and the aggregated between-case standardized |

| No | Author ID | Material | Method and treatmen | Participants | Purpose | Findings |
|---|---|---|---|---|---|---|
| | | | instruction for mathematics. | | | mean difference (BC-SMD) was 3.05 ($CI_{95}$ [2.54, 3.60]). |
| 4 | Root, 2018 | percent of change word problems, | MSBI video anchors, and goal setting with self-graphing | Three participants. One female and two male participants diag- nosed with autism and intellectual disability participated in this study. | Evaluate the effect of a multicomponent mathematics intervention mathematical problem-solving skills | all participants were able to generalize skills from word problems to real-world stimuli (i.e., coupons, receipts, menus).. |
| 5 | Brosh et al., 2018 | Numerical | MSBI and mathematical word problem solving | Three elementary students diagnosed with IDD | encrease teaching efficiency by embedding literacy instruction within mathematical word problem solving instruction | MSBI with instructive feedback to simultaneously address multiple academic domains or skills. |
| 6 | Browder et al., 2017 | addition and subtraction word problems | MSBI that embedded effective practices (e.g., pictorial task analysis, graphic organizers, systematic prompting with feedback) | eight participants with moderate ID | mathematics skills | Six students mastered the problem solving and an additional student mastered two of the three problem types by the end of the study |
| 7 | Buncher el al., 2018 | | Exploratory, quali- tative case study.<br><br>MSBI combined the use of visual representations with a variation in SBI in which the schemas were presented verbally rather than visually. | a sixth-grade student with high-functioning autism spectrum disorder as he engaged with sixth-grade level mathematics. | Interventions that a teacher utilise in response to the strengths and needs of a student with HFA engaging in complex mathematics situations. | multifaceted strategy (verbal schemas, gestures, mathematical notations on paper and manipulatives) used throughout the inter-vention sessions helped students engaged while |

| No | Author ID | Material | Method and treatmen | Participants | Purpose | Findings |
|---|---|---|---|---|---|---|
| | | | | | | organising and solving math word problems |
| 8 | Cox et al., 2018 | | MSBI with visual supports | Two middle school students with ASD | evaluate the effectiveness of modified schema-based instruction (MSBI) on the acquisition and maintenance of math content and practices<br><br>Mathematical word problem-solving flexibility and communication | Both participants correctly solved propor- tional word problems containing extraneous information using multiple strategies and explained their mathemati- cal reasoning more consistently and at a higher rate dur- ing intervention and maintenance phases |
| 9 | Cox et al., 2021 | multiplicative comparison and proportion | MSBI | Four students eligible for special education services under the area of autism enrolled in sixth-grade general education mathematics c | encrease the use of mathematical practices for middle school students | all participants generalized their use of mathematical practices to novel multiplicative comparison problems containing extraneous information, and three of the participants generalized mathematical practice skills to proportion problems containing extraneous information. |
| 10 | Peltier et al., 2018 | problem-solving | Case studies by SBI | four second-grade students with emotional and behavioral disorders. | the effects of schema instruction on the problem-solving performance | effect size (ES) demonstrate improvement in problem-solving accuracy for grade-level word problems involving addition and |

| No | Author ID | Material | Method and treatmen | Participants | Purpose | Findings |
|---|---|---|---|---|---|---|
| | | | | | | subtraction of two-digit integers without regrouping. |
| 11 | Fat one., 2018 | Word problem | Experiment by MSBI with computer-assistent | 32 fifth grade stu- dents with low-performing mathematics scores for Grades 3–6. | the effects of computer-assisted, schema-based instruction on the problem-solving skills. | the computer-assisted, schema-based instruction group showed greater gains relative to the control group |
| 12 | Flores et al., 2016 | problem solving in addition and subtraction | Case studeis, CRA and schema-based instruction | three 3rd Grades students | problem solving | A functional relation was found for the three students' problem-solving performance.<br><br>All three of the students improved their problem-solving performance and achieved mastery as defined as three probes with scores of 100% correct. |
| 13 | Jitendra et al., 2017 | *ratios and proportional* | Experiment group by SBI. Control Groups business as usual | 373 students 7th Grades, of whom 253 demonstrated MD. | proportional problem solving Skills | These results provide strong evidence of the superiority of SBI over instruction in the control condition in supporting student learning of ratios and proportional relationships. |
| 14 | Jitendra et al., 2020 | Ratio/Proporti on | Experiment group by SBI. Control Groups business as usual | seventh-grade | proportional Reasoning performance | Significant gains in per-formance on the proportional reasoning tasks for the students receiving SBI (g1⁄40.54 SD) compared to those in the control condition |

| No | Author ID | Material | Method and treatmen | Participants | Purpose | Findings |
|---|---|---|---|---|---|---|
| 15 | Root&Browder. 2017 | Additin, subtraction and equal (same as) | (MSBI) as a viable strategy for teaching conceptual and procedural knowledge and problem solving to students | Three middle school students with ASD/ID | effects of MSBI on problem solving of elementary students with ASD/ID | A functional relation between modified SBI and mathematical word problem solving. In addition, participants were able to correctly solve the word problems and had some success with generalizing problem solving when visual supports were faded. |
| 16 | Root et al., 2019 | Data Analysis | MSBI with Technology-Based Supports (on iPad) | Three students in Grades 4 and 5 participated in the study. | Problem solving | participants were able to generalize problem-solving skills when they were presented with data analysis problems from grade-level social studies textbooks and visual supports were faded. |

## 3. RESULTS

Research included in the analysis using experimental design (Im et al., 2019; Peltier, 2019; Fede et., 2018; Jitendra et al., 2017; Jitendra et al., 2020) and qualitative (Desmarais, 2019; Root, 2018; Brosh et al., 2018; Browder et al., 2017; Buncher el al., 2018; Cox et al., 2018; Cox et al., 2021; Peltier et al., 2018; Flores et al., 2016; Peltier et al., 2020; Root&Browder. 2017; Root et al., 2019)

Penelitian ini melibatkan siswa yang mempunyai kebutuhan khusus yaitu intelectual disabilities (Desmarais, 2019; Root, 2018; Browder et al., 2017), mathematics learning difficulties (Im et al., 2019; Jitendra et al., 2017), Spesific learning disability (Peltier, 2019; Peltier et al., 2020), IDD (Brosh et al., 2018), autism spectrum disorder (Buncher el al., 2018; Cox et al., 2018; Cox et al., 2021; Root&Browder. 2017), emotional and behavioral disorders (Peltier et al., 2018).

In addition several studies involved low-performing mathematics students (Fede et., 2018; Flores et al., 2016; Jitendra et al., 2020, Root et al., 2019).

Perlakuan yang diberikan kepada siswa terdiri dari menerapkan schema based instruction dan modified schema based instruction (MSBI). MSBI dilaksanakan dengan menambahkan komponen baru kedalam SBI antara lain video anchors, and goal setting with self-graphing (Root, 2018), mathematical word problem solving (Brosh et al., 2018), pictorial task analysis, graphic organizers, systematic prompting with feedback (Browder et al., 2017), visual representations with a variation (Buncher el al., 2018; Cox et al., 2018), computer-assistent (Fede et., 2018; Root et al., 2019), CRA and schema-based instruction (Flores et al., 2016), teaching conceptual and procedural knowledge and problem solving (Root&Browder. 2017).

Variabel dependent mencakup mathematical word problem (Desmarais, 2019; Root, 2018; Brosh et al., 2018; Cox et al., 2018; Peltier et al., 2018; Fede et., 2018; Flores et al., 2016; Jitendra et al., 2017), mathematical outcomes (Im et al., 2019; Root&Browder. 2017; Root et al., 2019), schema structure problems (Peltier, 2019), mathematics skills (Browder et al., 2017; Cox et al., 2021; Jitendra et al., 2020), students engagedment while organising and solving math word problems (Buncher el al., 2018), solving routine conditions.( Peltier et al., 2020),

## 4. DISCUSSION

SBI approach, which is based on principles that can guide effective teaching practice and facilitate deep learning by conveying problem structure. SBI, with its emphasis on the underlying problem struc- ture that requires grouping and conceptualizing multiple elements of information as a single schema, may have led to a reduction in working memory load that allowed for more efficient and effective learning (Kalyuga, 2009). It is also possible that visual-schematic diagrams helped students attend to the mathematical problem structure and acquire better problem comprehension with regard to understanding the relations between quantities in a problem. Furthermore, the explicit teacher guidance (e.g., think-aloud on how the problem can be solved or opportunities to explore different ways of solving the problem during small group or partner work) provided throughout the learning process may have supported student learning. By explicitly integrating instructional strategies (e.g., making sense of problems, reasoning, and explaining thinking to others) with math- ematics content (e.g., ratio, proportion, percent), SBI can improve learning.

SBI with its focus on the underlying problem structure required students to categorize problems into a few problems types by discerning the relevant quantities and their relations, which possibly reduced working memory load allowing for more efficient and effective learning (Kalyuga, 2009). Second, visual-schematic diagrams in SBI may have helped students organize information in the problem during the initial phase of the problem solving process (i.e., problem representation) to further reduce the cognitive memory demands and enable the learner to focus on problem solution (i.e., devise a plan to solve the problem). Evidence suggests that visual representational approaches improve mathematical problem solving of students with MLD (Gersten et al., 2009; Jitendra, Nelson, Pulles, Kiss, & Houseworth, 2016). Third, SBI promoted meaningful learning in that appropriate guidance (e.g., teacher think-aloud on how the problem can be solved or opportunities to explore different ways of solving the problem) provided throughout the learning process may have enabled the learner to understand and solve not only proportional problems but also mathematical problems involving other topics (e.g., algebra, geometry).

## 5. CONCLUSION

The research in mathematics is underdeveloped in such a way that special educators as well as general educators must make instructional decisions based on the best evidence (NMAP, 2008) when planning instruction for students with LD. It is our judgment, based on the results of this evidence-based review, that SBI has sufficient evidence to warrant its use by teachers and is likely more effective than current problem-solving strategies common in classrooms (Riccomini et al., 2016). The results of this systematic review bring continued insight into effective methods for teaching students with LD to understand and efficiently solve word problems in mathematics. The findings of this review build and extend the findings of previous analyses on SBI and provide additional confidence in the application of SBI by those responsible for providing students with LD high-quality mathematics programs and supports.

## ACKNOWLEDGMENTS

We would like to express our appreciation and thanks to the Directorate of Research and Development– Ministry of Research, Technology and Higher Education (Ristekdikti/MoRTHE), for financial support for this research. The authors would like to thank colleagues, Research Institution and The Master Program in Primary Education, Universitas Negeri Jakarta. The research grant number is 22/PG.02.00.PT/LPPM /III/2022, on April 18th, 2022.

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