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Enhancing mathematical reasoning: role of the search, solve, create, and share learning

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ABSTRACT

The capacity for mathematical reasoning, pivotal in grasping core math concepts, directly shapes a student's success in their mathematical studies. This study aimed to detail and analyzed how the search, solve, create, and share (SSCS) instructional framework impacts mathematical reasoning skills within the context of linear equations. We adopted a quasi-experimental research approach using a non-matching control group design. To gather data on mathematical reasoning proficiency, a validated and reliable essay-type test was employed. Data collection on mathematical reasoning abilities used an essay test instrument that has been valid and is reliable. This research involved 102 eighth grade students whereby they were selected by using a purposive sampling. To measure and describe the effect size, we utilized a specific method, yielding a result of 0.97. The t-test was employed to assess the influence of the SSCS learning model, and the significance value obtained was less than 0.05. The effect size, as determined, stands at 0.97, suggesting a substantial impact. The t-test results underscore a significant relationship between the SSCS learning model and the enhancement of mathematical reasoning abilities. This research delineates a framework for employing the SSCS model to enhance students' mathematical reasoning capabilities. It is evident that such reasoning abilities play a pivotal.

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1. INTRODUCTION

Mathematical reasoning abilities have an important role in understanding and overcoming basic mathematical challenges with intellectual processes involving logic and problem solving [1], [2]. Mathematical reasoning activities are needed in learning mathematics, which will later determine student achievement [3]–[5]. Students who have strong mathematical reasoning abilities tend to show better performance in processing information, solving problems, and making logical decisions [6], [7]. This ability allows them to develop effective strategies in overcoming challenges, thereby being able to handle mathematical problems more efficiently. In addition, with mathematical reasoning abilities, students can have cognitive skills that enable students to use mathematical concepts in everyday [8]. Reasoning abilities in mathematics are essential, as numerous research indicates that a significant number of students continue to demonstrate weak mathematical reasoning capabilities [9], [10]. The limited proficiency in mathematical reasoning is evident from students' incomplete efforts to tackle mathematical challenges based on the associated criteria [11].

Multiple research endeavors indicate that many educational institutions have yet to effectively nurture students' mathematical reasoning skills. Consequently, challenges frequently arise in the cognitive processes engaged in problem-solving [10], [12]–[15]. As a result, students' mathematical reasoning abilities are less developed, and a lack of attention to these abilities leads to repeated errors in problem-solving [16]–[18]. Therefore, theories discussing mathematical reasoning abilities are considered essential to reveal things neglected in the process of learning mathematics. Studies by Rizqi and Surya [19] indicated that capabilities in mathematical logic remain limited. There's a need for enriched educational experiences to familiarize students with problem-solving. Pahrudin [15] also revealed that mathematical reasoning skills require learning motivation to achieve good learning outcomes.

Issues related to mathematical thinking skills have been observed in a school in East Lampung. Through preliminary surveys and discussions with relevant subject instructors, it has become evident that students face challenges in their mathematical logic capabilities. Students cannot find more than one solution to a problem, so they have difficulty thinking about different aspects. Some students still struggle to identify methods to address the issue [18]. In preliminary research on mathematical reasoning skills, the investigators employed a descriptive assessment to gauge students' capabilities in this area. The findings indicated that the students' proficiency in mathematical reasoning remains underdeveloped.

Numerous past researches indicate multiple strategies to address the challenges in students' mathematical reasoning capabilities [20]. Implementing specific teaching frameworks that methodically nurture these reasoning skills in students is one such strategy [21]. There are several such instructional frameworks that have demonstrated success in enhancing students' capacity for mathematical reasoning, namely: i) problem-based learning models, which have proven effective because they can present problems in a learning context that will require higher-level thinking so that they can connect mathematical concepts with mathematical reasoning abilities and problems of everyday life [22]–[25]; ii) the blended learning model combined with a probing-prompting strategy, which has been demonstrated to enhance students' mathematical reasoning abilities [24]; and iii) search, solve, create, and share (SSCS) learning model, which had been proven to improve mathematical reasoning abilities, and can provide new experiences and insights for students [26]. The SSCS learning model, which is centered on student involvement, is an effective approach in improving students' mathematical reasoning skills [27].

This approach emphasizes students' active involvement in the learning process, not just the provision of information by the teacher [28]. With this model, students are given the opportunity to explore concepts and problems independently or in groups, allowing them to build their own understanding, beyond just memorizing. Students are encouraged to explore various problem-solving methods and engage in critical discussions with classmates and teachers [29]. It not only helps in building mathematical reasoning skills but also develops other important skills like critical, teamwork and independence [30]. In addition, the SSCS model supports student character formation. By fostering curiosity and the freedom to explore, students learn to appreciate the learning process and become more motivated to engage [31].

Several studies have been conducted regarding the SSCS learning model, Yasin *et al*. [32] reported that the SSCS approach has been demonstrated to enhance the capacity for mathematical reflection. Meanwhile, according to the research conducted by Zulnaedi *et al*. [33], the SSCS framework demonstrates a favorable influence on students' confidence, subsequently enhancing their capabilities in solving mathematical problems. This teaching approach consists of four distinct stages in its execution. The first phase is the search phase, in which students identify problems. The two phases are problem-solving, planning, and developing information gathering. The three phases are creating, carrying out problem-solving, and formulating the outcomes derived from the problem-solving process. The four share phases, or the final phase, are socializing the results of problem-solving by presenting them in front of the class [34]–[36]. Sugiarti *et al*. [26] found that the SSCS learning model boosts students' math reasoning skills. However, there's a gap: we don't know exactly how each stage of the SSCS model affects these skills. This study aims to fill that gap. We analyze how the SSCS learning framework impacts mathematical reasoning skills in the context of linear equations. Plus, we are providing a detailed guide a storyboard for teachers on using this model in their classrooms. This research is important because good reasoning is a way of understanding mathematical concepts in depth, and our guide aims to help teachers do just that.

2. METHOD

2.1. Research design

This research employs a quasi-experimental approach, utilizing a non-equivalent control group structure. Both the experimental and control groups were chosen through criterion-based sampling due to this method's ability to pinpoint participants with vital attributes or standards necessary for the investigation. The experimental group implemented the SSCS learning model, while the control group implemented the direct instruction learning model. The treatment is carried out only on the learning model, in terms of giving assignments, learning media, and the topics taught. Initially, a pre-test was administered to measure the students' baseline mathematical reasoning abilities. Following the application of the SSCS teaching framework, a subsequent assessment was conducted to ascertain alterations or to assess the efficacy of the approach.

2.2. Participant

Eighth-grade middle school students were the subjects of our research. We chose junior high school students because their cognitive development stage is suitable for testing the effectiveness of the SSCS learning model in enhancing mathematical reasoning skills. Out of the entire population, 102 students were selected using a purposive sampling method, because we aimed to capture a representative group that met specific criteria relevant to our research objectives. Before diving deep into the analysis, we verified the data's normality and homogeneity using SPSS 25, obtaining a significance threshold above 0.05. The normality checks for the intervention group showed a score of 0.096, whereas the control group had a score of 0.128. This indicates a normal distribution for both groups. The homogeneity test generated a significance of 0.321, suggesting that the sample groups had consistent variances. SSCS steps are presented in Figure 1.

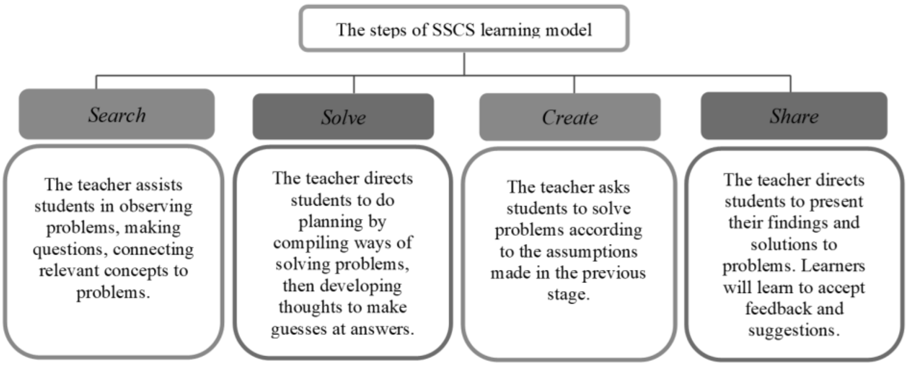


Figure 1. The steps of the SSCS learning model

2.3. Instrument

The study utilized a written examination to assess students' capacity in mathematical reasoning abilities, coupled with an observation checklist to evaluate the applicability of the instructional method. Prior to administering the examination, the tool undergoes evaluations for its validity, reliability, complexity level, and differentiation capability, ensuring the appropriateness of the instrument. Results from the validity and reliability assessment confirm that the instrument is both valid and dependable. The final examination tools encompass 6 questions targeting mathematical reasoning abilities.

2.4. Analyzing of data

In our research, we didn't merely evaluate the hypothesis, but we also utilized the t-test to analyze the differences in the initial and final test outcomes. The choice of using the t-test was based on the premise of data being normal and homogeneous [37]. A preliminary analysis was conducted to ensure these assumptions were met. The t-test is especially apt for assessing the average differences of two separate groups to identify if there exists a notable statistical variance between them.

Beyond the t-test, we determined the effect magnitude to gauge the scale of variance between the pre-test and post-test results. Effect size is a critical indicator as it provides insight into the practical significance of the observed differences. The inclusion of this measurement aids in discerning not just if the differences were statistically significant, but also if they were educationally meaningful. The test for effect magnitude enabled us to determine if the noticeable progress in the final test outcomes was due to the incorporation of the SSCS learning model.

3. RESULTS AND DISCUSSION

3.1. Results

An examination of the abilities in mathematical reasoning was undertaken through the pre-test and post-test stages as shown in Table 1. From the collected data, it's evident that the preliminary score of the group under study surpassed that of the comparison group. During the initial assessment, the group under study secured an average of 73, in contrast to the comparison group's average of 67. The group under study recorded an average of 81 in the subsequent evaluation, while the comparison group's average was 60. The progression in scores between the initial and subsequent evaluations for both groups can be viewed in Figure 2.

In Figure 2, we observe that the mean score after the test for the experimental group surpasses that of the control group. Additionally, the growth in the mean score from the pre-test to the post-test in the experimental group outpaces that of the control group. The enhancement in mathematical logic skills can be discerned by examining the score gains shown in Table 2.

Table 2 indicates a more pronounced score enhancement in the experimental group compared to the control group, as evidenced by the data gathered from both classes. The experimental group achieved an N-gain score of 0.49 for mathematical reasoning skills, while the control group secured a score of 0.33, falling within the medium range. This disparity between the experimental and control groups underscores the efficacy of the SSCS instructional approach in enhancing mathematical reasoning. Subsequent to this, an effect size assessment was conducted, with findings detailed in Table 3.

The SSCS learning model is effective if, after applying this model, there is an increase in mathematical reasoning abilities. From the effect size test results shown in Table 3, the SSCS learning model effectively increases mathematical reasoning abilities. Table 3 displays the effect size in mathematical reasoning ability to obtain a score of 0.97, which falls into the moderate category, indicating that mathematical reasoning ability positively impacts mathematics subjects. This is because the steps in the SSCS learning model encourage students to think at a higher level using their mathematical reasoning abilities.

Table 1. Value of students' mathematical reasoning ability

Data	Experimental class		Control class	
	Pre-test	Post-test	Pre-test	Post-test
Means	68	85	61	75
Max score	85	92	78	88
Min score	47	70	40	60

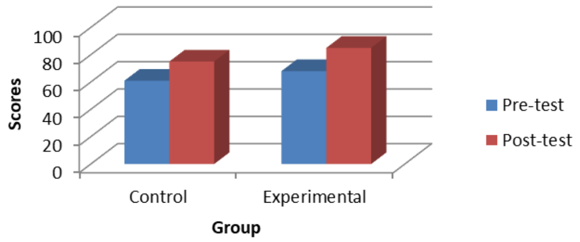


Figure 2. Graph of pre-test and post-test scores improvement

Table 2. N-gain value of mathematical reasoning ability

Data	N-gains		Criteria
	Experimental class	Control class	
Mathematical reasoning ability	0.49	0.33	Moderate

Table 3. Test results test effect size

Variable	Effect size	Standard deviations	Criteria
Mathematical reasoning ability	0.97	159,21	Moderate

3.3. Discussion

Findings indicate that the SSCS teaching framework has an influence on learners' capacity to mathematical reasoning. The impact of the SSCS teaching approach on pupils' academic achievements is evident, and this is intrinsically tied to its structured phases. Each stage of the SSCS framework plays a vital role in shaping the understanding and reasoning capabilities of the students. It's crucial for educators to delve deep into the intricacies of the SSCS method to optimize its benefits. A detailed breakdown of the SSCS methodology stages can be found in Table 4.

Table 4. The storyboard of the sscs learning model is based on mathematical reasoning abilities

SSCS models	Activity	Mathematical reasoning ability indicator
Search 	Explaining material, identifying problems, and asking questions about straight-line equations so that they become a set of ideas.	1. Students understand the material explanation of straight-line equations in terms of line relationships or mathematical models. 2. Students can express material as straight-line equations in writing, pictures, and diagrams, and they understand examples of problem-solving.
Solve 	Directing students to plan alternative solutions to problems that have been found.	3. Students find alleged solutions or ideas for solving problems. 4. Students perform mathematical manipulation in the process of solving problems.
Create 	Ask students to solve problems based on the alleged settlement plans obtained in the previous phase.	5. Students conclude by solving problems written on the worksheet. 6. Students check again the correctness of solving the questions that have been done.
Share 	The teacher directs students to present their findings and solutions to problems.	7. Students explain the proof of problem-solving and present the findings in front of the class. Other students listen and give feedback.

Mathematical reasoning ability is the foundation of learning mathematics, allowing students to understand general concepts that refer to one of the thinking processes used to conclude [38]. Table 3 presents the outcomes from hypothesis evaluation using the magnitude of effect assessment. The SSCS teaching framework was determined to be successful in enhancing students' capabilities in mathematical reasoning. This is because, through the learning process of applying the SSCS model, students can practice their reasoning abilities based on the information they have obtained. During the learning process, students can relate old and new material concepts, considering the material concepts that have been studied. In this educational approach, learners expand their understanding. By utilizing the explicit teaching method, students receive more insights from instructors, which means during the learning process, they are less practiced in addressing challenges with their analytical skills. The outcomes of this research coincide with earlier studies indicating that one crucial skill students should possess is mathematical reasoning [39].

Prior studies concerning the SSCS teaching approach indicated its potential in enhancing problem-solving capacities [40], sharpening critical thinking [31], fostering mathematical literacy, and nurturing self-confidence [41]–[43]. Within the educational context, the SSCS framework guides learners in devising solutions and constructing their understanding. This offers a unique learning experience, emphasizing the enhancement of problem-solving competencies, particularly in the realm of mathematical logic. Table 4 presents an in-depth look at student responses during both the pre-assessment and post-assessment across experimental and control groups, elucidating the variance in their responses post-intervention. dditionally, Table 5 will display sample responses from students exposed to the SSCS learning model as compared to those who experienced direct learning.

Table 5. Examples of post-test answers from the control class and the experimental class

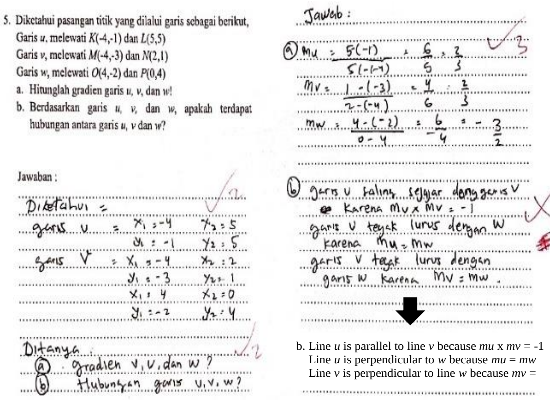
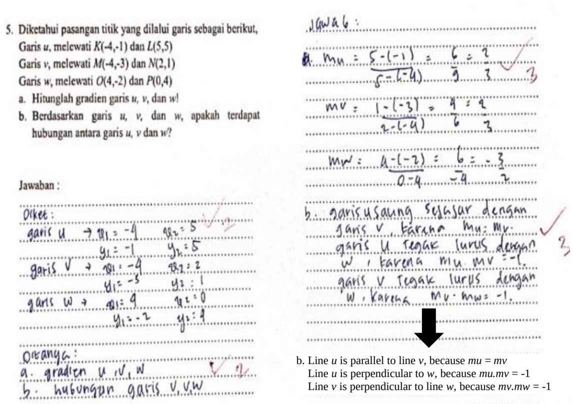
<table>
<tr><th>Control class</th><th>Experimental class</th></tr>
<tr><td colspan="2">Answer:
5. Given the following pair of points through which the line passes,
Line u, passes through K (-4, -1) and L (5,5)
Line v, passes through M (-4, -3) and N (2,1)
Line w, passes through O (4, -2) and P (0,4)
a. Calculate the gradients of lines u, v, and w!
b. Based on lines u, v, and w, is there a relationship between lines u, v, and w?</td></tr>
<tr><td>
b. Line u is parallel to line v because mu x mv = -1
Line u is perpendicular to w because mu = mw
Line v is perpendicular to line w because mv =</td><td>
b. Line u is parallel to line v, because mu = mv
Line u is perpendicular to w, because mu.mv = -1
Line v is perpendicular to line w, because mv.mw = -1</td></tr>
</table>

Table 5 illustrates the variance in responses between the control group students and those in the experimental groups. Prior to implementing the SSCS teaching framework, a majority of the students exhibited errors in problem-solving due to inaccurate analysis. Once two distinct teaching methods were introduced to the respective sample groups, evaluations revealed an enhancement in the students' capability to reason mathematically while tackling problems. Those in the experimental group demonstrated a greater depth and organization in their explanations, leading to improved outcomes. There's a noticeable contrast in the problem-solving approaches when students are exposed to the SSCS teaching framework as opposed to the direct teaching method. This distinction is evident in the manner students pinpointed the issues. For instance, the experimental group students elaborated on "the interrelation of lines u, v, and w" with comprehensive responses rooted in their learned concepts. This indicates superior problem-identification skills compared to the control group.

By assessing the problems tackled by the aforementioned students, it's evident that the group subjected to the teaching method outperforms according to the SSCS model's phases. Participants are adept at recognizing and noting down issues, subsequently strategizing their problem-solving by choosing relevant formulas derived from their initial identification. Following this, students address the problems efficiently and accurately, ensuring tasks are executed flawlessly. During the educational journey, to achieve positive outcomes and advantages in mathematical problem-solving, it's crucial to adhere to a well-structured procedure.

This research has research limitations in the generalization of the sample and subject matter used in the research. As an extension, this research can compare the effectiveness of the SSCS model with other learning methods in developing mathematical reasoning skills. In addition, it would be interesting to examine the influence of improved mathematical reasoning skills on achievement in other subjects, students' learning attitudes and motivation, as well as the integration of technology in SSCS. Long-term and follow-up studies would also be useful to assess the long-term impact of the SSCS model. This approach allows a more comprehensive understanding of the effectiveness of the SSCS model in the context of mathematics education and its overall contribution to education.

4. CONCLUSION

From the analyzed research findings, it's evident that the SSCS instructional framework is potent in enhancing pupils' capabilities in mathematical reasoning. This conclusion is supported by the effect size examination, revealing an efficacy value of 0.97 for the SSCS framework in the medium range, which notably impacts students' mathematical thought processes. The aptitude for mathematical thinking dictates the outcomes in math education. Pupils with proficient mathematical discernment in tackling problems undeniably achieve superior results compared to their counterparts with limited skills in this area. The aspiration is for the SSCS instructional method to bolster such cognitive prowess, fostering heightened engagement during instructional sessions, ensuring optimal academic achievements.

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