EMTEKA: Jurnal Pendidikan Matematika
Volume 7, No. 1, 2026. 324-333
DOI: https://doi.org/10.24127/emteka.v6i1.7271

e-ISSN 2746-5594
p-ISSN 2746-5608

MATHEMATICAL PROBLEM-SOLVING ABILITY BASED ON COGNITIVE STYLES WITH LAPS HEURISTIC-TIME TOKEN MODEL

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Received 02 December 2024; Received in revised form 02 January 2026; Accepted 15 March 2026

ABSTRACT

The low mathematical problem-solving ability of students, as reflected in the PISA and National Assessment results, highlights the need for effective instructional models such as the LAPS-Heuristic with Time Token Arends to develop these skills. This study aims to compare students' mathematical problem-solving abilities between the LAPS-Heuristic-Time Token and Direct Instruction models, analyze the interaction between instructional models and conceptual tempo cognitive styles, and evaluate the differences in abilities based on cognitive styles using the LAPS-Heuristic-Time Token model. Using a quantitative approach with a factorial design experiment method, data were collected from the MFFT and problem-solving ability tests, analyzed using ANOVA. The results indicate that: (1) there is no significant interaction between instructional models and cognitive styles, (2) the LAPS-Heuristic-Time Token model is more effective than Direct Instruction, and (3) there are differences in problem-solving abilities based on cognitive styles. Reflective and quick students adapt well to both models, impulsive students perform better with Direct Instruction, while slow students are better suited to the LAPS-Heuristic-Time Token model. Additional interventions are needed to support impulsive and slow students according to their characteristics.
Keywords: cognitive style; LAPS Heuristic-Time Token, mathematical problem-solving ability

ABSTRAK

Rendahnya kemampuan pemecahan masalah matematis peserta didik, sebagaimana terlihat pada hasil PISA dan Asesmen Nasional, menunjukkan perlunya model pembelajaran yang efektif seperti LAPS-Heuristik dengan Time Token Arends untuk mengembangan kemampuan tersebut. Penelitian ini bertujuan untuk membandingkan kemampuan pemecahan masalah matematis antara model LAPS-Heuristik-Time Token dan Direct Instruction, menganalisis interaksi model pembelajaran dengan gaya kognitif konseptual tempo, serta mengevaluasi perbedaan kemampuan berdasarkan gaya kognitif yang menggunakan antara model LAPS-Heuristik-Time Token. Dengan pendekatan kuantitatif menggunakan metode eksperimen factorial design, data diperoleh dari tes MFFT dan tes kemampuan pemecahan masalah, dianalisis menggunakan ANOVA. Hasilnya menunjukkan: (1) tidak ada interaksi signifikan antara model pembelajaran dan gaya kognitif, (2) model LAPS-Heuristik-Time Token lebih efektif dibandingkan Direct Instruction, dan (3) terdapat perbedaan kemampuan berdasarkan gaya kognitif. Siswa reflektif dan quick dapat beradaptasi dengan kedua model, siswa impulsif lebih sesuai dengan Direct Instruction, sementara siswa slow lebih cocok dengan LAPS-Heuristik-Time Token. Intervensi tambahan diperlukan untuk mendukung siswa impulsif dan slow sesuai karakteristiknya.
Kata kunci*: gaya kognitif; LAPS heuristic-Time Token; kemampuan pemecahan masalah matematis*

Introduction

Education is a crucial aspect. According UU RI No. 20 of 2003, education aims to produce individuals who possess the abilities necessary for their lives. In order to develop these abilities, mathematics serves as one of the subjects designed to foster and train various competencies, including mathematical problem-solving skills (Kemdikbudristek, 2022). According to Siswanto (2024), mathematical problem-solving ability is a fundamental skill that students must possess. This ability includes the capacity to analyze, predict, reason, evaluate, and reflect on prior knowledge when facing problems in new situations. However, Indonesia's PISA 2022 results still show a declining trend in scores and remain below the OECD average. Even at Level 2, Indonesia only achieved 18% compared to the OECD average of 69% (OECD, 2023). In addition, the National Education Report Card of 2023, derived from the 2022 National Assessment, indicates that improvements are still needed to enhance students' mathematical problem-solving abilities. Similar findings were also reported in Ciamis by Utami & Wutsqa (2017) and Nurmala et al. (2023), who found that students' problem-solving abilities remain low due to factors such as difficulties in the problem-solving process, lack of accuracy, and unfamiliarity with generating ideas.

In solving problems, individuals exhibit certain tendencies that become distinctive characteristics; these individual differences are referred to as cognitive styles. The strong interest of many researchers in the relationship between dimensions of cognitive style and mathematical ability arises because cognitive styles have the potential to enhance the effectiveness of learning activities. Cognitive style can be examined from various dimensions; however, one dimension that tends to be stable over time and across tasks is conceptual tempo cognitive style. Conceptual tempo cognitive style was first introduced by Jerome Kagan in 1964 and refers to a cognitive style closely related to an individual's tendency to respond either slowly or quickly when dealing with problems involving high uncertainty (Diana & Nurmawanti, 2020). Individuals possess one of four types of this cognitive style: reflective (tending to be cautious in performing cognitive tasks, requiring more time but producing more accurate answers), impulsive (tending to make decisions quickly without careful consideration, thus being more prone to errors), quick (tending to make fast decisions with accurate answers), and slow (tending to produce less accurate answers despite making careful decisions).

The problem-solving process requires the ability to understand, plan, and solve problems; therefore, these skills must be trained through the learning process. This implies that the selected learning model will have an impact on students' mathematical problem-solving abilities. The LAPS Heuristic learning model emphasizes the problem-solving process by involving guiding questions (heuristics) and follows learning syntax aligned with Polya's four stages of problem solving: (1) understanding the problem, (2) devising a plan, (3) carrying out the plan, and (4) looking back (Novitasari & Shodikin, 2020; Shoimin, 2020). Furthermore, to prevent the learning process from being dominated by only a few students, the time token method can be applied. This method aims to provide equal opportunities and encouragement through the use of speaking coupons.

Previous studies have shown differences in mathematical problem-solving abilities between reflective and impulsive students (Fadiana, 2016). The use of heuristic strategies in mathematics learning, such as the LAPS Heuristic model, provides opportunities for students to develop better problem-solving skills (Gyanthi et al., 2023; Kamid et al., 2021). Moreover, the LAPS Heuristic model combined with the time token method was found to contribute 59% to students' mathematical problem-solving abilities and resulted in a passing rate of 74% (Ali et al., 2021). Therefore, this study seeks to examine whether such differences are also found in classes using the LAPS Heuristic–Time Token model, as well as the interaction between the learning model and cognitive style.

Vector material is one of the topics that integrates algebraic and geometric concepts and is still perceived as difficult by students. Based on a preliminary study conducted at SMAN 1 Kawali, Ciamis, several problems were identified, including students' difficulties in solving non-routine problems that are not exactly the same as the examples provided by the teacher, errors resulting from working too hastily, uneven student participation in learning activities, and difficulties in vector material, particularly in three-dimensional graphical representations. The learning model commonly used at the school is the Direct Instruction model, employing lecture and drill methods. The steps of the Direct Instruction model include: (1) orientation, (2) presentation, (3) guided practice, (4) checking for understanding and providing feedback, and (5) independent practice (Shoimin, 2020).

Therefore, this study aims to determine whether the LAPS Heuristic–Time Token learning model is more effective than the Direct Instruction model in improving students' mathematical problem-solving abilities, to examine the interaction between learning models and cognitive styles on mathematical problem-solving ability, and to identify differences in mathematical problem-solving abilities based on cognitive styles among students using the LAPS Heuristic–Time Token model`R. The hypotheses tested in this study are as follows: (1) there is a significant interaction between the learning model and cognitive style on students' mathematical problem-solving abilities; (2) there is a significant difference in mathematical problem-solving abilities between students taught using the LAPS Heuristic–Time Token model and those taught using the Direct Instruction model; and (3) there is a significant difference in mathematical problem-solving abilities based on cognitive style among students taught using the LAPS Heuristic–Time Token learning model.

Research Methods

This study employed a quantitative approach using an experimental method. The variables in this study consisted of the learning model (independent variable), cognitive style (moderating variable), and mathematical problem-solving ability (dependent variable). The research design used in this study was a factorial design, as presented in Table 1 below.

Table 1. Research design

Factorial Design				
Treatment	R	X	Y_1	O
Control	R	C	Y_1	O
Treatment	R	X	Y_2	O
Control	R	C	Y_2	O
Treatment	R	X	Y_3	O
Control	R	C	Y_3	O
Treatment	R	X	Y_4	O
Control	R	C	Y_4	O

Notes:
R = Random selection of classes
X = Treatment for the experimental class (LAPS Heuristic-Time Token model)
C = Control class (direct instruction model)
Y_1 = Reflective
Y_2 = Impulsive
Y_3 = Quick
Y_4 = Slow
O = Mathematical problem-solving ability test

The population of this study consisted of all Grade X science students at SMAN 1 Kawali in the even semester of the 2023/2024 academic year. The sample was selected using a simple random sampling technique, resulting in two selected classes: Class X IPA 1 as the experimental class, which was taught using the LAPS Heuristic–Time Token learning model, and Class X IPA 3 as the control class, which was taught using the Direct Instruction learning model. Each class consisted of 34 students. The instructional designs implemented in this study are presented in Table 2 below.

Table 2. Instructional design of the LAPS Heuristic–Time Token model and the Direct Instruction model

LAPS Heuristic–Time Token Learning Model	Direct Instruction Learning Model
1. Understanding the problem Students were trained to restate the problem in their own words, create illustrations of the problem, identify what is known and what is asked, and understand the given information. 2. Planning the solution Students were trained to construct mathematical models of the problem and determine the procedures, strategies, and formulas to be used 3. Carrying out the plan Students were trained to solve the problem according to the plan that had been developed. 4. Looking back	1. Orientation Students were provided with an overview of the lesson and an introduction to the learning material. 2. Presentation Students observed the presentation of the learning material and examples delivered in a step-by-step manner. 3. Guided Practice Students worked on practice problems under the teacher's guidance. 4. Checking for understanding and providing feedback Students received verification of their understanding and feedback from the teacher. 5. Independence practice

LAPS Heuristic–Time Token Learning Model	Direct Instruction Learning Model
Students were trained to draw conclusions from the solution and explore alternative solutions to the problem. Each learning step involved discussion activities and the use of speaking coupons (asking questions, answering, and expressing opinions) to ensure equal participation within a specified time allocation.	Students were given independent practice materials by the teacher to be completed outside the classroom.

Matching Familiar Figures Test (MFFT)

The Matching Familiar Figures Test (MFFT), originally developed by Kagan (1965) and revised by Warli (2010), was used to identify students' conceptual tempo cognitive styles. The test comprised 13 items, each consisting of one standard figure and eight alternatives, and measured response time and error frequency. The mean response time and mean error frequency across all items were calculated for each student, with the overall population means serving as cutoff values for cognitive style classification. Students were categorized as impulsive, quick, slow, or reflective based on the combination of their response time and error frequency relative to these cutoff values.

Mathematical Problem-Solving Ability Test

Students' mathematical problem-solving ability was assessed using three open-ended essay questions on three-dimensional vectors, developed in accordance with Polya's problem-solving stages: understanding the problem, planning, implementing the solution, and reviewing. The instrument was validated by two mathematics education lecturers and one Grade X mathematics teacher.

Data were collected by administering the MFFT to both experimental and control classes, implementing the LAPS Heuristic–Time Token and Direct Instruction models over three meetings, and subsequently administering the mathematical problem-solving ability test. Data analysis involved normality and homogeneity tests, followed by hypothesis testing using ANOVA and post hoc analysis.

Results and Discussion

Description MFFT Results

The administration of the Matching Familiar Figures Test (MFFT) was conducted over four days during mathematics specialization class hours or agreed-upon free periods. Based on the test results, the distribution of students across each cognitive style category is presented in Table 3.

Table 3. Description MFFT results

Cognitive Style	**Experimental class**		**Control Class**		**Overall**	
	f	**%**	**f**	**%**	**f**	**%**
Reflective	8	23,53	9	26,47	17	25
Impulsive	9	26,47	11	32,36	20	29,41
Quick	10	29,41	10	29,41	20	29,41
Slow	7	20,59	4	11,76	11	16,18

Overall, Table 3 shows that the proportion of reflective–impulsive students in the control class and across the entire sample was higher than that of quick–slow students, which is consistent with the findings of Hairani et al. (2023). In contrast, the experimental class exhibited an equal proportion of reflective–impulsive and quick–slow students (50%), in line with the results reported by Ulya et al. (2023).

Findings in the Learning Activity

During learning activities in the experimental class, impulsive students were the first to use speaking tokens but often provided incorrect responses, consistent with findings that impulsive individuals respond quickly without sufficient consideration (Hairani et al., 2023; Ramadanti et al., 2022). In contrast, reflective students tended to delay responding to avoid potential errors.

The answer card was the most frequently used, reflecting the structured questioning inherent in the LAPS Heuristic model (Novitasari & Shodikin, 2020) and the motivational benefits of the Time Token method (Paksi, 2022). The use of ask cards increased across meetings, indicating enhanced curiosity (Shoimin, 2020), although it remained lower due to students' reluctance to ask questions (Pratiwi et al., 2019). Argue cards usage fluctuated but increased following instructional encouragement and reward–punishment strategies. Overall, speaking token usage increased across sessions, highlighting the effectiveness of the Time Token approach in promoting student initiative and confidence (Ardiyanti & Napfiah, 2023).

In contrast, students in the control class tended to remain passive during questioning sessions, reflecting a limitation of the Direct Instruction model, which may reduce students' curiosity by positioning the teacher as the primary source of information (Shoimin, 2020).

Interaction Between Learning Models and Cognitive Styles on Students' Mathematical Problem-Solving Ability

The interaction between learning models and cognitive styles on students' mathematical problem-solving ability was analyzed using a two-way ANOVA after the assumptions of normality (Shapiro–Wilk Sig. = 0.302 > 0.05) and homogeneity (Sig. = 0.328 > 0.05) were satisfied. The results indicated no significant interaction effect between the learning model and cognitive style (F = 0.958, Sig. = 0.419), suggesting that the combined influence of these factors did not affect students' mathematical problem-solving ability.

This finding contrasts with Son et al. (2020), who reported a significant interaction effect. The absence of interaction in this study may be attributed to reduced student concentration due to interrupted instructional time (Az-zahra et al., 2023), inadequate classroom lighting that affected learning focus (Pranasmara & Priyatmono, 2024), the lack of differentiated instruction for different cognitive styles, and the short duration of the intervention. As noted by Chinn and Ashcroft (as cited in Son et al., 2020), considering cognitive styles can enhance instructional effectiveness, and cognitive style remains an important factor in selecting appropriate learning models to support mathematical problem-solving ability (Marwazi et al., 2019).

e-ISSN 2746-5594
p-ISSN 2746-5608

Differences in Mathematical Problem-Solving Ability between Students Using the LAPS Heuristic–Time Token Model and Those Using the Direct Instruction Model

A two-way ANOVA revealed a significant difference in mathematical problem-solving ability between students taught using the LAPS Heuristic–Time Token model and those taught using the Direct Instruction model. Students in the LAPS Heuristic–Time Token group demonstrated higher mean problem-solving performance than those in the Direct Instruction group, corroborating previous findings that the integration of the LAPS Heuristic model with the Time Token strategy yields significantly better outcomes than Direct Instruction alone (Ali et al., 2021).

These results are consistent with studies reporting that the LAPS Heuristic model substantially contributes to students' problem-solving abilities (Kamid et al., 2021) and outperforms conventional learning models (Ariyanti et al., 2024; Putra et al., 2023). The effectiveness of this model can be attributed to its structured and systematic learning steps, which are well aligned with the development of mathematical problem-solving skills (Azwardi & Sugiarni, 2019; Novitasari & Shodikin, 2020). Furthermore, the incorporation of the Time Token strategy enhances student participation by ensuring equitable opportunities to express ideas, thereby preventing domination by certain individuals or groups and supporting active engagement during learning activities (Shoimin, 2020).

Differences in Mathematical Problem-Solving Ability Based on Cognitive Styles in Students Using the LAPS heuristic-Time Token Model

Differences in mathematical problem-solving ability among students with reflective, impulsive, quick, and slow cognitive styles in the experimental class were examined using one-way ANOVA, as the data satisfied the assumptions of normality and homogeneity. The results indicated a significant effect of cognitive style on mathematical problem-solving ability ($F = 3.838$, $p = 0.019$), confirming that students' cognitive styles contribute to individual differences in problem-solving performance (Fadiana, 2016). Consequently, a post hoc LSD test was conducted to identify specific group differences.

The post hoc analysis revealed no significant differences between reflective–quick and impulsive–slow students. This finding may be attributed to similarities in the characteristics of each pair: reflective and quick students tend to be cautious and deliberate in evaluating solutions, whereas impulsive and slow students are less thorough in considering solution strategies (Hairani et al., 2023). Similar patterns were also reported by Ulya et al. (2023), who found comparable mathematical problem-solving abilities between these cognitive style pairs.

In terms of performance trends, reflective students consistently achieved the highest mean scores across both learning models, supporting previous findings that reflective learners demonstrate superior task performance (Ningsih, as cited in Khoiriyah & Masriyah, 2022). However, the performance gap between reflective and quick students was minimal, as both groups tend to produce a higher proportion of correct. In the experimental class, slow students outperformed impulsive students, whereas the opposite pattern was observed in the control class. This discrepancy may be explained by the structured and systematic nature of the Direct Instruction model, which is more compatible with the rapid response tendencies of impulsive learners (Shoimin, 2020). Conversely, slow learners benefit more from the LAPS Heuristic–Time Token model, which provides sufficient time for problem comprehension before decision-making, although discussion time constraints may limit their full exploration of solution strategies.

Overall, these findings underscore the importance of aligning instructional models with students' cognitive styles. While the LAPS Heuristic–Time Token model is effective in fostering mathematical problem-solving through heuristic-guided, step-by-step processes, not all cognitive styles adapt equally well, indicating the need for instructional adjustments that account for individual differences, including cognitive style.

Conclusion and Suggestion

The results show no interaction between learning models and cognitive styles on mathematical problem-solving ability. However, students taught using the LAPS Heuristic–Time Token model outperformed those taught using Direct Instruction, and significant differences in problem-solving ability were found among cognitive styles within the LAPS Heuristic–Time Token model. The absence of interaction may result from the lack of differentiated instruction, as reflective and quick students adapted well to both models, whereas impulsive students were more suited to Direct Instruction and slow students to the LAPS Heuristic–Time Token model. Future studies should apply cognitively differentiated instruction and longer interventions to examine long-term effects.

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