

## The impact of problem-solving strategies on correcting mathematical misconceptions: A field study on a sample of high school students

Guenoua Abdellatif <sup>1</sup>, Lekhouimes Kouider <sup>2</sup>, Bellamouchi Abderrazak <sup>3</sup>

<sup>1,2,3</sup>University of El oued, Algeria

Email: [guenoua-abdellatif@univ-eloued.dz](mailto:guenoua-abdellatif@univ-eloued.dz), [lekhouimes-kouider@univ-eloued.dz](mailto:lekhouimes-kouider@univ-eloued.dz),  
[bellamouchi-abderrazak@univ-eloued.dz](mailto:bellamouchi-abderrazak@univ-eloued.dz)

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### Abstract

This study aimed to determine the impact of problem-solving strategies on correcting mathematical misconceptions among high school students. A quasi-experimental research design employing a pre-and-post-test non-equivalent groups design was used. The population of the study involved high school students at Didi Saleh High School in Hassani Abdel Karim Municipality, El Oued, Algeria, during the academic year 2023/2024. Two first-year literary classes, which were taught by the same teacher, were selected. Each class consisted of 24 students. After ensuring equality in the students' baseline mathematical concepts through a diagnostic test at the beginning of the school year, a random selection technique determined which group would be experimental and which would be the control. The experimental group was taught mathematics using a problem-solving strategy, while the control group was taught using the traditional method throughout the first trimester. An achievement post-test, conducted at the end of the first semester, revealed significant differences at the 0.01 significance level between the two groups' means, favouring the experimental group. This led to the conclusion that the problem-solving strategy is effective in correcting mathematical misconceptions among high school students.

**Keywords:** problem-solving strategy; misconceptions; mathematical concepts; high school students.

### I- Introduction

Teaching methods have undergone significant development in recent years due to the rapid advancements in modern technology and its contribution to disseminating educational research and sharing pioneering educational experiences. This has led to the adoption of modern strategies that have enriched the educational process. Among these contemporary teaching strategies is problem-solving, which has increasingly become a cornerstone in education. This strategy emphasizes the interaction between teacher and student during the teaching process and encourages students to think critically (Frejat, 2023). It involves the learner in solving meaningful problems, giving them an active

role in the learning process and providing educational experiences that positively influence their behavior. It is also crucial in achieving the desired cognitive outcomes (Bouchenak, 2021).

If the goal of the educational system is to develop the individual in all aspects of personality, knowledge, skills, and abilities, and to enhance the quality of learning inputs and outputs across various educational stages, then the steps towards this development begin with selecting appropriate and effective teaching strategies. These strategies should consider the learner's position as central to the educational process, shifting from the logic of teaching to the logic of learning. This learning-centered approach is based on the learner's active engagement, taking into account their characteristics, psychological traits, and developmental needs. Furthermore, these modern strategies consider the individual differences among learners, encourage active participation in the lesson's progression, and promote interaction among learners, all of which contribute to correcting misconceptions. These misconceptions refer to the mental perceptions, knowledge, and ideas held by learners about certain concepts and phenomena that do not align with accurate scientific explanations (Al-Naga, 2011). The difficulties in learning concepts often stem from the unstructured or developmentally inappropriate presentation and transfer of information and knowledge, which can pose challenges in the future when dealing with these concepts. For instance, an elementary school student may struggle with abstract concepts due to significant difficulty, while a high school student, who is capable of handling abstract concepts, may still face challenges when information is presented in a disorganized or disconnected manner. This disorganization hinders their ability to gather data and derive the underlying concepts and principles, leading to the formation of misconceptions (Al-Shukri, 2016).

Mathematics is considered one of the branches of knowledge and serves as a universal and comprehensive symbolic language. It is one of the most important educational activities provided to students across all educational stages. However, it has been observed that many students encounter difficulties in mathematics, to the extent that learning difficulties in mathematics are among the most significant learning challenges (Qasmiya, 2017). One of the main obstacles to learning mathematical concepts is the acquisition of incorrect mathematical concepts, which requires the selection of the most appropriate teaching strategy for correction. Therefore, the importance of this study lies in the fact that correcting mathematical misconceptions contributes to acquiring more knowledge and academic achievement for students, as well as selecting strategies that ensure the quality of the educational process. Moreover, numerous studies have shown that students at all educational levels have misconceptions about mathematical concepts (Al-Khuzaim, 2021).

Some studies have confirmed the effectiveness of problem-solving strategies, highlighting their significant impact on achieving learning objectives, as described in Bouchenak's (2021) study. Therefore, the aim of our study is to investigate the role of problem-solving as a modern teaching strategy in correcting students' mathematical misconceptions. As a teaching method that aims to develop intellectual and performance skills, problem-solving holds great importance in science education, providing an environment conducive to applying this strategy. It allows learners to practice solving problems related to their environment, community, or practical life, using a scientific approach based on familiar facts and theories. Additionally, this strategy has a positive effect on

students' academic achievement (Gasmi, 2017). In teaching mathematics, this strategy emphasizes thought-provoking questions and focuses on finding and obtaining correct answers (Belalia & Jenad, 2021). The results of some studies have shown a positive impact of teaching strategies, such as the conceptual change strategy, in correcting common mathematical errors, both conceptual and procedural (Al-Rifai, 2018). Furthermore, Bellamouchi's (2016) study found that cooperative learning strategies are effective in improving the mathematics outcomes of students who are academically weak in this subject. These strategies also effectively solve mathematical problems and enhance students' arithmetic skills (Omran, 2013). This significantly influences their attitudes towards mathematics and achievement in the subject (Hossain & Termizi, 2013). Moreover, the higher-level learning strategy is effective in raising academic achievement in mathematics (Guenoua et al., 2021). Since it is not sufficient to merely diagnose misconceptions, it is necessary to correct them. Many recent teaching strategies, as noted in Zaitoun's (2004) study, have focused on scientifically sound and accurate understanding. Among these strategies are conceptual change strategies such as cognitive conflict, analogies, discussion, scientific demonstrations, general constructive teaching models, metacognitive strategies, and bridging strategies. Our study proposes problem-solving as another strategy. This leads us to the following question: How effective is the problem-solving strategy in correcting mathematical misconceptions among first-year high school students?

Based on this question, a research hypothesis can be formulated as follows: The problem-solving strategy is effective in correcting mathematical misconceptions among first-year high school students.

Following the above-stated research hypothesis, the statistical hypothesis is formulated as follows: There are no statistically significant differences between the experimental group and the control group in the mean scores of the achievement post-test of mathematics.

## **1. Concept of Problem-Solving Strategy**

Problem-solving is a mental process where an individual utilizes all available knowledge, skills, past experiences, and acquired abilities to address unfamiliar situations to restore a lost state of balance or to clarify the ambiguity or danger arising from a problematic situation. The concept of problem-solving can also refer to the effort exerted by an individual to achieve a goal without having a ready-made solution (Said, 2007). It presents a challenge for the individual in the face of a situation or question that requires a solution (Al-Humaydi, 2005).

Shaheen (2010) defines it as an instructional plan that provides learners the opportunity for scientific thinking, whereby students confront certain problems, plan to investigate and address them, gather and organize various data, and draw their conclusions.

Problem-solving is one of the fundamental strategies in student-centred activities, relying on activating students' cognitive environment, recalling their prior experiences, building new knowledge, and acquiring new concepts. As a teaching strategy, problem-solving involves multiple processes and activities, adhering to a set of core principles (Shaheen, 2010).

In education, the problem-solving strategy allows learners to understand problems, develop steps to solve them, and use acquired knowledge to find the most effective solutions. This strategy helps students develop critical and creative thinking skills and encourages teamwork. Many studies have demonstrated its effectiveness in academic achievement across various subjects, including physics (Al-Jubouri, 2010) and mathematics (Gasmi, 2017). The strategy is also effective in solving mathematical problems (Frejat, 2023) and has even shown benefits in enhancing students' physical coordination and flexibility (Fawzi, 2021). These findings, among others, have led to the widespread adoption of this strategy in education, with its practice becoming increasingly common (Al-Sharaa and al., 2018).

### **1.1 Features of Problem-Solving Strategy**

The problem-solving strategy provides students with the opportunity to discover information independently rather than receiving it passively from various sources such as teachers or textbooks. This approach makes the learner a knowledge producer rather than a knowledge consumer. It emphasizes cognitive processes over merely imparting knowledge, focusing on analysis, interpretation, description, observation, and other mental operations aimed at development.

This strategy fosters students' individuality, making them more inclined to engage in new experiences, accept new knowledge, and seek exploration, innovation, and criticism. It trains learners on how to think, organize thoughts, and manage discussions, thus aligning with real-life applications. Facing and solving problems through the use of accumulated knowledge and life experiences prepares students for life challenges. Additionally, this strategy enhances critical and constructive thinking, strengthens the teacher-student relationship, and fosters a collaborative learning environment.

Problem-solving strategies prioritize thought-provoking questions over merely finding correct answers, encouraging students to be vigilant and self-assess their work while providing them with feedback (Belalia & Jenad, 2021). The findings of Al-Qaisi's (2007) study indicated improved student performance in mathematical reasoning when lessons were planned using problem-solving strategies. This approach helped clarify concepts and issues for students, enabling them to apply higher-level cognitive skills and infer learned mathematical concepts. It also maintained students' motivation towards learning mathematics (Hassan & Abduljawad, 2023).

### **1.2 Principles of the Problem-Solving Strategy**

As a student-centered strategy, problem-solving primarily focuses on activating students' cognitive roles by recalling their prior knowledge and experiences to acquire new knowledge and construct new concepts. The strategy involves multiple processes and activities, adhering to several key principles. These include enhancing learning motivation by linking learning to real life and ensuring that students perceive its relevance. The strategy emphasizes processes such as prediction, hypothesis formulation, testing, selection, generalization, and verifying the plausibility of solutions. It also provides students with opportunities for communication through problem analysis, prediction of solutions, formulation and study of these solutions, and deriving and documenting outcomes.

Problem-solving can be applied both individually and collectively, with an emphasis on independence in reaching a solution through hypothesis formation, testing, and expectation building. Students engage in prediction sessions and derive generalizations related to the problem, which they can apply in other situations. This strategy encourages students to benefit from one another, discuss their ideas and conclusions, and requires them to create and present a work plan as part of their performance portfolio. Finally, students must discuss, present, and defend their findings (Shaheen, 2010).

## 2. Misconceptions

Misconceptions are defined as mental perceptions, knowledge, and ideas present in the learner's cognitive structure regarding certain concepts and natural phenomena that do not align with scientifically accurate explanations (Al-Naga, 2011). According to Khataibeh (2005), a misconception is a label supported by constructivists, referring to an unacceptable interpretation of natural phenomena, not necessarily incorrect, offered by the learner as a result of life or educational experiences. It reflects a disruption in the organization of experiences, even though it stems from active, constructive, and deliberate processes (Ismail, 2023). When the learner's mental representations and knowledge do not align with the scientifically agreed-upon understanding, the learner possesses misconceptions about scientific concepts (Ismail, 2023).

### 2.1 Mathematical Misconceptions

A mathematical concept is expected to meet the following criteria:

- It should be a term or symbol with a verbal definition.
- It should be an abstraction of common characteristics from a set of dissimilar facts or situations.
- It should be broadly applicable, not limited to a specific situation but relevant to all situations within a given set (Al-Mashhadani, 2011).

Mathematical concepts can be categorized into several types:

- **Semantic Concepts:** These are concepts used to denote something, such as a true statement. Each concept defines a set of things and is associated with it; for instance, the set associated with the concept of a natural number is  $\{0, 1, 2, 3\}$ .
- **Descriptive Concepts:** These define a set of specific properties for a group of things, and they are not semantic concepts, such as the concept of truth or continuity in mathematical statements.
- **Sensory and Abstract Concepts:** Sensory concepts refer to things that can be observed and measured, such as geometric tools, while abstract concepts, like functions and numbers, cannot be directly observed.
- **Individual and General Concepts:** Individual concepts have a single-element set, such as the number **1** or the concept of a ratio. General concepts refer to sets with multiple elements, such as natural numbers or negative numbers.

Additionally, mathematical concepts include pure mathematical concepts, symbolic concepts, applied concepts, concepts related to sets, concepts related to procedures, and concepts related to relationships, such as equality, comparison, and order, as well as concepts related to mathematical structures, like commutativity, associativity, identity elements, and inverse elements (Al-Shukri, 2016). Misunderstanding mathematical concepts is a preliminary stage in identifying learning difficulties related to these concepts.

When an individual comprehends the meaning of a concept, they integrate it into their cognitive structures, recalling it in similar new situations. The meaning of the concept is formed primarily through learning the distinctive attributes of the concept via representative examples. This is closely tied to the learner's cognitive structures. When the learner encounters a similar educational situation, they recall the concept's meaning from their cognitive structures. If this meaning is unclear, the learner provides an unacceptable interpretation (a misconception) of the concept. As a result, the concept's meaning becomes unclear and non-functional, leading to what Novak refers to as an unacceptable state in concept learning. Bruner emphasized that the key to acquiring a concept is to list its attributes and distinguish between examples and non-examples. Learning difficulties arise when the learner cannot distinguish between examples and non-examples, often due to pre-existing misconceptions about the mathematical concept (Al-Shukri, 2016).

## 2.2 Sources of Mathematical Misconceptions

The sources of misconceptions can be identified as follows:

- Contradictions arising from students relying on intuition to interpret scientific phenomena.
- Discrepancies between daily observations of objects and scientific concepts.
- Contradictions between students' general language and the scientific language used by teachers.
- Contradictions between the nature of a concept as understood by students and how it exists scientifically.
- Non-curricular education from various media, textbooks, and the simplistic models used in teaching (Khataibeh, 2005).

To correct these mathematical misconceptions at different educational levels, appropriate teaching strategies must be employed. Numerous studies have examined these strategies and their effectiveness in correcting mathematical misconceptions. For instance, Salem (2011) demonstrated the effectiveness of using concept maps as a strategy to correct mathematical misconceptions among second-year middle school students.

Furthermore, Prediger's (2008) study conducted in Germany revealed the impact of mental constructivist models on correcting misconceptions related to fractions and their multiples. This study found that there were many misconceptions among students in earlier grades, which were corrected using mental constructivist models, leading to a deep conceptual change in their understanding.

## II - Method and Tools

This study was conducted in Didi Saleh High School in the district of El Oued (Algeria) from September to December, during the first trimester of the school year 2023/2024. Research methodologies in educational studies vary depending on the topics and scientific fields. Since our study aims to investigate the effectiveness of problem-solving strategies in correcting misconceptions among high school students, it examines the effect of the independent variable on the dependent variable. Thus, a quasi-experimental method is suitable for such studies. We chose a design with two groups: an experimental group that was taught using the problem-solving strategy and a control group that was taught using the traditional method. Both groups were taught by the same teacher, with pre- and post-tests.

The research sample consisted of 48 first-year high school students who were divided into two groups of 24 students each. We calculated the equality in achievement based on the diagnostic test of prior knowledge in mathematics, using a T-test for differences. The results were as follows:

**Table 1.**

*Equality of the Two Groups in the Diagnostic Test of Acquired Mathematics Knowledge*

Group	N	Mean	Std. Deviation	T-Value	Sig.	Decision
Group 1	24	5.91	2.46	0.166	0.869	Not significant at 0.05
Group 2	24	5.79	2.75			

As observed in Table 1, the significance level of the differences between the mean of Group 1 and the mean of Group 2 corresponding to the T-value for homogeneity is not significant at 0.05. This indicates that there are no significant differences in the mathematics scores between the two groups. After confirming the equality of the two groups, the random assignment was conducted by drawing lots to determine which group would serve as the control and which would be the experimental group. The results were as follows:

**Table 2.**

*Sample Distribution*

School	Class Group	Boys	Girls	Total	Group Type
Didi Saleh High School	1 J M Arts 1	8	16	24	Experimental Group
Didi Saleh High School	1 J M Arts 2	7	17	24	Control Group

The tools employed in this study included a diagnostic test and an achievement test. The diagnostic test was used to assess students' prior knowledge of mathematics. This test, administered during the first week of the school year, covers various subjects and is designed to measure the basic competencies and prior knowledge of students in each subject. The test was developed collaboratively by different teachers under the supervision and participation of subject-matter experts, tailored to the academic level and specialization. Coordination was made with the teacher assigned to teach both groups 1 and 2. Group 1 was taught throughout the first trimester using the problem-solving strategy,

while Group 2 was taught using the traditional method. The study also utilized an achievement test conducted at the end of the first trimester.

In our research, we used means, standard deviations, Independent Samples t-test, and Eta-squared to determine effect size. Statistical analysis was conducted using the SPSS software package.

### III - Results and Discussion

To test the hypothesis, "There are no statistically significant differences between the experimental group and the control group in the mean scores of the achievement post-test of mathematics," we calculated the T-test value for the differences in the achievement test scores between the experimental and control groups. Additionally, we calculated the Eta-squared coefficient to measure the effect size, aiming to assess the effectiveness of the strategy. The results were as follows:

**Table 3.**

*T-Test Value for Differences between the Experimental and Control Groups in Post-Test Achievement Scores and Eta-Squared Effect Size*

Group	N	Mean	Std. Deviation	T-Value	Sig.	Decision	Eta-Squared
Experimental Group	24	11.83	3.18	3.02	0.004	Significant at 0.01	0.166
Control Group	24	08.93	3.43				

Table 3 above shows that the difference between the mean of the experimental group and the mean of the control group is statistically significant at 0.01. Therefore, we reject the null hypothesis and maintain the alternative hypothesis, which states that there are statistically significant differences between the mean scores of the post-test in mathematics for the experimental group and the control group. This is because the mean score of the experimental group is higher, indicating the effectiveness of the problem-solving strategy in correcting mathematical misconceptions. Additionally, the table shows that the Eta-squared coefficient is 0.166, and compared to the explained variance criterion, it indicates a significant impact of the problem-solving strategy in correcting mathematical misconceptions.

After testing the study hypothesis, which asserts the effectiveness of the problem-solving strategy in correcting mathematical misconceptions, it is confirmed that this strategy is effective. It engages learners' interest and creates a sense of curiosity, which drives them to recognize their mistakes and build correct concepts by acquiring mental skills such as hypothesizing, observing, and conducting experiments to reach correct conclusions, refute misconceptions, build targeted competencies, and achieve educational goals.

This conclusion aligns with the study by Bouchenak (2021), which found that this strategy significantly contributed to achieving learning objectives. It also concurs with the results of Al-Qaisi's (2007) study, which found that the problem-solving strategy helped students clarify the connections, concepts, and issues they possessed, enabling them to employ higher-order thinking skills and infer the mathematical concepts learned. Since the problem-solving strategy is one of the strategies based on constructivist ideas, and the constructivist model, as Snyder argues, relies on teaching strategies that confront learners with problems related to their lives and environment, this study also agrees with

Prediger's (2008) study, which revealed the impact of mental constructivist models in correcting misconceptions related to fractions and their multiples. The study concluded that there are many misconceptions among students in previous grades, and that this strategy was effective in correcting their misconceptions and deepening the conceptual change that occurred in them.

This result can be interpreted as evidence that the problem-solving strategy is an effective approach to teaching mathematics for correcting mathematical misconceptions. By engaging students in problem-solving activities, they may become more aware of their mistakes and the misconceptions they have acquired. This awareness drives them to develop more effective problem-solving strategies, which can lead to increased self-confidence, improved academic performance, and greater competence in problem-solving. Problem-solving strategies are thus a powerful tool for overcoming errors in learners. As students become more aware of their thinking patterns and errors, as explained by Hassan and Abduljawad (2023), they are better equipped to identify and correct them.

This strategy is essential in teaching mathematics, especially since many students lack problem-solving skills. By utilizing this strategy, students can become more proficient in solving mathematical problems, enhancing their cognitive performance, correcting their misconceptions, and ultimately improving their learning outcomes.

#### **IV- Conclusion**

Our study concluded that the problem-solving strategy is highly effective in correcting mathematical misconceptions among first-year high school students. This strategy avoids providing knowledge to the learner in a ready-made form, instead, it views knowledge as a process of discovery and construction by the students themselves. This approach helps students become accustomed to and proficient in research methods, fostering creativity, innovation, analysis, critical thinking, self-awareness of errors, and finding possible solutions to correct them. Based on the study's results, we can offer the following recommendations:

- Urge the Ministry of National Education to incorporate the problem-solving strategy into the mathematics curriculum and other subjects due to its effectiveness in correcting misconceptions that hinder student learning.
- Utilize this strategy across different educational levels and stages.
- Develop a training schedule for various educational staff at all levels to master this strategy and understand its effectiveness in correcting learning errors.
- Reconsider the teaching methods currently used in the educational system, as they are often traditional practices, and it is necessary to adopt such innovative strategies.

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