Enhancing Problem Solving and Creative Thinking in Integral Calculus via Search Solve Create Share Model and MATLAB

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Abstrak

Kesulitan siswa dalam memahami kalkulus integral disebabkan oleh sifatnya yang abstrak dan kompleksitas proses simboliknya. Penelitian ini bertujuan untuk menelaah dampak penerapan model pembelajaran Search, Solve, Create, and Share (SSCS) yang didukung oleh perangkat lunak MATLAB terhadap peningkatan kemampuan berpikir kreatif dan pemecahan masalah matematis siswa. Desain penelitian yang digunakan adalah kuasi-eksperimen dengan kelompok kontrol, di mana data dikumpulkan hanya melalui post-test. Partisipan penelitian berjumlah 216 siswa kelas XII IPA dari tiga Madrasah Aliyah Negeri di Kota Banjarmasin. Kelompok eksperimen mendapatkan pembelajaran menggunakan model SSCS dengan bantuan MATLAB, sedangkan kelompok kontrol menggunakan metode konvensional. Hasil uji statistik Mann–Whitney menunjukkan adanya perbedaan signifikan antara kedua kelompok ($p < 0{,}05$), dan analisis ukuran efek dengan Cohen's d menunjukkan pengaruh dalam kategori sedang hingga tinggi. Temuan ini menegaskan bahwa integrasi model SSCS dan MATLAB efektif dalam mengembangkan kemampuan berpikir tingkat tinggi dalam pembelajaran matematika.
Kata Kunci: Berpikir Kreatif; Kalkulus Integral; MATLAB; Model SSCS; Pemecahan Masalah

Abstract

Students often struggle with integral calculus due to its abstract concepts and the complexity of symbolic operations. This study investigates the impact of applying the Search, Solve, Create, and Share (SSCS) learning model assisted by MATLAB software on students' mathematical creative thinking and problem-solving abilities. A quasi-experimental design with a post-test-only control group was implemented, involving 216 twelfth-grade science students from three public Islamic senior high schools in Banjarmasin. The experimental group received instruction using the SSCS model with MATLAB integration, while the control group was taught using conventional methods. The results of the Mann–Whitney U test indicated statistically significant differences between the two groups ($p < 0.05$). Furthermore, effect size analysis using Cohen's d revealed a moderate to high practical impact. These findings suggest that the combination of SSCS and MATLAB is effective in promoting students' higher-order thinking skills in mathematics learning.
Keywords: Creative Thinking; Integral Calculus; MATLAB; SSCS Model; Problem Solving

I. INTRODUCTION

Mathematics is an essential discipline in forming the ability to think systematically and logically in students. It provides a structured framework for problem-solving, encouraging learners to analyze situations, identify patterns, and draw conclusions based on sound reasoning. Beyond its abstract nature, mathematics fosters critical thinking skills that are transferable to a wide range of real-life contexts, from making financial decisions to interpreting scientific data (Niss, 1996; Tajuddin et al., 2023). Moreover, the discipline cultivates precision, consistency, and creativity, enabling students not only to master numerical and symbolic manipulation but also to approach complex challenges with clarity and confidence (Schoenfeld, 1992). In this sense, mathematics serves as both a foundational academic subject and a vital tool for developing intellectual maturity and adaptability in an increasingly data-driven world (National Council of Teachers of Mathematics [NCTM], 2000).

One of the subjects that is considered complex and often causes difficulties is integral calculus (Ningsih & Deswita, 2023). This material demands an understanding of abstract concepts, such as the area under curves and continuous changes, which are not easy to master through a procedural approach alone (Harmini & Suprihatiningsih, 2024). These barriers are often compounded by teaching styles that focus too much on giving formulas and mechanical exercises, without leaving room for concept exploration and deep understanding (Machmud, Pusi, & Pauweni, 2022; Nuraeni, Nurjanah, & Siregar, 2024).

This phenomenon is reinforced by previous studies that show that conventional learning models are less effective in fostering higher-level thinking skills. For example, students are more oriented towards the end result rather than understanding the process, so their ability to solve contextual problems is limited (Godfred et al., 2021). Meanwhile, the challenges of education in the modern era require students to be able to think flexibly, adaptively, and be able to create original solutions in various situations (Voogt & Roblin, 2012).

Therefore, there is a clear need to transform learning practices from traditional approaches toward methods that emphasize both process and creativity (Arnisya & Afriansyah, 2024). Instead of focusing only on procedural mastery and final answers, students should be encouraged to explore multiple strategies, reflect on their reasoning, and actively engage in generating ideas, which research shows can significantly improve their problem-solving capacity and creative thinking (Leikin, 2009; Cahyani, Fathani, & Faradiba, 2023).

Polya (1973) states that mathematical problem solving is a process that includes understanding the situation, preparing plans, implementing strategies, and evaluating results. Meanwhile, Torrance (1974) emphasized that creative thinking includes the dimensions of fluency in generating ideas, flexibility of approach, originality of thought, and the ability to develop ideas. To cultivate these two abilities simultaneously, a structured and interactive learning approach is needed that not only strengthens logical reasoning but also nurtures creativity and adaptability in mathematics learning.

The Search, Solve, Create, and Share (SSCS) learning model offers an inquiry-based approach that can guide students through the stages of problem exploration, finding solutions, developing alternative strategies, and sharing results with peers. This model has been shown to increase student engagement and reflection in mathematics learning (Zulnaidi et al., 2021; Islami, Fatra, & Diwidian, 2023). On the other hand, software integration such as MATLAB can strengthen the learning process by providing symbolic and numerical visualization tools that help students understand integral concepts in a more concrete way (Nasution, Nasution, & Haryati, 2017; Adamu et al., 2023).

In mathematics education, MATLAB serves not only as a computational tool but also as a powerful environment for experimentation, modeling, and visualization. Its capacity to handle symbolic computation, numerical simulation, and graphical representation allows students to explore abstract mathematical ideas in a more tangible and interactive manner (Higham & Higham, 2017). By integrating MATLAB into inquiry-based models such as SSCS, learners can test hypotheses, analyze data, and validate their solutions through simulations, thereby bridging the gap between theory and practice (Attaway, 2020). Recent studies further highlight that the use of MATLAB enhances students' problem-solving skills, promotes deeper conceptual understanding, and increases motivation by linking mathematical concepts with real-world applications (Fokides, 2017). Thus, combining structured inquiry models with advanced technological tools like MATLAB offers a holistic approach to fostering both cognitive and creative competencies in mathematics learning.

However, research on the effectiveness of combining the SSCS model and MATLAB technology in the context of integral learning is still limited, especially at the high school level. Most studies only tested one approach separately. This is the research gap and the main reason why this research was conducted. The purpose of this study is to examine the impact of the application of the MATLAB-assisted SSCS learning model on improving the problem-solving and mathematical creative thinking skills of grade XII students on integral calculus material.

II. METHOD

A. Research Design

This study uses a quantitative approach with a quasi-experimental design of the post-test-only control group design. This design is commonly used in educational research that does not allow for full randomization due to pre-formed classroom conditions (Creswell, 2012). This design allows for an objective comparison of results between the treatment group and the control group.

The population in this study is grade XII science students from three State Aliyah Madrasah in Banjarmasin City. The sample is determined through cluster random sampling because the class division has been formed. Each school contributed two classes: one class for the experimental group and one class for the control group, for a total of 216 students.

B. Treatment Procedure

The treatment was carried out in three sessions. The experimental group received learning using the Search, Solve, Create, and Share (SSCS) model powered by MATLAB software. The learning process includes exploring problems, developing solutions, creating alternative strategies, and sharing results. Interactive visualization using MATLAB is used to aid in the understanding of integral concepts. The control group accepted conventional learning and the use of MATLAB was limited to basic illustrations. After the intervention, both groups followed a post-test.

C. Research Instruments

The main instrument is an open-ended description test that covers two aspects: first, problem-solving ability, referring to the Polya stages: understanding the problem, planning solutions, implementing strategies, and verifying results (Polya, 1973). Second, mathematical creative thinking, based on four Torrance indicators: fluency, flexibility, originality, and elaboration (Torrance, 1974).

The assessment was carried out using an analytical rubric. The problem-solving rubric was adapted from Cahyadi et al. (2023), while the creative thinking rubric refers to Blyman et al. (2020). The rating scale ranges from 0 to 4 points.

D. Data Analysis Techniques

Data were analyzed with descriptive and inferential approaches. Descriptive statistics are used to present means, standard deviations, minimum and maximum values. The difference test between groups was carried out using the Mann–Whitney U test, because the data were not normally distributed and were not homogeneous (Nachar, 2008).

In addition, effect size calculation was used using Cohen's formula d to determine the strength of the treatment's influence. The interpretation of the categories refers to the criteria suggested by Lakens (2013): small (0.20–0.49), medium (0.50–0.79), and large (≥ 0.80).

E. Research Ethics

This research was carried out by paying attention to the ethical aspects of education. Written permission is obtained from the school before the activity is carried out. Participants are given information about the destination, procedures, and guaranteed confidentiality of their identity. Student participation is voluntary, and the implementation of the test does not interfere with the routine learning process in the classroom. Therefore, the implementation of this research has been in accordance with ethical principles in educational research.

III. Result and Discussion

A. Descriptive Statistical Results

The results of the post-test data analysis showed that students in the experimental group performed better in problem-solving and creative thinking skills compared to students in the control group. In mathematical problem-solving skills, the average score of students in the experimental group was 79.30, higher than the control group of 69.19. In more detail, the distribution of grades in each school is shown in Table 1.

Table 1.
Descriptive Statistics of Mathematical Problem-Solving Abilities

MAN	Group	M	SD	Min	Max
I	E	79.42	22.64	44.44	100
	K	70.63	23.28	22.22	100
II	E	80.55	21.84	44.44	100
	K	69.82	25.38	22.22	100
III	E	77.94	22.45	44.44	100
	K	67.12	25.81	16.67	100
Average	E	79.30	22.31	44.44	100
	K	69.19	24.82	20.37	100

Similarly, on mathematical creative thinking skills, the experimental group obtained an average score of 80.18, while the control group only achieved 72.85. The comparison of grades in each school is described in Table 2.

Table 2.
Descriptive Statistics of Mathematical Creative Thinking Ability

MAN	Group	M	SD	Min	Max
I	E	80.66	17.95	56.25	100
	K	71.79	17.85	50.00	100
II	E	79.61	17.52	50.00	100
	K	72.79	15.13	50.00	100
III	E	80.27	17.85	50.00	100
	K	73.96	16.07	46.88	100
Average	E	80.18	17.77	52.08	100
	K	72.85	16.35	48.96	100

B. Performance Analysis Based on Indicators

More in-depth analysis is carried out based on indicators on each ability. On the troubleshooting capabilities, the results are shown in Figure 1. The experimental group showed the highest achievement on the "understanding the problem" indicator of 91.51%, much higher than the control group which was only 57.06%. This shows that students in the experimental group are able to identify the essential information in the question better.

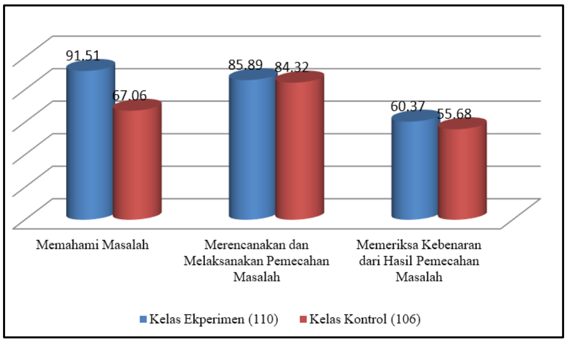

Figure 1. Performance Based on Mathematical Problem Solving Indicators

For creative thinking, Figure 2 shows that the experimental group excelled in all indicators, especially in originality (87.92%) and elaboration (82.85%). This shows that the SSCS approach provides a wide exploratory space to develop unique ideas and solutions.

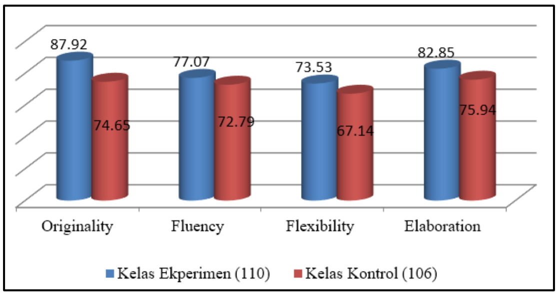

Figure 2. Performance Based on Mathematical Creative Thinking Indicators

C. Hypothesis Testing

To determine the significance of differences between groups, the Mann–Whitney U test was performed.

Table 3.
Mann–Whitney U Test Results

Variabel	U	Z	p-value
Problem Solving	4406.5	-3.205	0.001
Creative Thinking	4142.0	-3.690	0.000

Both variables yielded p-values < 0.05, indicating significant differences between groups. The calculated effect sizes using

Cohen's d were 0.65 (problem solving) and 0.72 (creative thinking), interpreted as moderate to large effects (Cohen, 1988).

D. Qualitative Analysis of Student Work

Students' written responses were also analyzed qualitatively. Figure 3 shows a student who used algebraic expansion correctly and demonstrated fluent, logical reasoning. Meanwhile, Figure 4 presents an alternative strategy using substitution, showcasing originality and conceptual understanding.

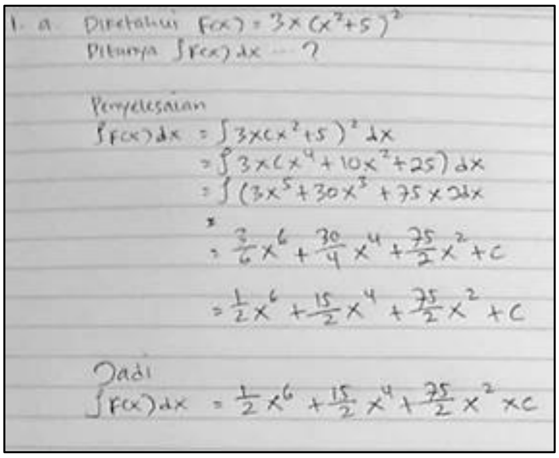

Figure 3. Student's Solution to the Integral Problem $\int 3x\,(x^2+5)^2 dx$

The solution in Figure 3 shows that the student performed the algebraic expansion \left($x^2 + 5$\right)^2 into $x^4 + 10x^2 + 25$, multiplied it by $3x$, and integrated each term accurately. The integration steps were shown clearly, and the final answer was complete with the constant of integration. This response reflects strong fluency in mathematical thinking—demonstrating logical transitions, consistent procedures, and a complete, accurate result.

Figure 4. Student's Work on Integral Using Substitution Strategy

As shown in Figure 4, the student chose a substitution strategy rather than performing algebraic expansion. The substitution $u = x^2$ was used, leading to $du = 2xdx$, and thus the integral was transformed entirely into the u-domain. After integration and returning to the original variable, the student correctly derived the final expression. This approach demonstrates originality because it deviates from standard procedures while maintaining accuracy and coherence. Such creative strategy selection is uncommon among peers and indicates deep conceptual understanding and flexible problem solving fostered by the SSCS learning model supported by MATLAB.

E. Why SSCS + MATLAB Worked

The combination of SSCS and MATLAB proved effective because both components complemented one another in supporting students' cognitive development. The SSCS model provided a structured, inquiry-based learning path that engaged students through searching, solving, creating, and sharing. Each stage encouraged active thinking, reflection, and collaboration.

Meanwhile, MATLAB served as a dynamic learning medium that allowed students to visualize abstract integral concepts, manipulate variables interactively, and immediately test their hypotheses. Rather than relying solely on manual procedures, students could observe the graphical effects of changing mathematical expressions, which reinforced their conceptual understanding and encouraged experimentation.

This synergy—pedagogical structure from SSCS and technological scaffolding from MATLAB—created a learning environment where students could explore, reflect, and articulate their mathematical reasoning more effectively than in conventional instruction.

F. Addressing Contradictions and Variation

Although the findings overall favoured the experimental group, it is important to acknowledge that not all students responded equally to the intervention. In a few cases, students in the control group produced creative or correct solutions, suggesting that prior knowledge, motivation, or classroom climate may also play a role. These individual variations indicate that while the SSCS-MATLAB approach is effective overall, future research should explore moderating factors such as learning style, teacher facilitation quality, or technological proficiency.

G. Limitations of the Study

This research has several limitations that need to be acknowledged. First, sampling uses the cluster random sampling technique, which means that class selection is not done randomly individually. This can affect the generalization of the findings to a wider population. Second, the study only measured the effects of treatment in the short term through post-tests directly after the intervention. No measurements have been made of long-term effects such as concept retention, transferability to other materials, or their impact on learning motivation over a longer period. Third, some results between indicators are not entirely consistent, especially on flexibility indicators that still show moderate scores despite improvements. This may be due to variations in students' cognitive readiness or the lack of optimal use of the "Create" stage in SSCS learning.

IV. CONCLUSION

The results of this study show that the application of the Search, Solve, Create, and Share (SSCS) learning model integrated with MATLAB software has a significant influence on improving students' problem-solving and mathematical creative thinking skills. In general, students in the experimental group obtained higher learning outcomes than the control group, both from the average score, the distribution of scores per indicator, and the variation in problem-solving strategies. This can be seen from the success of students in understanding problems, formulating effective solutions, and displaying original and argumentative answers.

The advantage of SSCS-based learning lies in its stage structure that encourages active engagement, exploration of ideas, and reflection. When integrated with MATLAB, students gain an in-depth visualization of integral concepts that were previously abstract. This combination not only facilitates conceptual understanding, but also develops students' thinking flexibility and courage in trying alternative approaches. Statistically, the difference in scores between the experimental and control groups proved to be significant, and effect measures showed that the learning impact was in the medium to high category. These findings reinforce the belief that inquiry-based learning innovations and technology are able to answer the challenges of teaching mathematics in the modern era.

In connection with these findings, it is recommended that mathematics teachers start applying the SSCS model in learning, especially in materials that require conceptual understanding such as calculus. MATLAB can be used as a visual aid that supports students' self-exploration. In addition, schools and education policy makers are expected to provide adequate training and facilities for teachers to develop technology-based pedagogic competencies. For subsequent researchers, this research can be further developed with a longitudinal approach, or applied to other mathematical topics such as derivatives, limits, or integral applications in real contexts. Future research may also explore the influence of SSCS models on non-cognitive aspects such as self-efficacy, motivation, or mathematical communication skills.

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