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Strengthening Mathematical Connections in Middle School Geometry: The Role of Means-Ends Analysis in Learning Cubes and Rectangular Prisms

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Abstract

The mathematical connection abilities of middle school children are the primary subject of this study, which aims to understand how means-end analysis (MEA) policies and procedures might assist. Students need to build mathematical connection abilities that enable them to comprehend and associate various mathematical concepts to improve their ability to comprehend and apply mathematics in real-world contexts. This is an essential component of the learning process. The research uses a quasi-experimental methodology by administering tests to the control and experimental groups before and after the intervention. One group utilized the MEA tactics in the mathematics lesson, while the other group remained committed to the tried-and-true method. Data was collected through mathematical connection tests, and then statistical analysis was performed to determine whether the intervention was effective. According to the findings, students whose courses contained MEA strategies showed a considerable improvement in their mathematical connection abilities compared to the control group. This study validates that incorporating MEA approaches into the mathematics curriculum is a viable alternative for increasing students' mathematical literacy and competence. The findings of this study provide more evidence to support this idea.

Keywords: Cubes and blocks; Mathematical connectivity; Means-Ends Analysis.

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1. Introduction

The purpose of teaching mathematics courses at the elementary to high school levels is to provide students with the ability to think logically, systematically, analytically, critically, creatively, and collaboratively. These skills will enable pupils to obtain, analyse, and utilise knowledge for survival. When it comes to the goals of learning mathematics, one essential skill that students should possess is the capacity to establish connections and effectively solve problems. NCTM (2000) also asserts that students must possess mathematical connectivity skills. Mathematical connection ability refers to the capacity to establish connections between mathematical concepts, mathematical concepts, and other scientific disciplines and concepts with practical applications in daily life. Wahyudin (2008) states that the capacity to establish connections and resolve mathematical problems is not solely a skill taught and employed in mathematics. Instead, it is a skill that can be applied to address everyday life difficulties. The clarity of this statement stems from the fact that mathematics finds extensive application in several scientific domains that are directly relevant to everyday life, including trade, business, and similar areas.

However, pupils' proficiency in making mathematical connections is still minimal. According to a mathematics teacher at the school, students hardly receive mathematical connection questions. When pupils encounter inquiries that need advanced cognitive abilities, they nonetheless require assistance resolving them. This indicates that the mathematical connecting skills of students are not yet at their maximum potential. To address the issues above, educators should carefully organise the learning process to foster students' aptitude for making mathematical connections. A practical approach is to develop a learning environment that optimises both the process and outcomes (Ratnawulan & Kania, 2020). This approach goes beyond simply imparting knowledge and instead fosters students' ability to use their skills, including their capacity to make connections and solve their challenges.

Learning mathematics begins with presenting a contextual problem suitable for the given situation. The means-end analysis strategy is a learning approach that starts by formulating a problem, as these principles advise. When presented with a problem, students determine the current and desired target states. They then break down the problem into smaller sub-problems and systematically seek answers for each (Boerchi et al., 2024; Damrongpanit, 2022). This process ultimately allows them to achieve the intended aim or purpose of the problem. This learning approach can enhance pupils' mathematical reasoning skills. Bruner (Ruseffendi, 1991) proposes that enhancing students' proficiency in mathematics requires increased opportunities to perceive and comprehend the interrelationships among postulates, theories, topics, and branches of mathematics. This activity is utilised in learning by implementing the Means-Ends Analysis method. The problems presented in this lesson are organised into multiple subproblems resolved sequentially. The resolution of specific subproblems involves the amalgamation of outcomes obtained from the resolution of two or more preceding subproblems (Fikriani & Nurva, 2020; Sutiarso et al., 2022). When tackling the prearranged sub-problems, students can utilise their capacity to connect mathematical concepts with both other mathematical concepts and real-life scenarios.

Engaging in Means-Ends Analysis enables students to uncover novel concepts through problem-solving. In addition, the problem-solving process employing the Means-Ends Analysis technique is conducted sequentially. This entails breaking down the given problem into smaller sub-problems, which students tackle individually to prevent overwhelming them. The preceding explanation implies that the stages involved in learning through the means-end analysis technique are believed to impact students' mathematical reasoning skills. The author aims to investigate the potential of the means-end analysis technique in enhancing students' mathematical connecting abilities.

2. Methods

This research is a quasi-experiment, carried out by applying learning using the Means-Ends Analysis strategy in the experimental class and conventional learning in the control class. The experimental design used was a non-equivalent control group design (Ruseffendi, 2005: 52), which is described as follows:

$$\begin{array}{ccc} O & X & O \\ \hdashline O & & O \end{array}$$

Equation:

O = pretest questions = posttest questions

X = acquiring knowledge using the Means-Ends Analysis approach

In the design above, both groups underwent a pretest before receiving any treatment. Following the administration of therapy, both groups underwent a post-test measurement. The goal of administering a pretest is to assess the equivalence of the beginning abilities of the two groups. This study encompasses independent variables and dependent variables. The independent variable in this study pertains to utilising the Means-Ends Analysis technique for learning, whereas the dependent variable focuses on the individual's mathematical connecting skill.

The study focused on the student population in the eighth grade at a specific SMPN (public junior high school) located in Serang City. The reason for choosing class VIII was the presence of the material that needed to be assessed, specifically the chapters on cubes, blocks, prisms, and pyramids. The sampling process included a purposive sampling strategy, which involved selecting mathematics teachers from specific schools based on predetermined criteria. One class was designated as the experimental group, which got instruction utilising the Means-Ends Analysis technique, while the other class served as the control group and received traditional instruction.

The research uses a mathematical connection ability exam as the primary instrument. The test consists of descriptive questions organised according to the mathematical connection indicators that must be assessed. The test preparation process involves constructing a grid, then organising the questions according to the prepared grid, along with an answer key, and providing scoring rules for the questions. The scoring criteria for the connection ability exam were modified from the Holistic Scoring Rubrics suggested by Cai, Lane, and Jakabcsin (Delima, 2011). Prior to administering the test instrument to all students in both study groups, the instrument underwent preliminary testing to ensure that it met the criteria for being a reliable measuring tool. The criteria encompass validity, reliability, level of difficulty, and differentiating power.

The independent sample t-test is the statistical test employed to assess the research hypothesis on the disparity between two means. Subsequently, if it is determined that acquiring knowledge in means-end analysis substantially enhances students' aptitude for making connections, problem-solving skills, and mathematical inclination, the subsequent course of action will involve assessing the magnitude of this impact (effect size). Olejnik and Algina (Santoso, 2010) define effect size as a metric that quantifies the extent to which a variable influences other variables, measuring the degree of differences or correlations while excluding the impact of sample size.

3. Results and Discussion

3.1. Results

The results of students' work in the initial test and final test of connection ability, as well as mathematical problem solving, were corrected by two different people, namely the researcher himself and UPI postgraduate mathematics education students, to ensure the suitability of scoring and avoid data manipulation. In data processing, students whose data did not take one of the tests (initial test or final test) were not included. In the experimental class, 6 students did not take the test, and in the control class, there were 2 students.

The two people's examination results were then tested using the t-test, and the correlation was seen using the Pearson Product Moment formula.
The hypothesis formulation to test correlation is:

Ho: $\rho=0$
Ha: $\rho\neq0$

Information:
$\rho=0$: There is no relationship between correcting data 1 and correcting data 2
$\rho\neq0$: There is a relationship between correcting data 1 and correcting data 2

The test criteria used are: if sig. is more significant than $\alpha = 0.05$, then Ho is accepted; for other conditions, Ho is rejected. The following are the results of the data correlation test from examining two proofreaders.

Table 1 - Data from correlation test results of two correction scores

Class	Mathematical connection			
	Pretest		Posts	
	P1	P2	P1	P2
Experiment	0.000 (r12 = 0.942)		0.000 (r12 = 0.637)	
Control	0.000 (r12 = 0.870)		0.000 (r12 = 0.778)	

Note: P1 = corrector 1
P2 = corrector 2

The table above displays statistical significance. The correlation coefficient between the examination outcomes of two individuals for each test is 0.000. Since the significance level is less than 0.05, the null hypothesis (Ho) is rejected. This indicates a substantial correlation between the correction of data 1 and the correction of data 2 in every test. Based on the calculated correlation coefficient, the total correlation coefficient is positive. There is a direct correlation between corrector data 1 and 2, meaning that when the value of corrector data 1 increases, so does the value of corrector data 2. Typically, the correlation coefficient calculated is highly proximate to the value 1. This demonstrates a strong correlation between the first set of corrected and the second set of proofread data, indicating high accuracy.

Subsequently, a statistical test will compare the average values of correcting data 1 with correcting data 2. A t-test will compare the means and determine if there is a significant difference.

Before the t-test, two precursor tests must be performed: the Kolmogorov-Smirnov test to assess data normality and the Levene test to assess homogeneity of variance. The results of the computations for testing the normality and homogeneity of the data can be found in the attachment.

Based on data normality test calculations, some of the data comes from populations that are not normally distributed. Therefore, the mean difference test was carried out using the t-test and the Mann-Whitney nonparametric test.

The formulation of the statistical hypothesis tested is as follows:

$H_o : \mu_1 = \mu_2$ (There is no difference between correcting data 1 and correcting data 2)

$H_a : \mu_1 \neq \mu_2$ (There is a difference between correcting data 1 and correcting data 2)

The test criteria used are as follows: if sig. If more significant than 0.05, Ho is accepted; for other conditions, Ho is rejected. The results of the mean difference test for experimental class data are presented below.

Table 2 - Data from test results of the difference in mean scores of two correctors of connection

Data			Sig.		Conclusion	Decision
			T	Mann-Whitney		
Experiment	Pretest	P1 P2		0,417	Ho Accepted	No Difference
	Posttest	P1		0,840	Ho Accepted	No Difference
Control Class	Pretest	P1 P2		0,212	Ho Accepted	No Difference
	Posttest	P1	0,401		Ho Accepted	No Difference

In the next step, a t-test will examine the difference in improving mathematical connection abilities between students who use the means-end analysis strategy and those who use conventional learning. Before hypothesis testing, a prerequisite test will be conducted, namely the data normality test using the Kolmogorov-Smirnov test and the homogeneity of variance test using the Levene test.

The normality of the data is assessed using the Kolmogorov-Smirnov test. The formulation of a hypothesis to test the normality of data is as follows: Null hypothesis: The data sample is derived from an average distribution population. Ha: The data sample originates from a normally distributed population. Ho: The data sample originates from a non-normally distributed population. The criteria used for testing are as follows: if the significance (sig.) value is more than α = 0.05. The results of the normality test calculation are presented in the following table 4.9:

Table 3 - Data from normality test results for mathematical connection ability gain scores

Learning	Kolmogorov-Smirnov			Conclusion
	N	Sig.	Information	
Means-Ends Analysis	41	0.105	H_o Accepted	Normal
Conventional	45	0.851	H_o Accepted	Normal

The table above shows that the sig. The experimental and control class gain data are 0.105 and 0.851, respectively. Because both values are more significant than 0.05, Ho is accepted. This means that the experimental and control class gain data come from a normally distributed population.

The homogeneity of variance test for the two classes will be carried out because the data obtained by the experimental and control classes comes from a normally distributed population.

The formulation of the statistical hypothesis tested is as follows:

H_o: $\sigma_1^2 = \sigma_2^2$

H_a: $\sigma_1^2 \neq \sigma_2^2$

The test criteria used are: if sig. is more significant than α = 0.05, then Ho is accepted; for other conditions, Ho is rejected. The results of the variance homogeneity test calculation are presented in Table 4.10 below:

Table 4 - Normalized gain results of homogeneity test mathematical connection skills

Learning	Levene Test		Information	Conclusion
	N	Sig.		
Means-Ends Analysis	41	0,142	Ho Accepted	Homogenous
Conventional	45			

The table above displays significant data. The obtained value of 0.142 is greater than the significance level α = 0.05, indicating that the null hypothesis (Ho) is accepted. The homogeneity of the variances of the two classes can be inferred. Following the completion of the precondition exams, the subsequent hypothesis test was conducted using the t-test to analyse the differences in mathematical connection ability gain data.

The research hypothesis posits that students who employ the means-end analysis strategy in their learning will exhibit superior improvement in their mathematical connection abilities compared to students who rely on conventional learning methods. In order to evaluate the hypothesis suggested earlier, a further statistical hypothesis is formulated:

$H_o : \mu_1 = \mu_2$ = Increasing the mathematical connection abilities of students whose learning uses the Means-Ends Analysis strategy is the same as those using conventional learning.

$H_a : \mu_1 > \mu_2$ =Enhancing the mathematical reasoning skills of students who employ the Means-Ends Analysis approach is superior to pupils who rely on traditional learning methods.

The test criteria employed are as follows: if the significance level (one-tailed) is higher than α = 0.05, then the null hypothesis (Ho) is accepted; otherwise, the null hypothesis is rejected. The results of the mean difference test computation are displayed in the table below:

Table 5 - Test results for differences in mean gain scores mathematical connection ability

Learning	T-test (1-tailed)	Information	Conclusion
Means-Ends Analysis	0.002	Ho Rejected	There are Differences
Conventional			

The table above indicates a significant t-test on the gain data with a value of 0.02. Since the significance level is less than 0.05, the null hypothesis (Ho) is rejected. This indicates that the mean increase in performance for the experimental group is more significant than the mean increase in performance for the control group. The data suggests that students who employ the Means-Ends Analysis strategy in their learning exhibit a notably superior improvement in their mathematics connection abilities compared to students who rely on conventional learning methods.

Next, we will assess how mastering Means-Ends Analysis enhances mathematical connection abilities. Appendix D provides the entire procedure for calculating the effect magnitude. The following are the findings of the effect size calculation for the t-test.

Table 6 - Effect sizes T-test: Quantifying Mathematical Connection Ability

Learning	$\overline{x}$	S_{gab}	d
Means-Ends Analysis	0.54	0.17	0.45
Conventional	0.45		

The table above indicates that the effect size obtained is 0.45. The size falls under the small category. It may be concluded that using the means-end analysis strategy in learning minimally impacts improving students' mathematical connection abilities. The research results showed that the average mathematical connection gain obtained by the experimental class was 0.54, and the control class was 0.45. Based on the t-test of mean differences, the increase in mathematical connection abilities of students using the Means-Ends Analysis strategy is better than that of students using conventional learning.

This is because when solving existing problems, students must link mathematical concepts or concepts with everyday life during the learning process. Learning using the Means-Ends Analysis strategy provides relief to students when solving problems (Kania & Ratnawulan, 2022; Setiana et al., 2021; Sung & Black, 2020). The problems given are arranged into several sub-problems and then solved one by one by the students. Specific subproblems are solved by combining the results of solving two or more previous subproblems. This shows that learning by utilising non-routine questions can train students' mathematical connection abilities. During learning, students can follow the mathematical connection process well, but most students still need guidance from the teacher. Students' abilities still lack in determining and applying the procedures used to solve sub-problems by linking mathematical concepts.

This happens because learning means-end analysis is new for students, and students rarely get questions related to mathematical connection abilities (Septian & Komala, 2019). The explanation above shows that students' mathematical connection abilities are trained in learning using the Means-Ends Analysis strategy. Therefore, the increase in the mathematical connection ability of the experimental class is better than that of the control class. However, the effect size calculation results show that learning using the Means-Ends Analysis strategy has a negligible effect on increasing students' mathematical connection abilities, and the increase in mathematical connection abilities is still in the medium category.

Then, if we look at the post-test scores, the scores obtained by students on the indicator of applying relationships between mathematical topics reached 69.51% of the maximum score on the questions. Students' scores on applying mathematics in everyday life reached 65.24%, and the indicator of looking for the relationship between a procedure and another procedure in an equivalent representation only reached 51.22%. Overall, the score obtained by the new experimental class reached 61.75% of the ideal maximum score. Some students still made mistakes when working on the final test questions for mathematical connection abilities. This is because the mathematical connection test questions differ from the questions students usually encounter in learning.

4. Conclusions

Based on the results of data processing, analysis, and discussion presented in the previous chapter, the following conclusions show that the mathematical connection abilities of students whose learning uses the Means-Ends Analysis strategy are better than those of students whose learning uses conventional learning, even though they are in the medium category. Learning using the Means-Ends Analysis strategy has a small effect on increasing students' mathematical connection abilities. Here are several recommendations including to ensure active participation in group discussions, it is imperative to develop tactics that effectively engage all students in the learning process. The third step of the means-end analysis, which involves identifying and implementing processes to attain sub-goals, is given greater importance to enhancing students' mathematical connection abilities.

Conflict of Interest

The authors declare no conflicts of interest.

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