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Exploration and Measurement of Students' Critical Thinking Skills Through the ELPSA Model Integrated with Math City Map in Real Environments

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ABSTRACT

This study aims to explore and measure students' mathematical critical thinking skills through the ELPSA (Experience, Language, Pictorial, Symbolic, Application) learning model integrated with Math City Map (MCM). Using Mixed methods with a sequential explanatory design involving 130 MTsN students in Sarolangun Regency, who were divided into experimental and control classes. Quantitative data were collected through pretests and posttests, while qualitative data were gathered through observation, interviews, and field notes. Through the independent sample t-test, the posttest score of the experimental class (M = 65.68; SD = 14.231) was higher than the control class (M = 52.98; SD = 11.737) with a 2-tailed Sig. <0.001 and a large effect size (Cohen's d = 0.973). Qualitative analysis strengthens these findings by showing increased engagement, courage to express opinions, and students' ability to provide logical reasons. The synergy of ELPSA and MCM has been proven to provide contextual, interactive, and meaningful learning, thus encouraging students to be more active in critical thinking. Further research is recommended to expand the context and educational levels to assess the consistency of the ELPSA model integrated with Math City Map at various cognitive levels.

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1. INTRODUCTION

Critical mathematical thinking skills are crucial because they enable a person to analyze, evaluate, and solve problems logically and structurally (Raj et al., 2022; Suryawan et al., 2023). In a global context, these skills are a key factor in facing the increasingly complex challenges of a world filled with diverse data and information (Umam et al., 2020; Monteleone et al., 2023). Students who master critical mathematical thinking skills can adapt to the dynamics of global change and make decisions based on evidence and logical reasoning (Kania & Bonyah, 2023; Syafril et al., 2020). Therefore, developing these abilities is a priority in education so the younger generation is ready to compete.

Even though critical thinking skills are a much-needed skill, in practice students still show low mathematical critical thinking skills (Basri et al., 2019; Solichah & Sari, 2023; Suningsih et al., 2025; Susandi, 2021). Students often experience difficulties when faced with non-routine questions that require in-depth analysis (Mullis et al., 2020). This is because students only memorize mathematical formulas and procedures, so they have difficulty or even fail to apply the formulas to new situations or contextual problems (Muslim et al., 2021; Tiyana, 2023). This condition shows that mathematics learning is still oriented towards the final result, and has not fully encouraged the critical thinking process.

The low level of critical mathematical thinking skills cannot be separated from learning, which tends to focus on teachers (Aini et al., 2019; Darhim et al., 2020; (Artuz & Roble, 2021); Zamzam & Agustin, 2024; (Sunismi & Fathani, 2017). Teachers often deliver material procedurally, while students become passive recipients. As a result, students are less accustomed to developing ideas, asking questions, or developing creative problem-solving strategies. Furthermore, mathematics learning in schools is often perceived as abstract and disconnected from everyday life. So, when students do not find a real connection between mathematical concepts in class and real-world experiences, their motivation to learn decreases (Gyasi Alfred et al., 2024). This condition has an impact on inhibiting the development of critical thinking skills (Rafiepour & Faramarzpour, 2023).

An alternative solution to improving low critical thinking skills can be implementing more interactive learning models and media, such as the ELPSA model integrated with the Math City Map. The ELPSA model is a learning framework based on constructivism. Its stages begin with real-life experience (Experience), language use (Language), visual representation (Pictorial), mathematical symbolization (Symbolic), and application of concepts (Application) (Adams et al., 2023; Kinasih & Hardiani, 2020; Lowrie & Patahudin, 2015). Math City Map is a mathematics learning tool that integrates mathematical concepts with real-life situations through exploration of the surrounding environment (Kusmayanti, 2022); (Ludwig & Jablonski, 2019). Using a city map as a tool, students are tasked with identifying, calculating, and analyzing real-world mathematical elements, such as distance, area, and volume.

Previous research Adams et al., (2023); Febrilia & Winarti (2018); Nissa et al., (2019) and Rozalia et al., (2020) ELPSA can improve students' understanding of spatial concepts and skills and deepen their inquiry. However, the application of ELPSA is still limited to a single learning model. It has not yet implemented all ELPSA's components nor been integrated with technological media that can present a real-world context. Research on the Math City Map was conducted byAriosto et al., (2021), Barbosa & Vale (2023) and Cahyono & Ludwig (2019) This application still positions itself as an independent learning medium without being integrated with a specific pedagogical framework. As a result, the potential of MCM to strengthen learning structures has not been optimally utilized.

The integrated implementation of ELPSA with Math City Map is designed to explore and measure students' critical thinking skills by encouraging them not only to master formulas but also to analyze, evaluate, and solve contextual problems, ultimately drawing appropriate conclusions. In this process, students are required to learn actively. They are encouraged to think systematically and logically and make connections between the mathematical concepts they understand and real-world situations around them.

2. METHODS

The study was conducted on ninth-grade students at one of the Islamic Junior High Schools (MTsN) in Sarolangun Regency from August to September 2025 using a mixed methods approach through a sequential explanatory design (J. Creswell & Creswell, 2018); J. W. Creswell & Clark, 2018; Tashakkori & Creswell, 2007). Researchers involved 65 active participants in the experimental class using the Math City Map integrated ELPSA model and 65 students in the control class using conventional learning. First, participants took a pretest and posttest to measure their mathematical critical thinking skills before and after the treatment. Data were analyzed using SPSS version 30 through prerequisite tests (normality and homogeneity), then an independent sample t-test and a paired sample t-test to determine the differences and effectiveness of the treatment. Before the test was carried out, the test instrument had been validated by three experts and tested.

Second, qualitative research was conducted through observation and field notes during the treatment and then interviews with 12 students selected using purposive sampling (J. Creswell & Creswell, 2018) based on posttest results (high, medium, low). Qualitative data were analyzed using the Miles & Huberman (1994) model with the help of Nvivo 15, and its validity was tested through triangulation (Denzin & Lincoln, 2018). This section aims to explore in depth the thinking skills and learning experiences of students during the implementation of the ELPSA model integrated with Math City Map to obtain a comprehensive understanding of how the model influences the development of students' mathematical critical thinking skills.

3. FINDINGS AND DISCUSSION

Findings

Table 1 shows the mean and standard deviation of students' critical thinking skills in the experimental and control classes. Table 2 shows the results of the pretest normality test, and Table 3 shows the homogeneity test.

Table 1. Mean and standard deviation of critical thinking ability results

	Experiment		Control	
	Mean	Standard Deviation	Mean	Standard Deviation
Pretest	24,06	5,01	23,94	4,96
Posttest	65,68	14,231	52,98	11,737

Table 2. Results of the typical test (pretest)

Class	Sig. Shapiro-Wilk	Conclusion
Experiment	0,074	Normally
Control	0,301	Normally

Table 3. Results of the homogeneity (pretest)

Levene's Statistic	*df1.*	*df2*	*Sig*
0,012	1	128	0,913

The results of the normality and homogeneity tests in Tables 2 and 3 show that the experimental and control classes are usually homogeneously distributed. Therefore, before administering treatment, a test for equality of means between the two classes can be conducted. Table 4 shows the results of the equality of means test.

Table 4. Initial Critical Thinking Ability Average Similarity Test

Statistics	Experiment Class	Control Class	Description
Mean	24,06	23,94	Almost the same
Standard Deviation	5,006	4,956	Relative variability is the same
Independent samples t-test	-	-	0,141
Sig. (2-tailed)	-	-	0,888 (> 0,05), not significant
Confidence Interval 95%	-	-	-1,606 s.d. 1,852 (load 0)
Cohen's d	-	-	0,025

Based on Table 4, the average pretest score for the experimental class was 24.06 with a standard deviation of 5.006, while the average pretest score for the control class was 23.94 with a standard deviation of 4.956. Furthermore, the t-test results showed a calculated t-value of 0.141 with a 2-tailed significance of 0.888 (>0.05), indicating no significant difference between students' initial critical thinking abilities in the experimental and control classes. Therefore, the experimental class using the ELPSA model integrated with Math City Map and the control class using conventional learning can be used for research. Table 5 shows the posttest normality test, and Table 6 shows the posttest homogeneity test.

Table 5. Results of the typical test (posttest)

Class	Sig. Shapiro-Wilk	Conclusion
Experiment	0,816	Normally
Control	0,789	Normally

Table 6. Results of the homogeneity (posttest)

Levene's Statistic	*df1.*	*df2*	*Sig*
2,304	1	128	0,132

Table 7 shows the differences in students' critical thinking abilities using the ELPSA model integrated with Math City Map and conventional learning. However, prerequisite tests (normality and homogeneity) were previously conducted, as shown in Tables 4 and 5.

Table 7. Differences in mathematical critical thinking abilities

Class	N	Mean	Standard Deviation	t	df	Sig. (2-tailed)	Mean Difference	95%CI (Lower–Upper)	Cohen's d
Eksperiment	65	65,68	14,231	5,547	128	< 0,001	12,692	8,165 – 17,220	0,973
Control	65	52,98	11,737						

Table 7 shows that the post-test scores of students in the experimental class (M = 65.68; SD = 14.231) were higher than those in the control class (M = 52.98; SD = 11.737). Furthermore, the Sig. (2-tailed) value was <0.001. This indicates that there is a significant difference in the average between the experimental class and the control class. The average difference of 12.692 with a 95% confidence interval (8.165 – 17.220) further confirms that the experimental class achieved better learning outcomes than the control class. In addition, the effect size obtained through Cohen's d of 0.973, which is included in the large category, indicates that the difference is statistically significant and practically meaningful.

Meanwhile, Table 8 shows a difference in the results of mathematical critical thinking skills between the two groups before and after the treatment was given.

Table 8. Qualification of pretest and posttest results

Qualifications	test scores	Experiment Class Students		Control Class Students	
		Pretest	Posttest	Pretest	Posttest
High	76-100	-	16	-	2
Medium	51-75	-	38	-	35
Low	1-50	65	11	65	28

Based on Table 8, the percentage of students in the experimental class who obtained high post-test scores was 24.62%, with 58.46% achieving moderate scores and only 16.92% achieving low scores. In the control class, the percentage of students who obtained high post-test scores was 3.08%, with moderate scores 53.84% and low scores 43.08%.

The effectiveness of a learning model needs to be demonstrated through measurable data. Therefore, the results of the data analysis regarding the implementation of the ELPSA Model integrated with Math City Map are presented in Table 9.

Table 9. Effectiveness of the ELPSA model integrated with Math City Map

Statistik	Score
Mean Pretest	24,06 (5,006)
Mean Posttes	65,68 (14,231)
Difference Mean	-41,615 (11,647)
Correlation Pretes–Posttes	r = 0,645; p < 0,001
t test (df = 64)	-28,808; p < 0,001
Cohen's d (CI 95%)	-3,573 (−4,234 s.d. −2,907)
Hedges' correction (CI 95%)	-3,531 (−4,185 s.d. −2,873)

Table 9 shows a significant increase in scores after treatment. The correlation between the pretest and posttest was 0.645 with a Sig. (2-tailed) < 0.001, indicating a strong and significant relationship between the pretest and posttest. The mean difference test showed a difference of -41.615 with a standard deviation of 11.647, Sig. (2-tailed) < 0.001. Thus, there was a very significant difference between the pretest and posttest.

Furthermore, the effect size calculated using Cohen's d was -3.573 (CI: -4.234 to -2.907) and Hedges' correction was -3.531 (CI: -4.185 to -2.873), indicating a considerable effect. These findings suggest that the treatment or intervention given to the experimental group significantly improved students' mathematical critical thinking skills. The significant increase from the pretest to posttest average indicates that the implemented Math City Map integrated ELPSA model improves students' mathematical critical thinking skills.

The results of observations by observers of teachers in the experimental class at meetings 1-16 achieved a success rate of 91.72%, indicating that teacher activities in the experimental class were running very well. Meanwhile, observations of students in the experimental class were 88.45%, indicating that student activities in the experimental class were running very well. Furthermore, observations by observers of teachers in the control class were 93.12%, indicating that teacher activities in the control class were running very well. Meanwhile, observations of students in the control class were 81.88%, indicating that student activities in the control class were running very well.

The observer's observations concluded that mathematics learning in the experimental class with ELPSA and through Math City Map activities outside the classroom increased student engagement, understanding, and positive attitudes. Students who were initially passive and hesitant to express their opinions gradually showed the courage to ask questions, answer questions, and lead discussions. Representations ranging from pictures to mathematical symbols helped them understand concepts more deeply, accompanied by the growth of critical and creative thinking skills in comparing solution strategies and critiquing class work results. Cooperation between students was also strengthened, even though some were still dependent on certain members. MCM activities in the field provided a more meaningful learning experience because they were directly related to real life, fostering enthusiasm and a positive attitude towards mathematics.

Meanwhile, learning in the control class proceeded in an orderly and focused manner, with students able to follow the teacher's explanations effectively. Students demonstrated seriousness when working on problems individually and when asked to come to the board. Note-taking activities were also fairly consistent, allowing for well-documented material. Although interaction remained limited, some students began to demonstrate courage in answering questions and speaking in front of the class.

In the final meeting before the exam, almost all students appeared more focused and disciplined in their preparation, demonstrating a sense of responsibility for their learning.

The results of interview data analysis of subjects in the experimental class with high critical thinking skills demonstrated excellent performance in all four indicators: interpretation, analysis, evaluation, and inference. Subjects with moderate skills excellently performed in three indicators: interpretation, analysis, and evaluation. Subjects with low critical thinking skills demonstrated excellent performance in one indicator: interpretation.

The results of the interview analysis showed that the control class's high critical thinking ability met three indicators: interpretation, analysis, and evaluation, very well. The subjects with moderate critical thinking ability met two indicators: interpretation and analysis, very well. Meanwhile, the subjects with low critical thinking ability met one indicator: poor interpretation.

These findings indicate that students in the experimental class were more dominant in meeting the critical thinking ability indicators than the control class. This was evident in their ability to identify important information, formulate problems accurately, provide logical reasons for answers, and re-evaluate the solutions they obtained. This trend suggests that implementing the learning model in the experimental class effectively encouraged students to engage in higher-order thinking processes.

Analysis by comparing quantitative data with qualitative data. The relationship between quantitative and qualitative data results is presented in Table 10.

Table 10. Relationship between quantitative data and qualitative data

Results of quantitative data analysis	Results of qualitative data analysis
❖ Based on the two-tailed hypothesis test results, Sig obtained the critical thinking ability value. (2-tailed) = <0.001 (<0.005) indicates a difference in critical thinking ability. ❖ The one-tailed hypothesis test analysis results on the posttest data showed a correlation between the pretest and posttest of 0.645 with Sig. (2-tailed) <0.001 indicates a strong and significant relationship between the pretest and posttest. The mean difference test showed a difference of -41.615 with a standard deviation of 11.647 and Sig. <0.001.	❖ Based on the interview results, it was found that the experimental class subjects had better critical thinking skills than the control class subjects. ❖ Observation data showed that the success rate of students in the experimental class was 88.45% and in the control class 81.88%, indicating that the learning process was progressing very well. ❖ Field notes showed that the experimental students were more active than the control class.

Quantitative and qualitative data analysis results show consistent findings that complement and reinforce each other. From a quantitative perspective, comparing pre-test and post-test scores shows a significant increase in critical thinking skills in students in the experimental class. Meanwhile, qualitative analysis through observation and interviews supports these results by revealing that students in the experimental class were more active in asking questions, could provide logical reasoning, and demonstrated skills in evaluating and solving problems. Thus, it can be confirmed that the critical thinking skills of students who received learning with the ELPSA model integrated with Math City Map developed significantly more than those of students in the control class who only received conventional learning.

Discussion

The ELPSA (Experience, Language, Pictorial, Symbolic, Application) learning model, combined with the Math City Map (MCM), has significantly improved students' mathematical critical thinking skills. The results showed an increase in the average score from 24.06 in the pretest to 65.68 in the posttest, with a Cohen's d value of 3.57, indicating a significant and practically meaningful effect. This success is due to the role of each phase in ELPSA, which systematically develops aspects of critical thinking such as interpretation, analysis, evaluation, and inference. In the Experience phase, students are introduced to real-world experiential learning through Math City Map activities that link mathematical concepts to concrete situations in everyday life. This context activation helps students develop interpretation skills by understanding the meaning of mathematical problems from direct experience. In addition, contextual experiences foster higher interest and motivation to learn (Husna et al., 2020; Malaluan & Andrade, 2023).

In the Language phase, critical thinking skills develop through mathematical communication activities that allow students to express ideas, explain reasons, and defend arguments logically. Group discussions and presentation activities encourage students to think analytically and assess the validity of opinions based on evidence(Aini et al., 2019). This phase strengthens the dimensions of analysis and evaluation (Bahmani et al., 2021), as students learn to review the accuracy of their own thinking and constructively criticize the ideas of others. Qualitative results show that students become more confident in expressing opinions and can provide rational reasons for proposed solutions. Thus, the Language phase links concrete experiences and formal thinking, forming the basis of reflective thinking.

The Pictorial/Symbolic phase emphasizes students' representational abilities through various visual forms and mathematical symbols such as pictures, tables, graphs, and formal notation. The transformation from concrete experiences to abstract representations strengthens the analysis and inference aspects (Bernadez & Montero, 2025)because students must link information from real contexts into a more formal conceptual structure. Observations show that students in the experimental group could use various representations to explain concepts and problem-solving strategies, indicating flexibility of thinking and depth of understanding. Through this phase, students understand concepts, can reason relationships between ideas, and interpret mathematical meanings more deeply.

The Application phase is the culmination of the ELPSA learning process, integrating all previously developed critical thinking skills. In this phase, students are challenged to apply learned concepts to new problems or situations that differ from their initial experiences (Herwandi & Kaharuddin, 2020; (Setiawati et al., 2021). This activity fosters inference and decision-making skills, as students must adapt problem-solving strategies based on their existing conceptual understanding. The significant increase in posttest scores demonstrates the success of this phase in fostering generalization and application of concepts to new contexts. Furthermore, reflection activities conducted after problem-solving help students assess the effectiveness of their strategies, thus strengthening the evaluative aspect of critical thinking.

Overall, improving students' mathematical critical thinking skills through the application of the MCM-integrated ELPSA model occurs gradually and continuously according to the sequence of learning phases. The Experience phase fosters contextual and interpretive understanding, Language strengthens analysis and evaluation through argumentation, Pictorial/Symbolic hones representation and inference skills, while Application strengthens conceptual application and reflection. The synergy of all these phases makes learning result in significant grade increases and changes students' thinking patterns to be more rational, analytical, and reflective. Thus, the integration between ELPSA and Math City Map plays an important role in developing mathematical critical thinking skills that are deeper, contextual, and relevant to the demands of scientific and technological developments.

4. CONCLUSION

Students who participated in learning with ELPSA integrated with Math City Map experienced a significantly higher increase in critical thinking skills compared to students who received conventional learning, as indicated by a significance value ($p < 0.001$) and a large effect size (Cohen's $d = 3.57$). Qualitative findings supported these results, where students appeared more active, could argue logically, and demonstrated better analytical and evaluation skills in solving contextual problems. Each phase of ELPSA contributes to strengthening students' critical thinking skills. The Experience phase activates understanding through real-life experiences with MCM, the Language phase fosters communication and mathematical argumentation skills, the Pictorial/Symbolic phase enhances representation and reasoning skills, and the Application phase encourages knowledge transfer to new situations.

The integration of ELPSA with Math City Map has been proven to be able to develop students' thinking patterns that are in accordance with the demands of today's global competencies. The need for teachers to implement the ELPSA-MCM model as a real-life, experiential learning approach that fosters higher-order thinking skills. Schools are advised to provide technological support and teacher training for continued implementation. Further research is recommended using analysis of covariance (ANCOVA) to control for covariate variables such as initial ability and learning motivation, as well as a longitudinal gain approach to assess the sustainability of critical thinking improvements across broader contexts, materials, and educational levels.

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