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Enhancing Students' Algebraic problem-solving skills through multi-step equations

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Abstract

Aim: This study examined the effectiveness of multi-step equations as an instructional strategy for enhancing students' algebraic problem-solving skills. The research aimed to determine whether structured problem-solving instruction can improve students' mathematical reasoning and performance in algebra.

Methodology: The study employed an experimental research design using a pretest–posttest control group approach. Sixty public secondary school students were divided into experimental and control groups. The experimental group received instruction using the multi-step equation strategy, while the control group was taught through conventional teaching methods. Data were analyzed using descriptive statistics, including mean and standard deviation, and inferential statistics through the t-test.

Results: The findings revealed that both groups demonstrated comparable performance in the pretest, indicating similar baseline algebraic problem-solving abilities. After the intervention, the experimental group showed a substantial improvement in posttest scores, achieving a very satisfactory level of performance, while the control group maintained a fair level with minimal improvement. Statistical analysis indicated a significant difference between the pretest and posttest scores of the experimental group.

Conclusion: The results demonstrate that the use of multi-step equations as an instructional strategy significantly improves students' algebraic problem-solving skills. Structured and sequential problem-solving approaches enhance students' conceptual understanding and procedural fluency in algebra, suggesting that such strategies can be effectively integrated into mathematics instruction to strengthen students' analytical and reasoning abilities.

Keywords: *algebraic problem-solving, multi-step equations, mathematics instruction, problem-solving strategies, secondary education*

INTRODUCTION

Algebraic problem-solving is essential in mathematics education, especially for junior high students as they begin abstract thinking (Baidoo & Ali, 2023). Algebra builds skills such as relationship analysis, modeling real-world scenarios, and logic, all of which are vital for academic and daily decision-making. Many grade-school students struggle with multistep algebraic problems, often due to weak foundational skills and difficulty understanding implied operations or structuring solutions (Pourdavood et al., 2020). Challenges also include difficulty with inverse operations, maintaining equation balance, and following steps, resulting in limited improvement in algebra grades (Adeniji & Baker, 2023).

Traditional teaching often focuses on isolated steps rather than problem-solving skills. Lacking coherence and progression, teachers may overlook how multi-step equations confuse students (Salani & Jojo, 2022). Used as a problem-solving strategy, multi-step equations help students reason, order, and repeatedly apply algebraic tools. This approach breaks down complex problems so students can solve each part individually to reach a solution (Jahudin & Siew, 2023).

In the Philippine context, students face significant challenges in mathematics, particularly in algebraic problem solving. PISA results show the Philippines ranked among the lowest-performing countries in mathematics, with scores of 353 in 2018 and 355 in 2022, well below the OECD average of around 470. Over 80% of Filipino students did not reach the minimum proficiency level (Level 2), indicating serious difficulty with multi-step and real-world problems.

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These findings underline the need for more effective, context-specific instructional strategies to strengthen students' algebraic problem-solving skills. Although problem-solving is emphasized in the K to 12 curriculum, it is underutilized in the classroom, affecting overall comprehension of algebraic concepts. This study focuses on multi-step equation instruction through integrated pedagogical scaffolding, aiming to address gaps in the literature and practice of teaching multi-step equation solving.

This study investigates how using multi-step equations as a teaching strategy can strengthen students' algebra problem-solving skills. The strategy uses instructional supports, such as guided instruction, practice, and reflection, to promote accuracy and confidence in solving algebraic equations.

Review of Related Literature and Studies

Effectiveness of Problem-Solving Frameworks in Algebra Learning

Algebraic problem-solving is a well-recognized mathematical field in educational research that requires mastery of both core concepts and procedural fluency (Hyland & O'Shea, 2022). Research shows that students who understand interrelationships among mathematical operations outperform those who depend mainly on procedural memorization (Ho, 2020). Conceptual knowledge enables learners to interpret problems in multiple ways and consider various solution methods (Hurrell, 2021).

Recent research shows that applying systematic problem-solving frameworks improves student outcomes in algebra (Baidoo, 2025). Such frameworks help students organize their thinking and minimize errors on complex problems (Fadzil et al., 2025). Multi-step equations are a problem-solving strategy that requires logical mathematical operations.

Algebra problem-solving enhances students' metacognition by encouraging them to reflect on and assess their own problem-solving processes. Such approaches are central to the emerging student-centered paradigm, in which students actively construct their knowledge. This highlights the value of multi-step problem-solving and structured methods across the continuum of algebra instruction.

Multi-Step Equations as an Effective Instructional Strategy

There is considerable evidence in the literature suggesting that students experience challenges in problem-solving when they do not receive guidance on the organization and order of their solution steps (Fadzil et al., 2025; Qetrani et al., 2021). Mistakes and miscalculations occur with relative frequency when students attempt to solve problems without a framework or structure (Vo et al., 2024). The instruction that most effectively addresses these challenges is paired with explicit step modeling and guided practice. The instruction of multi-step equations as a strategy is most likely to promote students' emphasis on the problem-solving process rather than merely on obtaining the correct answer.

This method improves their problem analysis capabilities, solution operations, and solution verification skills. It also strengthens their metacognition skills, as students need to think critically about their answers after solving each step of a problem (Reyes & Reyes, 2024). Research on instructional interventions has shown that teacher-directed approaches increase students' involvement and achievement. Clear step-by-step instructions and regular repetition build problem-solving self-reliance and self-assurance (Moleko, 2021). Such evidence reinforces the effectiveness of defined methods, like multi-step equations, in developing algebraic competencies.

Using an example from the previous section, we can see how multi-step equations encourage the development of metacognitive capabilities, as students must evaluate how far they have come, validate each step, and justify the answer they provide at the end of the process. Such an approach is consistent with modern educational standards that prioritize self-regulated learning and critical analysis as the primary goals of teaching. Therefore, multi-step equations serve the dual purpose of being content to be learned and as a deliberate means to promote more sophisticated levels of mathematical insight.

Synthesis and Research Gap

The existing literature consistently shows that guided problem-solving approaches, conceptual understanding, and structured instruction significantly improve students' algebraic performance and engagement. Several studies show that breaking problems into manageable steps reduces cognitive load and enhances accuracy, helping learners handle complex algebraic tasks. However, some studies emphasize general problem-solving heuristics, while others argue that without explicit and systematic instruction, students still struggle to apply these strategies independently, revealing a contradiction between strategy exposure and actual skill mastery. Moreover, while prior research strongly supports the effectiveness of structured and scaffolded instruction, it tends to treat multi-step equations as part of broader algebra

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topics rather than as a focused instructional strategy. This limits deeper insight into how sustained emphasis on multi-step problem structures can directly influence learners' higher-order thinking skills. Critically, there is also a lack of classroom-based and action research that examines the practical implementation and effectiveness of such targeted strategies in addressing diverse learner difficulties. Hence, despite general agreement on the importance of structured approaches, the literature reveals gaps in specificity, application, and empirical validation, underscoring the need for studies that explicitly investigate multi-step equations as a central pedagogical intervention to strengthen algebraic problem-solving competencies.

Theoretical Framework

The study is underpinned by constructivist learning theory, which posits that learners actively construct knowledge through meaningful engagement, prior experiences, and reflective thinking. This theoretical lens directly guided the research design by structuring the intervention around student-centered, scaffolded activities where learners progressively solved multi-step equations through guided practice, collaborative tasks, and reflection. In this way, the multi-step equation strategy operationalized constructivist principles by allowing students to build understanding step-by-step, connect prior knowledge to new concepts, and actively engage in sense-making rather than passively receiving procedures. Furthermore, data interpretation was anchored on constructivist assumptions by analyzing how students demonstrated improved conceptual understanding, reasoning, and independence in solving problems as evidence of knowledge construction.

In parallel, the study was also anchored in Polya's Problem-Solving Theory, which provided a clear procedural framework for both instruction and analysis. The multi-step equation strategy was explicitly aligned with Polya's four stages. This alignment guided the design of learning tasks, ensuring that each activity reinforced a systematic problem-solving process. In interpreting the results, improvements in students' performance were examined in relation to their ability to follow these stages effectively.

Conceptual Framework

This research is based on the hypothesis that teaching multi-step equations as an instructional method positively affects students' performance in solving algebraic problems. The independent variable in this case is teaching multi-step equations, which in this context provides students with a methodical means to solve algebra problems. The dependent variable is a student's performance on solving algebraic problems, which is determined by the difference between the pre- and post-test means. The framework also examines the impact of teaching on learning. The experimental group is taught the multi-step equation strategy, and the control group is taught using a conventional method. The difference in scores attained by the two groups measures the effectiveness of the teaching method.

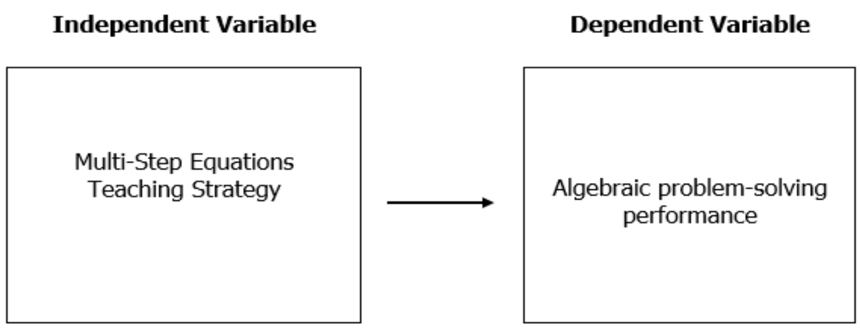

Figure 1. Research Paradigm

Statement of the Problem

Students' ability to solve algebraic problems remains a significant concern in mathematics education, particularly when tasks involve multi-step equations requiring logical reasoning, conceptual understanding, and procedural accuracy. Many students struggle to sequence operations correctly, apply inverse operations, and maintain equation balance when solving algebraic problems. These difficulties often result from limited conceptual understanding and insufficient exposure to structured problem-solving strategies in mathematics instruction.

Despite the emphasis on higher-order thinking skills within the mathematics curriculum, traditional teaching approaches frequently focus on isolated procedures rather than guiding students through structured reasoning processes. As a result, students may experience confusion when solving complex algebraic problems that require

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multiple steps and logical organization. The lack of systematic instructional scaffolding can hinder the development of students' algebraic problem-solving skills and overall mathematical proficiency.

Given these challenges, there is a need to explore instructional strategies that support structured and sequential problem-solving processes. Multi-step equation instruction provides a framework that encourages students to analyze problems systematically, apply appropriate operations, and verify solutions through logical reasoning. Therefore, this study investigates the effectiveness of using multi-step equations as an instructional strategy in improving students' algebraic problem-solving skills. Specifically, the study compares the performance of students taught using the multi-step equation strategy with those taught through conventional teaching methods. By examining students' pretest and posttest scores, the study aims to determine whether structured instruction through multi-step equations significantly enhances students' ability to solve algebraic problems.

Research Objectives

General Objective

To determine the effectiveness of multi-step equations as an instructional strategy in enhancing students' algebraic problem-solving skills.

Specific Objectives

The study aimed to:

1. Determine the pretest algebraic problem-solving mean scores of students in the control and experimental groups.
2. Determine the posttest algebraic problem-solving mean scores of students in the control and experimental groups.
3. Determine whether a statistically significant difference exists between the pretest and posttest mean scores of students in the control and experimental groups.

Research Questions

The study sought to answer the following questions:

1. What are the pretest algebraic problem-solving mean scores of students in the control and experimental groups?
2. What are the posttest algebraic problem-solving mean scores of students in the control and experimental groups?
3. Is there a statistically significant difference between the pretest and posttest mean scores of students in the control and experimental groups?

Hypotheses

H_0 (Null Hypothesis)
There is no significant difference between the pretest and posttest mean scores of students in the control and experimental groups.
H_1 (Alternative Hypothesis)
There is a significant difference between the pretest and posttest mean scores of students in the control and experimental groups.

Methodology

Research Design

This study used a quasi-experimental pretest–posttest control-group design. The design enabled the researcher to examine the effectiveness of multi-step equations as an instructional strategy in enhancing students' algebraic problem-solving performance. Two groups of students were involved in the study. The experimental group received instruction using the multi-step equation strategy, while the control group received instruction using the traditional method. Both groups were administered a pretest prior to the intervention to determine their initial level of performance and a posttest after the intervention to measure improvement. The design allowed for comparison within groups through pretest and posttest scores and between groups through posttest performance. This approach provided a basis for determining whether the observed changes in performance could be attributed to the instructional strategy.

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Population and Sampling

The study population consisted of 60 Grade-level students enrolled in a public secondary school in the Schools Division of Cavite. The table below illustrates the distribution of respondents and reaffirms that the experimental and control groups were of equal size. Two intact classes were selected through purposive sampling based on comparable academic performance, similar class size, and equal teacher allocation to ensure group equivalence. One class was designated as the experimental group, while the other served as the control group, with equal numbers of students in each to maintain balance.

The use of intact classes was necessary due to administrative and ethical constraints within the school setting, where reorganizing students into new sections or randomly assigning individuals was not feasible. This approach also preserved the natural classroom environment, minimized disruption to regular instruction, and maintained existing teacher–student dynamics, thereby enhancing the ecological validity of the study while still allowing for meaningful comparison between groups.

Group	Number
Control	30
Experimental	30
Total	**60**

Research Instruments

The main instrument used in the study was a researcher-developed algebraic problem-solving test focused on multi-step equations. The test consisted of 10 items, each structured as a problem requiring students to apply multiple operations and follow a logical sequence in solving equations. The instrument was organized into two parallel forms (pretest and posttest) to ensure comparable difficulty and content coverage. Each item measured students' ability to analyze given information, select appropriate operations, execute solution steps, and arrive at correct answers.

To establish content validity, the instrument was evaluated by three expert validators, composed of mathematics educators and experienced teachers in algebra instruction. Their feedback led to revisions in item clarity, alignment with learning objectives, and appropriateness of difficulty level. For reliability, the instrument was pilot-tested with a group of students similar to the study participants. The test's internal consistency was measured using Cronbach's alpha, yielding a coefficient of 0.82, indicating good reliability. These procedures ensured that the instrument was both valid and reliable for assessing students' algebraic problem-solving skills.

Data Collection Procedure

The data collection process consisted of several structured phases. Prior to implementation, permission was secured from the school administration, and participants were informed about the purpose of the study, with assurance of confidentiality and voluntary participation. A pretest was administered to both the control and experimental groups to establish baseline performance in algebraic problem-solving. The intervention lasted 4 weeks, with 3 instructional sessions per week, each lasting approximately 60 minutes. During this period, the experimental group was exposed to the multi-step equation strategy through structured lessons, guided practice, and collaborative problem-solving activities aligned with step-by-step procedures. In contrast, the control group received instruction using the traditional teaching approach, covering the same algebraic topics and allotted the same instructional time to ensure comparability. At the end of the intervention, a posttest was administered to both groups to measure changes in performance. All answer sheets were collected and systematically recorded to ensure accurate and consistent data handling, providing a reliable basis for subsequent statistical analysis.

Treatment of Data

The data were sorted, checked for accuracy, and analyzed using IBM SPSS Statistics 28 and relevant inferential and descriptive statistical techniques to answer research questions about the multi-step equation strategy and students' algebraic problem-solving performance. Descriptive statistics were used to summarize the performance of both the control and experimental groups. To summarize students' performance on the pretest and posttest, the mean for algebraic problem-solving was calculated. A paired-samples t-test was used to assess the difference in mean scores between the pretest and posttest for each group. This test assessed whether the control and experimental groups showed changes in performance and whether those changes were statistically significant. All statistical tests were done at a 0.05 level of significance. This level served as the foundation for decision-making in the testing of the hypothesis.

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Ethical Considerations

The researchers obtained formal approval from the school administration before conducting the study and strictly adhered to established ethical research standards. Informed consent was obtained from both the students and their parents or guardians before participation, ensuring that all parties were fully aware of the study's purpose, procedures, and their rights as participants. Participation was entirely voluntary, and students were informed that they could withdraw at any time without any consequences.

To further uphold ethical standards, it was explicitly communicated that participation in the study would not affect students' academic grades or standing in class. Confidentiality and anonymity were strictly maintained, with no identifying information disclosed in any part of the research report. All collected data were used solely for academic purposes. Additionally, no participant was harmed or placed at a disadvantage during the study. To ensure fairness, both the control and experimental groups were provided with appropriate instructional materials aligned with the curriculum, guaranteeing equitable learning opportunities throughout the research process.

RESULTS and DISCUSSION

This section presents the results of the study and provides a comprehensive discussion based on research questions. The findings are interpreted considering established learning theories and related empirical literature to clarify the observed results.

Table 1.
Mean score of the students in the pre – test

Groups	N	Pretest	
		$\bar{x}$	Descriptive Rating
Experimental	30	8.10	Fair
Control	30	8.23	Fair

Table 1 shows the mean pretest scores of students in both the experimental and control groups. The experimental group had a mean score of 8.10, while the control group had a slightly higher mean score of 8.23. This means both groups had a "Fair" level of algebraic problem-solving ability before the instructional intervention. The small mean difference indicates that both the experimental and control groups had about the same level of prior knowledge and skills in algebraic problem-solving. The "Fair" level of performance in both groups shows that students had little ability to solve algebraic problems, especially those that required more than one step of reasoning. From an instructional perspective, these results highlight the need for structured and scaffolded teaching approaches that explicitly guide learners through the problem-solving process. The comparable baseline performance of both groups, therefore, underscores the need for targeted interventions, such as the use of multi-step equation strategies to address students' difficulties and enhance their overall problem-solving competence.

Recent journal studies show that the findings are accurate. Adeniji & Baker (2023) state that the struggles students face in algebraic problem-solving stem from difficulties understanding the context, translating the problem into a mathematical one, and following the steps to find a solution. These issues indicate a lack of understanding of both conceptual and procedural structures. Solving algebra problems involves more than one step, and many students are unable to control the steps to be solved or strategize the solution order.

Algebraic problem solving is a complex cognitive activity that requires the solver to analyze relationships, abstract and operationalize, and accurately execute a series of steps (Junarti et al., 2022). The less developed these skills are, the less the expected outcome of the student and their performance. More recent work has focused on the multifaceted nature of student learning barriers in algebra, with cognitive and instructional factors contributing to gaps in solid foundational knowledge, limited exposure, and unstructured strategies for solving the problems at hand (Ario et al., 2025). The need for specific strategies to help students perform algebraic operations is evident.

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Table 2.
Mean score of the students in the posttest

Groups	N	Posttest	
		x̄	Descriptive Rating
Experimental	30	14.73	Very Satisfactory
Control	30	8.23	Fair

Table 2 shows mean posttest scores for students in experimental and control groups after the instructional intervention. The experimental group achieved a mean score of 14.73, or "Very Satisfactory," and the control group scored a mean of 8.23, or "Fair." In the posttest, the experimental group showed greater improvement in students' performance on solving algebraic problems than the control group. The increase in scores for experimental students demonstrates that the instructional technique of solving problems in multiple steps was successful in improving students' algebraic problem-solving abilities. As for the control group, a decrease in mean scores from pretest to posttest indicates no improvement, suggesting that traditional instructional methods may not fully foster students' problem-solving abilities.

The effectiveness of the multi-step problem-solving strategy can be further understood through the lens of constructivist theory, which posits that learners actively construct knowledge by organizing and integrating new information with prior understanding. As a structured approach, the multi-step strategy enables students to engage in meaningful learning by progressively building their understanding of algebraic concepts through a sequenced, logical progression. Rather than passively following procedures, learners are guided to make sense of each operation, recognize relationships among mathematical processes, and develop coherent solution pathways. Prior research has shown that students receive guidance and organized, step-by-step instruction, along with understanding the relationship between operations and the steps involved in maintaining accuracy in algebra problem-solving, and that this instruction enhances algebra understanding (Junarti et al., 2022). When students receive structured instruction, they can reduce cognitive load by qualitatively breaking down and stepwise rearranging their instructional guide, ultimately enhancing their performance.

Moreover, these results reinforce and corroborate other recent studies, which, to some degree, show that multi-layered problem-solving instructions are step-by-step, instructional teaching methods and problem-solving strategies that enhance students' achievement in mathematics, which, in essence, should enhance students' mathematics instruction and teaching pedagogy (Kleopas et al., 2023). Thus, the multi-step equation illustrates an ideal framework for the algebra curriculum and provides the levels of complex skills needed for teaching and learning in algebra.

Table 3.
Significant difference of the two groups' pre – test and posttest mean scores

Group	t-value	*p*-value	Decision
Experimental Group	**-8.19**	**0.000**	**Significant**
Control Group	**0.00**	**1.000**	**Not Significant**

Significant @ 0.05

The goal of this study was to examine whether there were significant differences between the pretest and posttest mean scores for both the control and the experimental groups. In Table 3, the control group did not show a significant change, while the experimental group did. In the experimental group, the calculated t-value was -8.19, and the p-value was 0.000, which falls below the 0.05 significance level. In contrast, the control group showed no changes, resulting in a calculated t-value of 0.00 and a p-value of 1.000.

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Researchers have also seen that teaching problem-solving improves the students' mathematical abilities (Nurjanah et al., 2023). The small advancement in the control group indicates the inadequacy of traditional teaching methods in fostering students' critical thinking and problem-solving skills at advanced levels. Students do not work well when left to determine the steps for a given problem and ultimately are unable to appropriately relate different mathematical concepts. Studies show the inability to solve advanced-level problems because of "traditional teaching methods that placed emphasis on taking steps to solve problems as opposed to helping students construct meaningful understandings of the concepts involved" (Seepiwsiw & Seehamongkon, 2023). In addition, these results align with other studies that have found that well-thought-out teaching approaches are necessary for learning mathematics. Effective teaching methods that include guided practice and step-by-step reasoning have been found to increase students' achievement and problem-solving skills considerably (Lee & Paul, 2023). Such methods aim to help students understand and improve their mastery of higher-level algebra.

These findings have important implications for various stakeholders. For mathematics teachers, the results highlight the need to adopt structured, multi-step problem-solving strategies that actively guide students in organizing their thinking and reasoning processes. For school administrators, the study underscores the importance of supporting professional development programs that foster innovative, student-centered instructional practices in mathematics.

Conclusions

Based on the findings of the study, several conclusions were drawn.

First, the experimental and control groups demonstrated comparable levels of algebraic problem-solving ability during the pretest, indicating that both groups had similar baseline knowledge prior to the instructional intervention.

Second, the experimental group exhibited substantial improvement in posttest performance after receiving instruction using the multi-step equation strategy. This improvement resulted in a "Very Satisfactory" level of performance, indicating that structured problem-solving instruction can effectively enhance students' algebraic reasoning and procedural skills.

Third, the control group maintained a "Fair" level of performance from pretest to posttest, suggesting that traditional teaching approaches may not sufficiently support the development of students' higher-order problem-solving abilities.

Fourth, the statistical analysis revealed a significant difference between the pretest and posttest scores of the experimental group, confirming that the multi-step equation strategy had a positive effect on students' algebraic problem-solving performance.

Overall, the findings demonstrate that structured and sequential instructional strategies such as multi-step equations can strengthen students' conceptual understanding and procedural fluency in algebra. The study contributes to mathematics education by highlighting the importance of guided problem-solving instruction in improving student learning outcomes.

Recommendations

Based on the findings and conclusions of the study, the following recommendations are proposed.

1. Mathematics teachers may integrate multi-step equation strategies into their instructional practices to help students develop structured problem-solving skills and improve their understanding of algebraic concepts.
2. Schools and curriculum developers may incorporate structured problem-solving approaches into mathematics learning materials and instructional frameworks to support the development of students' analytical and logical reasoning skills.
3. Teacher education institutions may include training on guided problem-solving strategies and scaffolded instruction to help future teachers effectively facilitate algebra learning.
4. Educational leaders and policymakers may consider supporting professional development programs that emphasize innovative instructional approaches for improving mathematics instruction.
5. Future researchers may replicate the study using larger sample sizes, different educational levels, or diverse learning contexts to further validate and expand the findings of the present research.

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