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The effect of cognitive strategy instruction enriched with active learning techniques on word problem solving skills of students with learning disabilities

Abstract

This study aimed to investigate the effectiveness of cognitive strategy instruction (CSI) enriched with active learning (AL) techniques in teaching word problem solving to primary school students with learning disabilities, as well as to examine the overall instructional process. Word problem solving is the process of using contextual information from real-life or fictional situations to develop mathematical solutions. The research was designed with an embedded mixed method model. The quantitative phase included 30 third-grade students with learning disabilities, while the qualitative phase involved six randomly selected students from the experimental group. Quantitative analyses revealed that students in the experimental group showed significantly higher achievement in problem-solving tests, indicating the positive impact of CSI enriched with AL techniques. Qualitative findings highlighted increased class participation, enhanced collaboration, and more positive attitudes toward mathematics. Furthermore, teacher and peer interactions supported the problem-solving process, and the use of tools promoting mathematical thinking strengthened performance. The results demonstrated that CSI enriched with AL techniques encouraged strategic thinking and the generation of alternative solutions in word problem solving. The study, limited to three learning outcomes within the third-grade mathematics curriculum in Turkey, suggests that teachers should adapt and implement such instructional approaches across other mathematical domains, given the students' positive experiences and outcomes.

Keywords: Word problem solving, active learning, cognitive strategy instruction, primary school mathematics education, learning disabilities.

1. Introduction

Cognitive strategy instruction (CSI) helps students to develop effective strategies by focusing their attention on the conceptual meanings of problems and to carry out problem-solving processes more systematically (Myers et al., 2023). At the same time, it contributes to students becoming independent learners by enabling them to control their learning processes better (Pfannenstiel et al., 2015). Research shows that CSI reduces the load on working memory by dividing the problem-solving process into more manageable steps and supports the self-regulation skills of students with learning disabilities (LD) (Zheng et al., 2013). Indeed, metacognitive strategies such as self-regulation enable students with LD to be more effective in planning, monitoring, and evaluating the problem-solving process (Krawec & Huang, 2017). Although using cognitive and metacognitive strategies together is an effective method in teaching problem-solving to students with LD (Jitendra et al., 2015), studies on the effectiveness of these strategies in word problems (WPs) have been limited (Morin et al., 2017; Myers et al., 2022; Powell et al., 2020; Sharp & Dennis, 2017).

Solving WPs is critical for students' success in and out of school because this skill reflects their capacity to apply mathematical concepts to everyday life (Björn et al., 2016; Fuchs et al., 2021; Tarım, 2017). However, the textual complexity of WPs makes it difficult for students with LD to understand quantitative relationships in problems (Powell, 2011). Moreover, since the word problem solving (WPS) process requires higher comprehension skills, students with LD should be supported in this regard. Indeed, students who are not supported in this regard cannot use the cognitive processes necessary to identify missing information in problems and make inferences (Driver & Powell, 2017; Shin et al., 2021).

Curricula that equip students with basic skills such as critical thinking, problem-solving, and collaboration promote sustainable development goals by enabling them to participate responsibly and constructively in future challenges (Karjanto & Acelajado, 2022; Rehman et al., 2023). Quality education, one of the development goals, emphasizes the need to create safe, non-violent, inclusive, and effective learning environments for all. This study will create an effective and inclusive learning environment by supporting the problem-solving skills of students with LD. In this respect, active learning (AL), student-centered approaches, and flexible pedagogical methods are essential. In this study, the abbreviation “AL” was used for the term active learning, and active learning included collaborative problem solving, peer discussion, concept mapping and the use of manipulatives. In particular, innovative teaching methodologies such as CSI will improve students' knowledge and skills related to sustainability and make them more equipped and responsible individuals. This study is expected to make a significant contribution to the literature by

providing empirical evidence on the effectiveness of CSI for solving word problems among students with LD. Beyond its theoretical contribution, the study also offers practical implications for educators by presenting insights that can guide the revision and improvement of instructional methods to better support students with LD in mathematics teaching.

1.1. Literature review

1.1.1. Active learning and cognitive strategy instruction

In AL, students actively participate in learning instead of passively receiving information (Litster et al., 2020). In this model, students make sense of and apply knowledge through problem-solving, exploration, experimentation, discussion, and collaboration (Ting et al., 2019). Unlike traditional teaching methods, AL focuses on developing thinking, questioning, and discovery skills by keeping the student at the center (Žakelj et al., 2024). By integrating real-world applications and interactive exercises into the learning environment, AL promotes a deeper understanding of mathematical principles and their practical implications (Cirillo et al., 2024). In this respect, AL can meet the individual needs of students with LD, enabling them to participate actively in the process. Different sensory learning methods, collaborative working models, gamification, and technology-supported applications enrich the learning experiences of these students (Žakelj et al., 2024). Thus, the learning process becomes more meaningful, permanent, and motivating for them. AL refers to a wide range of behaviors; this study will include students' participation in the learning process and in class discussions, problem-solving, and generalization.

Students with LD may experience various difficulties in processing, remembering, or applying information. AL offers various strategies to support their learning processes and help them overcome their difficulties. For example, working with concrete materials in math lessons or using lesson content supported by visuals and audio narrations facilitates students' comprehension of information (Authors, 2023). On the other hand, CSI is an approach that includes teaching and practical demonstrations of cognitive and metacognitive strategies to improve students' problem-solving performance (Montague et al., 2011). CSI helps students develop strategies appropriate for problem types, complete problem-solving steps, and increase their self-regulation skills (Pfannenstiel et al., 2015). Moreover, when combined with metacognitive strategies, it strengthens students' planning, monitoring, and evaluation skills (Krawec & Huang, 2017). As a result, while AL focuses on how to conduct the process, CSI teaches students how to learn more effectively. The two can overlap and, when used together, can make the learning process more efficient.

1.1.2. Cognitive strategy instruction enriched with active learning in teaching word problem solving

WPS requires the combination of cognitive processes (e.g., attention and memory) and metacognitive skills (e.g., self-monitoring and evaluation) (Jitendra et al., 2015). This process involves students acquiring information about the problem, mentally describing the problem, developing an appropriate solution, and calculating the result (Krawec et al., 2013). WPS refers to the process of interpreting and solving mathematical problems presented in a narrative form, a process particularly challenging for students with LD. According to Verschaffel et al. (2020), mathematical word problems are verbal descriptions of problem situations, from which one or more questions are raised, and to which answers can be found by applying mathematical operations to either numerical data presented or derived from the problem statement. The stages of problem-solving generally proceed as understanding and interpreting the problem, creating a plan for the solution, and implementing the determined plan. WPs are complex and require students, especially those with LD, to apply operations, monitor problem-solving processes, adapt previous knowledge to new problems, and engage in strategic planning (Verschaffel et al., 2020). Therefore, it is important to focus on critical thinking, reasoning, and problem-solving skills in teaching (Jitendra et al., 2015). Providing students with LD with cognitive and metacognitive strategies, and showing how to apply them in the WPS process, is essential for successful learning (Montague et al., 2011). For successful problem-solving, students with LD need to have cognitive, socio-emotional, and interpersonal (e.g. motivation) competencies (Cirino et al., 2015). Therefore, CSI enriched with AL techniques can effectively teach WPS to students with LD.

Meta-analyses show that interventions, especially those involving cognitive strategies, improve problem-solving skills for students with LD (Author, 2021; Montague et al., 2014; Swanson et al., 2013; Lein et al., 2020; Myers et al., 2023; Zhang & Xin, 2012). Although there are different WPS approaches in the literature, this study utilizes heuristic methods, a form of CSI, to support primary school students with LD in WPS (Witzel & Myers, 2023). Heuristics play a critical role in problem-solving and offer a more flexible approach than algorithms in complex mathematical problems (Safarini et al., 2021; Calucag, 2016). Heuristics enable students to develop flexibility in different problem types by allowing them to select relevant information in WPs and create a general strategy in the solution process (Gersten et al., 2009).

Heuristic methods have long been used in education to guide students in solving complex problems (Polya, 2014). In this method, students should learn strategies to solve problems. Each step is modeled through thinking aloud so that students with LD can comprehend the processes of analyzing the problem, creating a plan, implementing the plan, and evaluating the correctness of the solution (Witzel & Myers, 2023). Based on Polya's (2014) problem-solving heuristic, a standard four-step technique (UMDR, also known as

UPSCheck in some sources) is presented in many mathematics textbooks: (1) Understand the problem, (2) Make a plan, (3) Do the plan and (4) Reflect and analyze.

The terms “heuristic method” and “heuristic strategy” are sometimes used interchangeably in the literature. However, they differ conceptually. A heuristic method refers to a general, structured approach that guides students through the problem-solving process. A heuristic strategy denotes the specific, individualized techniques a student may employ to solve a problem. In this study, “heuristic method” is considered more appropriate because the intervention is designed to teach students a systematic, step-by-step problem-solving approach based on Polya’s (2014) four-step framework, rather than focusing on the spontaneous strategies students might individually develop. This distinction ensures conceptual clarity and aligns with prior research on cognitive strategy instruction for students with learning difficulties (Witzel & Myers, 2023; Gersten et al., 2009).

1.1.3. Previous studies and importance of the research

CSI is a structured instructional approach to improve the WPS skills of students with LD or math difficulties (Liao & Jiao, 2022; Powell et al., 2020). Research shows that students who receive this education are more successful than their peers in problem-solving accuracy and strategy use (Morin, 2014; Pfannenstiel et al., 2015; Swanson et al., 2015; Zhu, 2015). In addition, this method provides instant improvements and allows students to transfer the strategies they have learned to new problems and sustain them in the long term (Witzel & Myers, 2023). In this process, working memory capacity stands out as an important factor, and students with higher capacity show more significant improvements in targeted problem-solving tasks and transfer skills (Lanfranchi et al., 2015; Swanson et al., 2015; Swanson, 2016). The effectiveness of strategies may vary according to individual cognitive profiles; for example, visual strategies utilize more visual-spatial memory, whereas verbal strategies are more associated with executive functions (Lanfranchi et al., 2015; Swanson et al., 2015). In addition, combining verbal and visual strategies often leads to better results, and specific strategies, such as drawing a stick model, provide a clear and structured solution, especially for students with mathematical difficulties (Sharp & Dennis, 2017; Witzel & Myers, 2023). However, since the effectiveness of CSI can be influenced by individual differences, future studies need to focus on personalized teaching methods (Pfannenstiel et al., 2015; Zhu, 2015). Moreover, integrating cognitive strategies with metacognitive strategies or other teaching methods can further improve problem-solving skills (Morin et al., 2017; Pfannenstiel et al., 2015; Powell et al., 2020). In conclusion, although CSI is a powerful tool in increasing students' problem-solving competencies, adapting it to individual needs and supporting it with different interventions will maximize its effect.

Although previous research has extensively examined the impact of CSI on WPS for students with LD, most studies have primarily focused on either strategy-based instruction or active learning practices in

isolation. Few studies have investigated the integration of CSI with AL techniques, particularly in the context of primary school students with LD. Moreover, while the literature emphasizes the benefits of CSI in improving accuracy and transfer of strategies, limited attention has been given to how students' participation, collaboration, and attitudes toward mathematics are influenced when CSI is supported by AL techniques. Addressing this gap, the present study uniquely combines CSI with AL techniques to examine both cognitive and affective outcomes in WPS. This dual focus not only contributes to the literature on evidence-based interventions for students with LD but also provides practical implications for designing more engaging and effective instructional models in primary mathematics education.

In this study, CSI was enriched with AL techniques by systematically embedding collaborative problem solving, peer discussions, concept mapping, manipulatives, and station-based activities involving art, music, and drama at each stage of the problem-solving process. This integration provided structured guidance on cognitive and metacognitive strategies while actively engaging students in hands-on, collaborative, and reflective learning, thereby enhancing both their problem-solving performance and affective involvement in mathematics. The combination of AL and CSI offers a powerful and complementary approach to support students with LD. While AL actively engages students in problem-solving, exploration, discussion, and collaboration, CSI provides structured guidance on cognitive and metacognitive strategies to enhance their problem-solving performance. Together, this integration ensures that students not only participate actively in the learning process but also develop the skills to plan, monitor, and evaluate their problem-solving efforts. By addressing individual needs and promoting meaningful, hands-on engagement, the AL–CSI combination maximizes learning effectiveness and creates a more motivating and enduring educational experience.

This study will examine the effect of CSI enriched with AL techniques on the WPS performance of students with LD. Through such a strategy, students with LD are expected to improve their problem-solving processes by using cognitive and metacognitive strategies effectively. On the other hand, this study is expected to contribute to the literature on the effectiveness of CSI on WPs. This study has two main aims: (1) to examine the effectiveness of CSI enriched with AL techniques in teaching WPS to primary school students with LD and (2) to examine the process of teaching WPS with this teaching method. In line with these aims, the following research questions and hypotheses were sought to be answered:

- (1) When the pre-test scores from the problem-solving achievement test are controlled, is there a significant difference in the post-test scores between the experimental and control group students?

H1 CSI, enriched with AL techniques, improves students' WPS performance compared to conventional education.

- (2) What are the reflections of CSI enriched with AL techniques on WPS teaching process?
- a) What are the reflections on the teaching process in terms of course participation?
 - b) What are the reflections on the teaching process in terms of learning interaction?
 - c) What are the reflections on the teaching process in terms of feedback on the teaching method?

2. Method

2.1. Research Design

This study employed an embedded mixed method design, which allowed the researcher to collect and analyze quantitative and qualitative data within the same framework (Creswell & Clark, 2017). Using an embedded mixed method design enabled a more in-depth evaluation of the effect of CSI enriched with AL techniques on the WPS performance of primary school students with LD. In the quantitative dimension, the study was framed as a pretest–posttest control group quasi-experimental design. The independent variable was the group assignment (experimental or control), while the instructional approach represented the treatment condition applied to each group. Students in the experimental group received the intervention consisting of CSI enriched with AL techniques, whereas students in the control group continued their education according to the conventional curriculum recommended by the Ministry of National Education (MoNE). The dependent variable was the students' ability to solve word problems, which was operationalized through their scores on the PSAT. Both groups completed a pre-test prior to the intervention and a post-test following the intervention. While the experimental group received the CSI+AL treatment between the pre-test and post-test, the control group received no such intervention. In the qualitative dimension, interviews were conducted with the participants to complement and further explain the quantitative results. The integration of quantitative and qualitative findings provided a deeper understanding of how CSI enriched with AL techniques influenced the WPS performance of primary school students with LD.

2.2. Participants

This study identified participants using sequential mixed-method sampling (Baki & Gökçek, 2012). Firstly, groups for quantitative data were selected using the probability sampling method. Then, qualitative data were obtained from the experimental group of students selected by purposive sampling method. The study sample consisted of 30 third-grade primary school students (ages 9–11) diagnosed with LD by the Guidance Research Centre (GRC). The study was conducted at a state primary school operating within the framework of the regulations and curriculum established by the Turkish MoNE. In Turkey, the identification of students with LD can be conducted in two ways: medical and educational. Medical diagnosis is carried out in hospitals by child psychiatrists and other relevant specialists, while educational diagnosis is conducted

through GRC. The process begins with teacher observations and parental applications, and GRC specialists evaluate the student using intelligence tests, academic achievement tests, and observations to determine the type of learning difficulty and prepare an educational assessment report. Based on this report, individualized education programs (IEPs) are developed, and students receive instruction using support classrooms and specialized teaching methods. Throughout the educational process, the student's progress is regularly monitored, IEPs are updated as needed, and collaboration between families and teachers ensures the support of the student's academic and social development.

To select appropriate participants, the necessary permissions were first obtained from the MoNE, and the GRC was consulted regarding students' diagnoses. The recommended support programme for pupils using GRC and information regarding pupils' educational plan performance (e.g., numbers and operations (Level 2)) were discussed and obtained. In addition, consultations were held with school administrations, primary school teachers and parents to determine whether the student met the criteria set out below. Specific inclusion criteria were applied: students had to have a confirmed LD diagnosis, no accompanying or chronic illnesses, no other diagnoses besides LD, and an IEP prepared by their primary school teacher for mathematics instruction. During the meeting with the primary school teachers, information was gathered about the student's educational performance in the mathematics course and their problem-solving performance. Teachers were asked questions such as, "At which steps do students make mistakes or struggle during word problem solving?" and "How do students use problem-solving strategies (drawing, modelling, trial and error)?" Teachers' responses were evaluated as either present or absent according to participant selection criteria. Students selected for both the experimental and control groups are included in the support education programme by their class teacher at school. Care has been taken to ensure that all students in the experimental and control groups are at the 'Numbers and Operations (Levels 2 and 3)' stage of the support education course for mathematics. Following these steps, a list of schools with more than 15 students meeting these criteria was created, and two schools were randomly selected. The schools were visited, and informal consultations with the classroom teachers were conducted to identify students who experienced difficulties with word problem solving (WPS). Since the students in the school were in different classes, the implementation was carried out in the support education room after school. One of the schools was randomly selected as the experimental group (N=15, M=7, F=8) and the other as the control group (N=15, M=6, F=9). The demographic data of the participants in the quantitative part of the study are given in Table 1.

Table 1. Demographic data of the participants

	Experimental Group		Control Group	
Age	9,32		9,20	
Gender	8 (girls)	7 (boys)	9 (girls)	6 (boys)

IQ score (WISC-IV)	9 (80-90 point)	6 (91-100 point)	10 (80-90 point)	5 (91-100 point)
PSAT (pre-test mean)	17,52		17,87	

To ensure diverse perspectives in the qualitative phase, participants were selected using the maximum diversity sampling method. This approach was chosen to capture variations in students' problem-solving abilities and learning experiences. First, the post-test scores of the experimental group students were analyzed, and three achievement groups low (0-13 points), medium (14-26 point), and high (27–40 points) were formed. The primary objective of the qualitative phase was to examine students' problem-solving processes and experiences following the completion of the intervention. In this context, post-test outcomes were regarded as a more valid indicator of students' ultimate performance levels. While gain scores could have revealed relative improvements from baseline, they would not have adequately represented the range of achievement levels attained at the end of the intervention. Therefore, post-test scores were considered more appropriate for forming achievement groups and ensuring maximum variation in the qualitative analysis. From each group, two students (one girl and one boy) were randomly selected, resulting in a total of six participants. Code names were assigned to each selected student to maintain confidentiality and protect their identity throughout the study. The code names were HA1 (girl) and HA2 (boy) for the students in the high achievement group, MA1 (boy) and MA2 (girl) for the students in the medium achievement group, and LA1 (girl) and LA2 (boy) for the students in the low achievement group. When creating code names, the abbreviations HA for high achievement, MA for medium achievement, and LA for low achievement were used.

2.3. Instruments

The Problem Solving Achievement Test (PSAT) developed by the researcher and a semi-structured interview form were used as data collection tools. A literature review was conducted first before developing the PSAT. When the existing studies were examined, it was determined that the achievement tests developed to measure problem-solving skills did not fully overlap with the third-grade level problem-solving outcomes of the primary school mathematics Curriculum. Therefore, it was decided to create a new test to measure the WPS performance of the participant students.

The primary school mathematics curriculum was examined in detail during the test development process, and the third-grade level WPS objectives (problem-solving requiring addition, subtraction, and multiplication) were determined (MoNE, 2018). The questions included in the test were prepared taking into account the learning outcomes related to WPS in the MoNE primary school mathematics curriculum ("Solves problems requiring addition with natural numbers", "solves problems requiring addition and subtraction with natural numbers" and "solves problems requiring two operations, one of which is multiplication"). Alternative WPs were prepared for each outcome, and 21 WPs were developed in this

context. Considering the learning outcomes, a specification table was developed to evaluate the practicality of each problem (see Table 2).

Table 2. Example of a specification table prepared for the PSAT

Problems	LO	CD
Aziz has 19 toy cars. His father bought Aziz some more toy cars on his birthday, and Aziz has 41 toy cars in total. According to this, how many toy cars did his father buy?	2, 3	Analysis
Asya read 150 pages of her 640-page book on the first day and 85 pages more than she read on the first day on the second day. How many pages does Asya have left to read?	1, 2, 3, 4	Analysis
Ayşe puts 25 TL of the daily allowance given by her family into her piggy bank. How many TL did Ayşe put in her piggy bank after two weeks?	5, 6	Implementation
(1) Addition by hand, (2) finding the ungiven sum, (3) subtraction requiring decimalisation, (4) addition and subtraction requiring three operations, (5) multiplication, (6) mathematical expressions		

Note: LO = Learning Outcome (Turkish mathematics curriculums (MoNE, 2018)), CD = Cognitive Domain.

Within the scope of expert view ten primary school teachers experienced in mathematics teaching and continuing their postgraduate education in the same field analyzed the specification table. Among them, six were female and four were male, all with prior experience working with students with learning difficulties. Teachers evaluated the extent to which the questions measured the characteristic to be measured and their appropriateness to the curriculum (appropriate, should be corrected, not appropriate). Accordingly, it was determined that the Content Validity Ratio (CVR) value of the measurement tool varied between 0,75 and 0,86. In the literature, it was reported that this value should be at least 0.62 for 10 experts (Yurdugül, 2005).

All questions in the PSAT consist of open-ended questions based on WPs. Based on the literature, a holistic rubric was used to evaluate student responses to open-ended questions. This study, since the students' reaching the correct result in the problem-solving process was examined, a result-oriented holistic grading approach was preferred (Atılğan et al., 2017; Çepni, 2007). The rubric criteria were developed to assess key aspects of problem-solving in word problems -understanding the problem, planning, implementing, and reaching a solution- based on the UMDR model (Understand, Make a plan, Do, Review) and supported by previous studies (Krawec & Huang, 2017). Expert consultation and literature review ensured the rubric is both theoretically grounded and practically applicable. The rubric used in the study is presented below (see Table 3).

Table 3. Rubric for the evaluation of the PSAT

Grade	Statement
4	Solve WPs correctly by applying all four UMDR steps.

3	Understands WPs Makes a plan for a WP Implements the plan and finds the solution wrong
2	Understands WPs Difficult to plan for a solution
1	Difficulty in understanding the problem Makes an operation error and reaches the wrong result
0	Reaches the wrong conclusion without any action Leaves empty

The reliability of the measurement tool (PSAT) was determined by calculating Cronbach's alpha coefficient (0.84). This value is above the widely accepted value (.65 and above) for achievement tests (Field, 2009). In this direction, the achievement test is reliable. PSAT was piloted by applying it to 115 students who learned the third-grade problem-solving acquisitions. Item analyses of the test were conducted using the data obtained from the pilot application. As a result of the item analyses, the test was finalized with 10 questions. The maximum score that can be obtained from the PSAT assessment tool is 40, while the minimum score is zero. The item analyses of the academic achievement test are presented below (Table 4).

Table 4. Item analyses for the PSAT

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Item Difficulty index	0,61	0,65	0,63	0,50	0,65	0,50	0,53	0,66	0,49	0,57
Item Discrimination Index	0,75	0,60	0,80	0,82	0,62	0,90	0,85	0,60	0,93	0,69

Item difficulty indices of the test are distributed between .48 and .66, and item discrimination indices are distributed between (.60 and .93). These values indicate that the test has a high level of discrimination and is of medium difficulty.

Semi-structured interview forms were also utilized as another data collection instrument in the study. Interview forms were prepared by evaluating the qualitative and mixed-method studies conducted in the literature to analyze teaching processes. The interview form included 10 open-ended questions covering course participation, learning interaction, and teaching techniques. The first three questions examined students' engagement, attitudes toward the course, and participation in collaborative learning. The next three questions focused on interactions with the teacher and peers, as well as the use of tools supporting mathematical thinking. The final four questions addressed the use of problem-solving strategies, generation of alternative solutions, use of physical manipulatives, and the impact of classroom discipline on learning. The prepared questions were presented to two mathematics educators who are experts in WPS teaching and

CSI, and the appropriateness of the questions was evaluated. Necessary corrections were made by considering the expert views. Then, pilot interviews were conducted with five third-grade students who were not involved in this study's implementation to determine the questions' comprehensibility. The feedback from the students revealed that the questions were appropriate for the student's level and that there was no need for correction. Some of the questions in the form are as follows: *"How did you interact with your classmates while solving WPs? How did working together affect the problem-solving process?"*, *"How did working by discussing with your friends help you improve your solutions?"* and *"Did your skills of planning, monitoring, and controlling the process change while solving a problem? How did you notice?"*. Documents were used in this study to support the discussions. During the intervention, the four-step (UMDR) structured activity sheets used by the pupils in their problem-solving process and the A4 sheets used by the pupils in their problem-solving process were used as documents. The pupils' creation of different strategies for solutions, their mathematical thinking skills, and their use of strategies were supported through these documents.

2.4. Intervention

In the implementation section of the study, the teaching process for the experimental and control groups was carried out in accordance with the primary school mathematics curriculum of the Turkish Ministry of National Education. The experimental group students were taught with CSI enriched with AL techniques. Metacognitive components such as interaction, discussion, generalization, collaboration, and active participation were embedded in the activities of the experimental group. Students in the control group continued their education according to the conventional curriculum recommended by the MoNE. None of the students participating in the intervention had any experience in using the AL and CSI approaches. Before the intervention, a pre-test was administered to ensure the equivalence of the experimental and control groups. After analyzing the pre-test scores of the experimental and control groups, it was determined that there was no significant difference between the pre-test scores of the two groups and that they were similar groups. Students were informed that participation in the training was voluntary, would not affect their grades, and would be allowed to withdraw at any stage. Considering that different instructors would affect the results of the experiment, both experimental and control group students were taught by the researcher (who had more than 10 years of experience teaching mathematics to students with LD).

The active learning techniques integrated into the AL-CSI intervention included collaborative problem solving, peer discussion, concept mapping, and the use of manipulatives. For instance, students worked in small groups to solve word problems, discussed their reasoning and solution strategies with peers, and used visual representations such as charts, diagrams, and tokens to model problem situations. Additionally, station activities incorporating art, music, and drama allowed students to engage with problems through

role-play, creative visualization, and hands-on manipulative materials, promoting active participation, multiple perspectives, and metacognitive reflection throughout the problem-solving process.

In the AL-CSI intervention, the UMDR steps were systematically implemented. First, students understood the problem by reading the word problem, identifying known and unknown information, and discussing their understanding with the teacher and peers, often using concept maps to organize information. Second, they made a plan by designing solution strategies, encouraged to use visual representations and the snowball technique to share and refine ideas collaboratively. Third, students carried out the plan by applying the chosen strategies, solving problems using manipulatives, visual aids, and station activities (art, music, drama) that allowed hands-on and creative engagement. Finally, in the reviewing stage, students evaluated the correctness of their solutions through metacognitive strategies such as self-questioning, peer discussion, and reflection, exploring alternative solution paths and consolidating their understanding. Each step was embedded with active learning techniques to enhance engagement, collaboration, and deeper problem-solving skills.

The intervention period of the study was limited to eight weeks. The PSAT was administered to the experimental and control group students during a 40-minute course in the first week. Only the test was applied in the first week, and no other application was made. For six weeks, applications were made two days a week and two consecutive 40-minute class hours. The applications were completed in a total of 24 sessions. In this context, three separate activities were applied to the students. Each activity was completed in 8 class hours. In the eighth and last week, the PSAT was administered to the students during a 40-minute class period, followed by interviews with teachers and students for one class hour.

2.4.1. Implementation process of experimental group

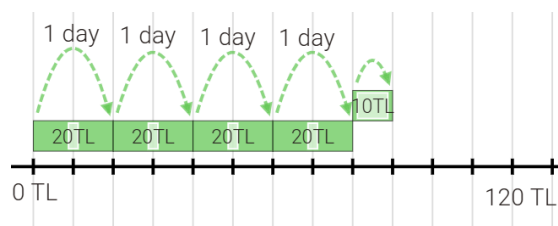
The first activity applied to the students with LD in the experimental group was a WPS activity involving addition. In the second activity, students were taught WPS, which involved addition and subtraction. Then, in the third and last activity, a problem-solving activity involving multiplication was carried out. The problem-solving activity involving multiplication is described in detail below. For the applications, worksheets based on CSI enriched with AL techniques were designed (see Fig. 1). The worksheets were presented to two mathematics educators and two primary school teachers, and expert views were obtained regarding student and subject matter suitability. In addition, the worksheets were piloted by two primary school teachers in their classrooms to check whether they worked or not. As a result of both expert view and pilot implementation, it was decided that the worksheets were appropriate.

Fig. 1 An example of a worksheet for CSI enriched with AL techniques

In Example (see Table 5) students are asked to solve a WP. Students with learning disabilities analyse and solve the problem using cognitive strategy instruction enriched with active learning techniques.

Table 5. An example of word problem solving with cognitive strategy teaching enriched with active learning techniques

Stage	Explanation
Example	Emre saves the pocket money given by his family in a piggy bank. Emre put 20 liras in his piggy bank every day for 4 days. In the following days, how many days will he accumulate 120 liras by putting in 10 liras every day?
(U)nderstand the problem	In the first stage of the process, students read the problem and share with the teacher and their peers what is happening in the problem and what they need to do to reach a solution. At this stage, it is ensured that students understand the problem. At this stage, a concept map can help students understand the problem better and organize the solution process. The concept map visualizes the essential components of the problem, allowing students to structure the information and see the relationships more clearly. The given information and missing parts of the problem can be separated by different colors or sections in the concept map. Students can direct their thoughts by asking themselves about the problem (For example, what do I know to solve the problem? What information do I need?).
(M)ake a plan	In the second stage, students create a plan for solving the problem. At this stage, students often resort to trial and error on how to solve the problem. Encouraging students to use visual representations can reduce the probability of using trial and error. With the snowball technique, one of the AL techniques, students are encouraged to share their thoughts and learning. In this way, students are encouraged to develop different perspectives and solution strategies. Students are asked to think about visual representations and patterns related to the problem's solution. Considering the example above, the savings of 20 liras for the first 4 days are calculated, and then, in increments of 10 liras, the number of days to reach 120 liras is calculated.



(D)o the plan In the third stage, students apply the plan they have designed to solve the problem. In problem-solving, students can create a visual representation using a graph or an equation explaining the visual. Using the visual in the second stage, students will calculate how many days they will reach 120 liras by adding 10 liras after the first 6 days until they reach 120 liras. At this stage, three stations (Art, Music, and Drama) are created using the station technique from AL techniques. Problem situations are adapted according to these stations, and students can solve the problem in the environment they are interested in. Problems are solved by using physical manipulatives shaped according to the stations. Students produce solutions to the problem in the form of small group teaching. For example, students prepare a piggy bank table at the art station by visualizing the money Emre saves daily. For the first 6 days, they represent 15 liras each with money pouches or coin visuals, then add 10 liras each in the following days and create a visual presentation reaching 120 liras. In this process, students' mathematical thinking skills are supported using colored cardboard, pencils, and piggy bank-shaped worksheets.

(R)eflect and analyze In the fourth and final stage, students use metacognitive techniques (e.g., self-talk) to check the appropriateness of the answers. Students go back to the WPs and check the accuracy and suitability of the results. This stage is enriched by discussion, one of the AL techniques. Students are asked to create different solutions to the problem. Students think about the problem, create solutions, and share them with their peers. Then, students are asked to express their views about the solution, and the correctness of the solution is checked in a discussion environment. In general, reflecting on all UMDR stages encourages more in-depth analyses of problems and helps students explore alternative solutions.

2.4.2. Implementation process of control group

Students in the control group continued their education according to the conventional curriculum recommended by the MoNE. The implementation lasted 15 hours, and three different teaching activities were conducted. The teaching activities were taken from the students' textbooks. Each instruction and evaluation process was carried out in five 40-minute lessons. The first activity was a problem-solving activity involving addition. In this activity, students were asked to solve problems related to addition with and without sums and finding the ungiven sum, respectively. In the second activity, students were asked to solve addition and subtraction problems. In the third and last activity, students were asked to solve problems requiring multiplication. After the implementations were completed and the data collected, three activities

were implemented for the students in the control group using CSI enriched with AL techniques. The activities implemented in the experimental and control groups are presented visually below (see Fig. 2).

Fig. 2 Activities implemented in the experimental and control groups

2.5. Data analysis

Since the research was conducted using a mixed research method, data analysis includes evaluating both quantitative and qualitative data and the relationship between these two types of data. Descriptive and inferential statistical methods were used to analyze quantitative data. Descriptive statistics were used for general information about the group, and inferential statistics were used for comparison between groups. Firstly, it was checked whether the data obtained met the normality conditions. With the normality analysis, skewness and kurtosis values of the measurements were examined, and it was determined that they were in the range of -1 and +1. In addition, when the measures of central tendency were examined, it was seen that the mean, median, and mode values were close to each other. The histogram graph, one of the assumptions of normality, was also examined, and it was seen that the data were normally distributed. Accordingly, the analysis of covariance (ANCOVA) method was used to manipulate the pretest scores. Since a pretest–posttest control group design was employed, ANCOVA was used to control for initial differences between groups. By adjusting for pretest scores, ANCOVA allows for a more accurate comparison of posttest outcomes, ensuring that observed differences reflect the effect of the intervention rather than pre-existing variations. Before conducting ANCOVA, its key assumptions were tested. The independence of observations was ensured, and the normality assumption was considered satisfied as no major deviations were observed. The homogeneity of regression slopes ($F = 0.03, p > .05$) and homogeneity of variance (Levene's test: $F = 0.005, p > .05$) were both met. A linear relationship between pretest and posttest scores was also confirmed. These results indicate that the assumptions of ANCOVA were fulfilled, validating its use for analyzing group differences in posttest scores. In addition to statistical significance testing, effect sizes were calculated. For ANCOVA, eta squared (η^2) values were reported, and for group comparisons, Cohen's d was computed to evaluate the magnitude of observed effects. The effect size obtained was interpreted according to Cohen's (1988) guidelines as small ($r = .10$), medium ($r = .30$) and large ($r \geq .50$) effect levels.

The content analysis method was used to analyze the qualitative data. In this context, the researchers code the collected data, classify the codes according to their common characteristics, and create categories and subcategories. The In Vivo coding technique was employed to present the identified codes and categories, and open coding was conducted. This approach relies on direct quotations from participants' statements and is particularly appropriate for questions that elicit brief responses (Saldaña, 2021). In this study, the method was chosen because the structured questions generated short answers. For example, one student

stated, “Before, I would just add or subtract the numbers I saw to reach the answer. Now, I first make a plan and solve the problem accordingly” (HA1), and another student noted, “...while reading the problem, our teacher asked us to ask ourselves questions like ‘What do I know and what is missing?’ and I answered them myself” (HA2). Both statements were coded as “strategy use” and grouped under the category “feedback on teaching method,” supporting the broader theme that the instructional approach positively influenced students’ problem-solving strategies. This example demonstrates the systematic coding process from open codes to categories and themes. Firstly, a code matrix was created for the collected data. A researcher not involved in the study checked the relevant code matrix, and the degree of inter-coder agreement was calculated. While calculating the inter-coder agreement, the formula $[\text{Number of consensus} / \text{Total Number of views}]$ was used and calculated as .83. This ratio is accepted as sufficient for reliability, according to Miles and Huberman (1994).

2.6. Validity and reliability

In this study, various measures were taken to ensure validity and reliability. The research sample and the findings obtained were discussed in detail and contributed to the validity of the research. In the discussion, studies that contradicted the results of this study were presented in detail. The fact that the study consisted of quantitative and qualitative sections whose results supported each other also contributed to Validity. Research problems were considered while presenting the findings to ensure reliability in the current research. The inter-coder agreement rate was calculated. In addition, the transcripts of the interviews with the participants were given in detail, and pictures from the research process were added.

3. Results

3.1. Results for comparing WPS achievements of experimental and control groups

In this study, a one-way analysis of covariance (ANCOVA) was applied to evaluate the posttest difference between the WPS achievement of the students in the experimental and control groups. It is important to perform homogeneity tests and homogeneity regressions on the scores of the two groups to ensure that ANCOVA meets its basic assumptions. The homogeneity of regression slopes was tested on the learning achievement scores of the two groups ($F = 0.03$, $p > 0.05$), and the homogeneity of variance was checked by examining Levene's test ($F = 0.005$, $p > 0.05$). These data show that ANCOVA analysis can be used to analyze the posttest results. ANCOVA results for the posttest scores of the experimental and control groups are given in Table 6. The adjusted mean values and standard error (SE) were 11.56 and 0.59 for the experimental group and 9.17 and 0.59 for the comparison group, respectively. The findings showed a significant difference in the posttest scores of the two groups ($F = 8.58$, $p = 0.007 < 0.05$). The experimental group had significantly higher posttest scores than the control group. This finding indicates that CSI

enriched with AL techniques is more effective in teaching WPS. The ANCOVA results showed a significant effect of the intervention on students' WPS achievement, $F_{(1,27)} = 8.58$, $p = .007$, $\eta^2 = .241$, indicating a large effect size. Furthermore, the magnitude of the difference between the experimental and control groups was also large, Cohen's $d = 0.95$, suggesting strong practical significance of the intervention.

Table 6. ANCOVA results for the post-test scores of the experimental and control groups

Group	N	Mean	SD	Adjusted M	SE	F	η^2
Experimental	15	11.60	2.79	11.56	0.59	8.58*	0.241
Comparison	15	9.13	2.38	9.17	0.59		

* $p < 0.05$

3.2. Results related to the teaching process of WPS with CSI enriched with AL techniques

The qualitative findings related to the teaching process of WPS with CSI enriched with AL techniques were systematically analyzed using the In Vivo coding method. The data were organized into three main categories (see Fig. 3): Course participation, learning interaction, and feedback on teaching methods. For the category of course participation, the subcategories identified based on students' statements were "active participation", "cooperative learning", and "attitude towards learning". For the category of learning interaction, the subcategories were "interaction with the teacher", "peer interaction", and "tools to supporting mathematical thinking". For the category of feedback on teaching methods, the subcategories were "strategy use", "generating alternative solutions", "using physical manipulatives", and "classroom discipline". Direct quotations from participants were used to illustrate the coding process, demonstrating how open codes were grouped into subcategories and broader themes, providing a clear and detailed understanding of students' experiences and perceptions during the WPS process.

Fig. 3 Categories and subcategories of word problem solving teaching process

3.2.1. Views on course participation

In the category of course participation three subcategories were determined as "active participation", "cooperative learning", and "attitude towards learning".

The students participating in the study emphasized that CSI enriched with AL techniques provided active participation. HA1 stated that the method provided active participation: *"We were always listening and taking notes in the lessons, but this time we tried to talk and produce solutions... (Line 56-57)"*. LA2 emphasized that active participation contributed to a better understanding of the course: *"Our teacher does not tell us the answer immediately; he wants us to think first. I understand better when I find my solution (Line 11-12)"*.

Another subcategory identified in the study is that CSI, which is enriched with AL techniques, allows students to engage in cooperative learning. For example, LA1: *“I solved problems with my friends. I did the calculation; a friend checked the result, and we corrected the mistakes with the teacher. This way, it is easy to solve problems... (Line 1-3)”*. HA2 expressed similar statements: *“Everyone had a task in group work. I wrote the data in the table; my friend did the operations. I understood more easily when we worked together (Line 46-47)”*.

Another subcategory determined by considering the students' views is that CSI enriched with AL techniques positively affects the attitude toward learning. HA2 stated that he was no longer bored with the mathematics course and expressed his view: *“I have difficulty learning mathematics, that's what my family says. But since we solve problems with games here, I always want to attend the lessons... (Lines 48-50)”*. The subcategories determined for the category of course participation according to student views are presented in Table 7.

Table 7. Sub-categories determined for the category of participation in the course according to student views

Sub-categories	Students	f
Active participation	MA2-MA1-LA1-LA2-HA2-HA1	6
Cooperative learning	LA1-HA2-MA2-HA1	4
Attitude towards learning	HA2	1

When Table 7 is examined, it is seen that all the students emphasized that CSI enriched with AL techniques provides active participation (f=6). After this subcategory, the most frequently mentioned subcategory is the view that this teaching method provides an opportunity for cooperative learning (f=4). The least frequently mentioned subcategory in this category was the view that the teaching method developed a positive attitude towards learning (f=1).

3.2.2. Views on learning interaction

Three subcategories were identified in the learning interaction category: “Interaction with the teacher”, “peer interaction”, and “tools to supporting mathematical thinking”.

In the learning interaction category, the students stated that the interaction with the teacher guided them in the WPS process. For example, MA2: *“...our teacher does not tell the answer immediately, she first makes us think and then guides us by listening to our thoughts... (Lines 33-35)”*. HA2 emphasized that the interaction with the teacher facilitated the problem-solving process and stated his views as follows: *“...the teacher talks to us after reading the problem. These conversations make it easier for me to understand and solve the problem (Lines 51-54)”*.

Another subcategory identified in the learning interaction category is peer interaction. The students whose views were taken emphasized that the interaction with peers during the WPS process contributed to seeing different solutions to the problems. For example, HA1: “...I learned new ideas as I talked with my friends. For example, I counted the days individually, but my friend subtracted 90 liras and found how many days were left. Her method took less time and made sense to me... (Lines 58-60)”. LA1 on this subject: “...I solved problems with my other friends at the music and art stations. When my friends shared their views, I found the places where I was wrong (Lines 4-6)”.

The students whose views were taken reported that the tools supporting mathematical thinking (e.g., concept maps, graphs, and figures) used in the teaching process in the learning interaction category contributed to understanding the problem in the WPS process. Expressing that using models facilitated problem-solving, MA2 stated the following: “...I understood the problems better thanks to the shapes I drew while solving problems. I still remember the graphs and tables we drew (see Fig. 4) with the teacher in the lesson (Lines 36-38)”. LA2 remembered the concept map, one of the active learning techniques used to solve problems in the lesson: “...I saw which information was missing on the map we drew (see Fig. 4). I liked marking the important information with colored pencils (Lines 15-17)”.

Fig. 4 Examples of WPS of students participating in CSI enriched with AL techniques

The subcategories determined for the learning interaction category according to student views are presented in Table 8.

Table 8. Subcategories determined for the learning interaction category according to student views

Sub-categories	Students	f
Interaction with the teacher	MA1-LA1-LA2-HA2-HA1	5
Peer interaction	MA2-MA1-LA1-HA1	4
Tools to supporting mathematical thinking	LA2-MA2-HA2-LA1	4

When Table 8 is analyzed, all students emphasized that the interaction with the teacher (f=5) within the scope of CSI enriched with AL techniques contributed to the WPS process. After this subcategory, the subcategories most frequently mentioned by the students are the view that the interaction with peers (f=4) and the tools that support mathematical thinking (f=4) also contribute to the WPS process within the scope of this teaching method.

3.2.3. Feedback on the teaching method

Four subcategories were identified in the feedback related to the teaching method: “Strategy use”, “generating alternative solutions”, “using physical manipulatives”, and “classroom discipline”.

The students participating in the study stated that CSI enriched with AL techniques encouraged strategy use. Regarding strategy use, HA1 said: *"...it has changed. Before, I used to add and subtract the numbers I saw and try to reach the result. Now I first make a plan and solve the problem that way (Lines 63-65)"*. Although the students who expressed views did not directly state that they used strategies, their expressions indicate that they used strategies. For example, HA2: *"...our teacher would ask us to ask ourselves questions while reading the problem. I asked myself questions about what I knew and what was missing and answered them myself (Lines 54-55)"*.

Another subcategory identified in this category is the view that CSI enriched with AL techniques contributes to students' generation of alternative solutions. For example, LA1: *"I solved the same problem with the table and multiplication. I reached the same result with both methods... (Lines 7-8)"*. Although MA2, who stated that she could solve the problem more easily when she produced solutions to the problem through models, did not express this clearly, this situation is understood from what she said. MA2 expressed her view (Line 43-45): *"Before, when I read the problems, I immediately added the numbers, but sometimes I was wrong. Our teacher told us to solve the problem by drawing. When we drew it, everything became clearer..."*.

Another subcategory identified in this category is the view that students enjoy using physical manipulatives in CSI enriched with AL techniques. For example, LA2: *"I like the tens blocks very much because they show the magnitude of the numbers better. For example, when I add 30 and 25, I put three tens, and then I add two tens and five ones so I can find the answer by myself. I think these blocks help me not to confuse the numbers in my head."* HA1, another student who expressed an view on this subject, said, *"...I like ice cream sticks very much while solving problems. They help me understand the numbers better. I write the numbers and solve the operations using tens and one's ice cream sticks. Thanks to the sticks, I solve faster and more accurately. It also makes me feel like playing a game, so problem-solving is more fun."* Some examples of the physical manipulatives used by the students at the stations are presented below (see Fig. 5).

Fig. 5 Examples of physical manipulatives used by students at stations

Another subcategory identified in this category is the view that it is difficult to ensure classroom discipline in CSI enriched with AL techniques. HA1, who expressed the only view on this issue, expressed the following views (Lines 66-69): *"The courses were very good, and I had a lot of fun. However, especially when we moved to different stations, I could not hear some topics because our friends made a lot of noise, making me uncomfortable"*. The subcategories determined for the feedback category related to the teaching method according to student views are presented in Table 9.

Table 9. Sub-categories determined for the feedback category related to the teaching method according to student views

Sub-categories	Students	f
Strategy use	MA2-MA1-LA2-HA1-LA1-HA2	6
Generating alternative solutions	MA1-HA1-HA2-LA1	4
Using physical manipulatives	MA2-HA1-HA2-LA2	4
Classroom discipline	LA1	1

When Table 9 is examined, most students whose views were taken emphasized that CSI enriched with AL techniques encouraged strategy use ($f=6$). On the other hand, it was stated that CSI enriched with AL techniques contributed to the students producing alternative solutions ($f=4$). In addition, it was observed that students who used this teaching method enjoyed using physical manipulatives in solving problems ($f=4$). After these subcategories, the subcategory in which the students expressed the least views is the view that this method makes it difficult to discipline the classroom ($f=1$).

4. Discussion

This study's results confirm the studies' findings in the literature on AL and CSI and take the discussions one step further. This study examined the effectiveness of CSI enriched with AL techniques in teaching WPS to primary school students with LD. In addition, the study brought a deeper perspective to the WPS learning process of students with LD.

When the study's quantitative data were analyzed, it was determined that the PSAT scores differed significantly. When the PSAT post-test scores of the students were examined, it was found that there was a significant difference in favor of the group receiving training with CSI enriched with AL techniques. When the study's qualitative data were analyzed, the students' views on CSI enriched with AL techniques in WPS instruction were collected in the categories of course participation, learning interaction, and feedback on the teaching method. From the views of the students participating in the study, it was determined that CSI enriched with AL techniques provided active participation and allowed cooperative learning. In addition, it was found that this teaching method encouraged the use of strategy and generating alternative solutions.

The study's quantitative results show a significant difference between the scores of the experimental and control groups according to the total scores of the students from the PSAT. In other words, it indicates that CSI enriched with AL techniques effectively affects the WPS skills of students with LD. In the literature, many meta-analysis studies report that interventions using metacognitive strategies improve the WPS skills of students with LD (Lein et al., 2020; Myers et al., 2023; Zhang & Xin, 2012). For example, Myers et al. (2023) summarized empirical evidence from 52 experimental and quasi-experimental studies. They found

that metacognitive strategies greatly impacted the WPS skills of primary school students with LD and effectively increased problem-solving accuracy. Myers et al. (2022), in a study examining interventions for students struggling with mathematics in upper primary and secondary school, reached similar results and reported that these strategies improved students' problem-solving skills. On the other hand, studies in the literature indicate that CSI improves the problem-solving performance of students with LD (Morin et al., 2017; Powell et al., 2020; Sharp & Dennis, 2017; Swanson, 2016; Zhu, 2015). Powell et al. (2020) found that memory-supported cognitive strategy (e.g., CUBES, UPSCheck, WIK, and WINK, STAR) training significantly affected the WPS performance of students with maths difficulties. Similarly, Sharp and Dennis (2017) found that the Model Drawing Strategy (MDS) intervention significantly impacted the WPS skills of fourth-grade primary school students. Morin et al. (2017) showed that bar model drawing is an effective strategy to increase the accuracy of primary school students with mathematics difficulties in solving mathematics WPs and their ability to use cognitive strategies to solve problems. However, some studies reported more limited effects of CSI-based interventions. For example, Swanson et al. (2013) found that the effectiveness of CSI varied depending on students' cognitive resources, such as working memory capacity, suggesting that students with more severe learning difficulties may benefit less from these interventions. Similarly, Swanson (2015) demonstrated that the impact of strategy instruction on problem-solving accuracy was moderated by students' working memory capacity. His study revealed that children with mathematics disabilities but higher working memory spans benefited more from strategy instruction than those with lower spans, highlighting that the success of CSI interventions is influenced not only by instructional design but also by individual cognitive differences. Similarly, Freeman–Green et al. (2015) indicated that the duration and intensity of instruction played a crucial role in determining the impact of CSI on WPS skills. These contrasting results highlight that while CSI enriched with AL techniques demonstrates strong effectiveness, contextual factors such as student characteristics, instructional duration, and implementation fidelity may influence outcomes. Therefore, the present study contributes to the literature by providing further empirical evidence that integrating AL techniques into CSI enhances the effectiveness of strategy-based interventions for students with LD, offering a promising instructional approach that balances metacognitive engagement and problem-solving accuracy.

In this study, students who received CSI enriched with AL techniques outperformed the control group on the PSAT, likely due to their progression according to a structured plan, which reduces cognitive load and facilitates problem-solving. This aligns with prior research showing that metacognitive strategies, such as planning, goal-setting, and evaluating outcomes, enhance problem-solving performance (de Blas et al., 2021; Smith & Mancy, 2018). The integration of AL techniques likely amplified these effects, as previous studies indicate that AL improves primary students' critical thinking, reasoning, and problem-solving skills (Bakar & Ismail, 2020; Lopez-Caudana et al., 2020; Nasser Alkathiri et al., 2024). However, mixed findings

in the literature suggest that AL's effectiveness can vary depending on implementation fidelity and student characteristics (Nasser Alkathiri et al., 2024; Polat & Özkaya, 2023), highlighting the importance of contextual factors. Overall, these results underscore that structured CSI enriched with AL techniques can meaningfully enhance problem-solving skills in students with LD, providing both practical and theoretical contributions to the field.

The qualitative results of the research specified which views were expressed more frequently by the six students regarding the categories of course participation, learning interaction, and teaching method. According to the views on course participation, metacognitive education enriched with AL techniques provided active participation and opportunities for collaborative work. AL techniques enabled students to participate actively in the WPS process and provided an opportunity for collaborative work. AL techniques such as snowball, station, and discussion supported students' problem-solving processes. Consistent with our findings, previous research has shown that teaching problem-solving with AL techniques increases interaction and discussion in the learning environment, enables students to participate in the problem-solving process actively, and encourages collaborative skills that contribute to learning (Bakar & Ismail, 2020; Ting et al., 2019). Similarly, Krawec and Huang (2017) emphasized that structured strategy instruction combined with interactive activities enhanced students' engagement in problem-solving tasks. In contrast, Zhu (2015) noted that students who lacked guidance in applying active strategies sometimes struggled to maintain focus during problem-solving, suggesting that AL techniques need to be carefully scaffolded.

Another finding stated by one of the participants is that CSI enriched with AL techniques develops a positive attitude toward learning. Metacognitive skills such as planning, monitoring, and evaluating learning processes positively affect students' attitudes and motivation toward mathematics (Bakar & Ismail, 2020). CSI enriched with AL techniques can improve students' attitudes and motivation toward mathematics by enabling them to plan and evaluate the problem-solving process. This result aligns with Montague et al. (2011), who found that metacognitive strategy instruction improved students' confidence and persistence in solving mathematical problems. On the other hand, Pfannenstiel et al. (2014) reported that without explicit support, students with LD may not fully benefit from such strategies, underscoring the importance of structured and guided implementation. Increasing learning effectiveness is possible with learning environments that allow and encourage students' active participation, and our study demonstrates how AL techniques can provide this support for learners with difficulties.

According to the view on learning interaction, it was concluded that the interaction with the teacher and peers improved students' performance in the WPS process. In other words, the snowball technique used at the planning stage and the discussion techniques used to support teaching at the thinking and analysis stage

improved students' WPS performances. Students with LD sharing their solutions to the problem with the whole class during the WPS process and the discussion environments created may have improved communication and interaction among peers (Coruhlu et al., 2024). In his study, Wang (2020) found that the interaction between teachers and students supports AL, and thus students are more likely to internalize knowledge and reach high-level learning skills. This finding is consistent with Montague et al. (2011), who demonstrated that structured peer and teacher interactions fostered collaborative problem-solving and improved students' mathematical reasoning. Similarly, Krawec and Huang (2017) emphasized that metacognitive strategies such as self-regulation, when supported by interaction, enabled students with LD to plan, monitor, and evaluate the problem-solving process more effectively. On the other hand, Sharp and Dennis (2017) cautioned that peer interaction without sufficient scaffolding may not guarantee successful strategy use, underscoring the importance of teacher guidance during discussions.

According to the students' views, it was determined that the tools supporting mathematical thinking (e.g., concept maps) used in the WPS process supported the understanding of the problem. In other words, concept maps used in the problem comprehension phase improve students' WPS performances. Concept maps help students organize the information and prior knowledge they seek during the learning activity. As stated by various researchers (Çilingir Altiner, 2024; Hwang et al., 2014; Mayer, 2009), concept maps can help students clarify possible misconceptions and understand the derived knowledge from a general perspective. Graphic organizers consisting of metacognitive strategies for remembering and organizing information, such as tables, diagrams, concept diagrams, and maps, are used in strategy teaching. Powell (2011) stated that schematic diagrams used in the WPS process help students to organize their problem-solving activities. Powell et al. (2020), who examined the WP performance of third-grade primary school students and the strategies they used, reported that students with LD frequently used keywords (e.g., UPSCheck) and visuals (e.g., strip diagrams) to represent problems. In line with this, Myers et al. (2023) argued that CSI helps students focus their attention on the conceptual meaning of problems, thereby reducing working memory load through manageable steps. Similarly, Zheng et al. (2013) showed that CSI supports self-regulation by enabling students to divide problem-solving into smaller phases. These results align with our finding that visuals and graphic organizers support WPS performance. However, Zhu (2015) found that without explicit training, some students struggled to transfer visual strategies to new problems, indicating that scaffolding is essential.

According to views on teaching methods, it has been concluded that CSI enriched with AL techniques encourages the use of strategies in the problem-solving process. Considering the different characteristics of students with LD, having different strategies can facilitate problem-solving. In addition, students can eliminate the complexity of the WPS process by using their existing strategies (Witzel & Myers, 2023). On

the other hand, the strategies students use in the problem-solving process can also provide students with flexible thinking skills. In many studies, it has been determined that CSI helps students with LD develop problem-solving strategies (Krawec & Huang, 2017; Pfannenstiel et al., 2015). In their study, Pfannenstiel et al. (2015) stated that CSI contributed to students developing strategies appropriate to problem types and complete problem-solving steps. Krawec and Huang (2017) found that metacognitive and cognitive strategies strengthen students' planning, monitoring, and evaluation skills. The findings in the literature are consistent with the findings obtained in this study.

Some students stated that the teaching method was effective in creating alternative solutions in the problem-solving process. This finding is consistent with previous research emphasizing that strategy diversity fosters flexible thinking and enhances students' ability to approach problems from multiple perspectives (Krawec & Huang, 2017; Witzel & Myers, 2023). Similarly, the snowball technique, in which students share their thoughts and learning, effectively develops different perspectives and solution strategies, aligning with studies reporting that collaborative learning environments promote the exchange of ideas and increase the repertoire of strategies used in mathematical problem solving (Montague et al., 2011; Zhu, 2015). On the other hand, students' engagement with visual representations and patterns during the plan-making phase contributed to creating alternative solutions. This result supports the findings of Sharp and Dennis (2017), who highlighted the role of model drawing and representations in enhancing students' understanding of mathematical problems. However, some studies (e.g., Pfannenstiel et al., 2014) have shown that not all students can effectively utilize visual strategies, suggesting that individual differences may influence the extent to which visual representations contribute to generating alternative solutions. In addition, during the plan implementation phase, students' participation in activities at different stations to solve WPs provided different learning experiences and enabled them to create alternative solutions. This is in line with studies indicating that active learning approaches and station-based teaching improve engagement and support the development of diverse problem-solving strategies (Krawec et al., 2013; Montague et al., 2011).

Some students indicated that they enjoyed using physical manipulatives during the WPS process. Physical manipulatives serve to concretize abstract and complex problem-solving processes, particularly benefiting students with LD by reducing cognitive load and facilitating strategy use. Öztürk (2021) reported that students appreciated engaging with physical manipulatives in metacognitive education, which aligns with the present findings. Similarly, prior research has shown that physical manipulatives positively influence students' affective characteristics, such as motivation and engagement (Bouck et al., 2014). In addition, studies focusing on students with LD have demonstrated that the use of manipulatives can enhance problem-solving success (Authors, 2023). However, not all studies report uniformly positive effects; some research suggests that the effectiveness of manipulatives may depend on instructional guidance and the complexity

of tasks (e.g., Shin et al., 2017), highlighting the need for structured implementation. Furthermore, in studies with typically developing students, manipulatives have also been found to support problem-solving skills, suggesting that their benefits extend beyond students with LD (Albarracín et al., 2022). Overall, these findings indicate that physical manipulatives can be an effective tool for supporting problem-solving, though their impact may vary depending on contextual and instructional factors.

One student said that integrating CSI with AL disrupted classroom discipline and made it difficult to control the classroom. Small group teaching in which students work at different stations according to their interests and participate in problem-solving is a possible reason for this difficulty. In the literature, it has been reported that the cooperative learning method integrated into metacognitive learning disrupts classroom discipline (Erdoğan & Şengül, 2017; Öztürk, 2021). Although the study provides important findings regarding the effectiveness of CSI enriched with AL techniques, it also has certain limitations. First, the sample size was relatively small and limited to third-grade students in Turkey, which restricts the generalizability of the results. Second, students' WPS performances were assessed using conventional measurement tools, which may not fully capture the complexity of their problem-solving processes. In addition, the intervention was applied only to a limited set of learning outcomes and within a specific instructional context. These limitations suggest that caution should be exercised when interpreting the findings. Future studies with larger and more diverse samples, alternative assessment methods, and different mathematical domains could provide a more comprehensive understanding of the effectiveness of CSI enriched with AL techniques.

4.1. Conclusions and future research

The results of the present study showed that CSI enriched with AL techniques had a positive effect on the WPS skills of students with learning difficulties (LD). Quantitative findings indicated significant improvements in problem-solving achievement test scores, while qualitative data revealed that students experienced increased course participation, enhanced learning interactions, and more positive attitudes toward mathematics. The teaching method encouraged collaborative work, the use of diverse strategies, and the generation of alternative solutions, with teacher and peer interactions, as well as tools supporting mathematical thinking, further contributing to students' problem-solving performance. Based on these findings, several recommendations emerge for researchers, practitioners, and policymakers. For researchers, future studies should employ larger and more diverse samples, explore additional mathematical domains, utilize alternative assessment tools to capture the complexity of students' WPS performances, and examine the integration of technology-supported instruction and collaborative learning methods within CSI enriched with AL techniques. For practitioners, especially primary school and mathematics teachers, the study underscores the importance of designing activities that scaffold problem-solving processes through

graphic organizers, visual representations, manipulatives, and station-based exercises, while managing classroom dynamics to maintain engagement and discipline. Emphasis should be placed on fostering structured peer and teacher interactions to support self-regulation, mathematical reasoning, and positive learning attitudes. For policymakers, the findings highlight the value of embedding evidence-based instructional strategies such as CSI enriched with AL techniques into curricula and professional development programs, ensuring that schools have the necessary resources and frameworks to promote inclusive and active learning environments. Collectively, these insights provide a roadmap for enhancing problem-solving skills among students with LD and guiding future research, instructional practice, and educational policy in mathematics education.

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Competing interests

The author declares no competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data can be obtained from the corresponding author if needed. The data associated with the results of this study are not publicly available because they contain information that may jeopardize the confidentiality of the students who participated in the study.

Ethical approval

This study was conducted in accordance with the ethical principles stated in the Declaration of Helsinki and the scientific research ethics guidelines of the Council of Higher Education of Turkey (YÖK). Ethical approval was obtained from the B University Ethics Committee (Approval Number: 251; Session Number:

12) on 24 December 2022. Ethical approval includes the implementation and data collection activities carried out for this study.

Informed consent

After obtaining ethics committee and research permission, written informed consent was obtained from all participants and their legal guardians before starting the application and data collection at the school. Consent was obtained by the corresponding author using a standardized written form signed by each participant and their legal guardian before participating in the study. Informed consent was obtained from the participants through face-to-face interviews with their legal guardians and themselves at the school between 6-10 February 2023. Each participant and their legal guardians were informed about the purpose and scope of the study, their voluntary participation in the study, their right to withdraw from the study at any stage of the study, and the measures taken to ensure anonymity and confidentiality. Consent covered participation in the study, collection of data, use of the data for the purposes of the scientific article, and publication of aggregated findings. All procedures were conducted in accordance with ethical research principles for non-interventional social science studies.

Author contributions

The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

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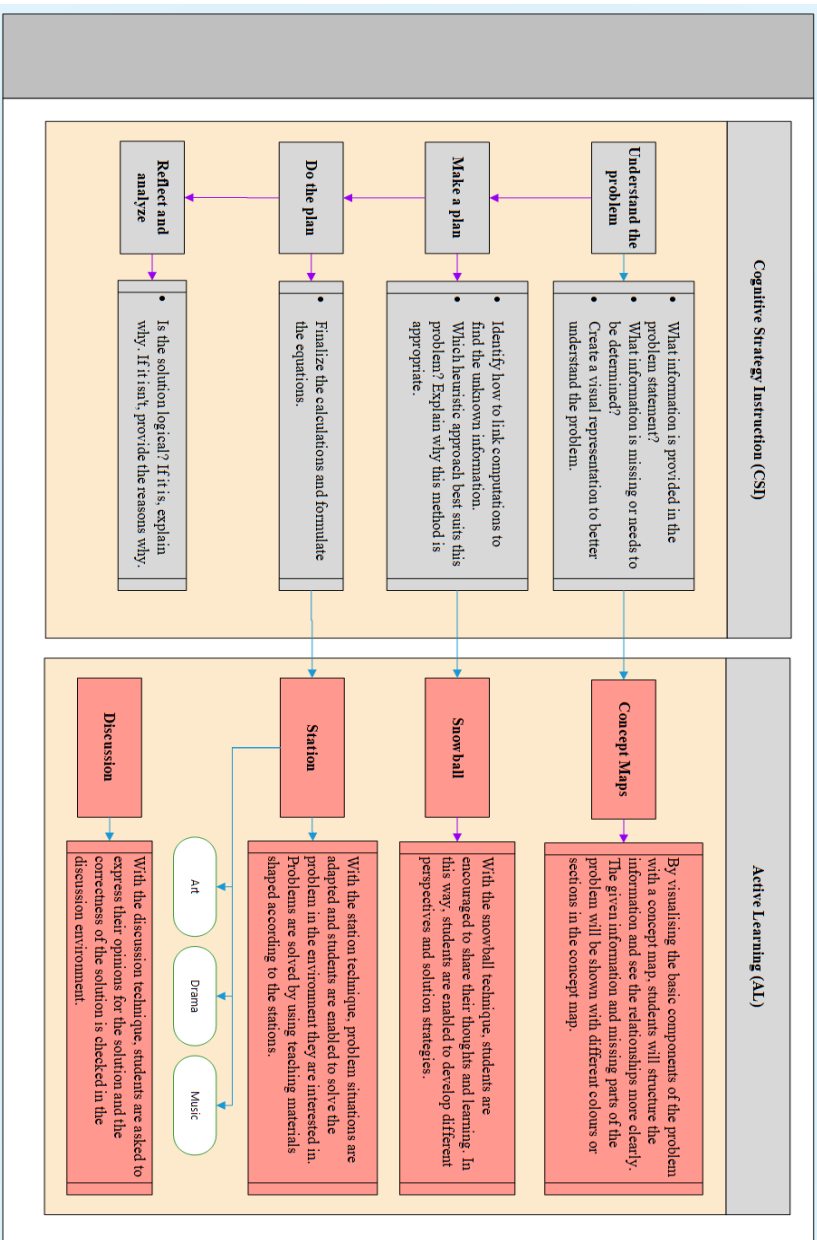
Fig. 1 An example of a worksheet for CSI enriched with AL techniques

Fig. 2 Activities implemented in the experimental and control groups

Fig. 3 Categories and subcategories of word problem solving teaching process

Fig. 4 Examples of WPS of students participating in CSI enriched with AL techniques

Fig. 5 Examples of physical manipulatives used by students at stations



	Experimental group	Control group
Pre-test	PSAT	
Learning process (six week)	Word problems involving addition	
	Students solved addition word problems using cognitive strategy instruction enriched with active learning techniques. They followed the UMDR stages -understanding the problem, making a plan, doing the plan, and reflecting- while using concept maps, visual models, manipulatives, and group discussions. Real-life contexts and station-based activities (Art, Music, Drama) supported students' engagement and mathematical thinking.	Students solved addition word problems using the conventional curriculum as recommended by MoNE, working individually in textbook-based activities without additional strategy instruction or active learning techniques.
	Word problems involving addition and subtraction	
	Students solved addition and subtraction word problems using CSI enriched with active learning techniques. They collaborated in small groups, visualized problem situations, shared solution strategies via snowball discussions, and used concrete and manipulative tools to plan and execute their solutions.	Students solved addition and subtraction problems following the standard classroom teaching and textbook exercises, without collaborative or active learning enhancements.
	Word problems involving multiplication	
	Students solved multiplication word problems through CSI enriched with active learning techniques. They applied real-life scenarios, dramatizations, and visual aids in station-based activities, planned solutions step by step, and reflected on their results in discussion sessions to explore alternative strategies.	Students solved multiplication problems using the conventional teaching method outlined in the curriculum, without additional strategy guidance or active learning components.
Post-test	PSAT	

