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Correlation Research on the Application of Scientific Debate Strategy to Academic Performance Based Mathematical Prior Ability of Students in The Integral Concept

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***Abstract* – This research examines the influence of learning with scientific debate strategy on academic performance throught the enhancement of mathematical competence of the student based MPA in the integral concept. The study design was a quasi-experiment that involving 200 students. The research instrument was mathematics competency tests with indicators: (1) Understanding of concepts; (2) Procedure fluency; (3) Strategic competence; (4) Adaptive reasoning; (5) Productive disposition. Data of mathematical competence enhancement were analyzed using Mann Whitney-U test. Data of pretest and posttest were analyzed by Kruskal-Wallis and ANOVA. Students who follow Integral Calculus learning with scientific debate strategy are significantly better than students who follow conventional learning. The Mathematical Prior Ability (MPA) factor in conventional class has a significant influence on academic performance throught the enhancement of student mathematical competence. The Mathematical Prior Ability (MPA) factor in the class of scientific debate strategy did not have a significant influence on academic performance throught the enhancement of student mathematical competence.**

***Keywords* – Scientific Debate, Academic Performance, Mathematical Competence, ANOVA, Kruskal-Wallis.**

I. INTRODUCTION

Integral and derivative are important concepts in mathematics. Integral and derivative are the two main operations in the calculus. The integral principles were formulated by Isaac Newton and Gottfried Leibniz in the 17th century by making use of the close relationship that exists between anti-derivatives and integral of course, a relationship that enables us to calculate easily the true value of many integral of course without the needing use Riemann amounts. This relationship is called the fundamental theorem of calculus. Through the basic theorem of the calculus, they develop an integral concept that is associated with a derivative. So the integral can be defined as anti-derivative.

The modern definition of the integrals expressed by Riemann with his first idea is the amount of Riemann. This idea raises the link between the integral and the area. In general, the integral necessarily denotes the boundary of the area covered between the curves $y = f(x)$ and the x-axis in the interval $[a, b]$. The width of the portion located at the top of the x-axis is given a positive sign, while the area of the width of the portion located at the bottom of the x-axis is given a negative sign.

Integral is an important concept in mathematics and has extensive applications in the field of science and industry. Student mastery in integral concepts will contribute to the development of mathematics and its applications in engineering, science and industry such as: the using of oil droplets from the tanks to determine the leakage amount over a certain time interval, the using of the shuttle speed Endeavor to determine the altitude achieved at a given time, the knowledge using of energy consumption to determine the used energy in a place one day [1]. In some fields, the integral is used to solve the volume related problems, the curve length, the estimated

population, cardiac output, dam style, business, consumer surplus, baseball, and others [2]. The using of integral will help and simplify the calculation. The importance of this integral concept is not corresponding to student' learning outcomes. Student's understanding of integral concepts has not mastery learning in as the show of the average score of 59.20 [3]. Most college students in the conventional class have a superficial and incomplete understanding of the basic concepts in calculus [4].

The reason for this low-level ability is stated by Ferrini-Mundy that rarely students are challenged to solve mathematical problems that can develop high-level mathematical thinking skills. Students view mathematics as a collection of static concepts and techniques to be completed step by step [5]. The learning process of Calculus in conventional class is presented in the form of concepts and techniques, explanation of concepts and techniques through examples, and problem-solving exercises [3]. These situations lack to give the space to develop integrated mathematical competence, self-regulated learning, critical thinking, and creative ability.

Based on the above conditions, it is necessary for a learning strategy that can develop academic performance throught enhancement of mathematical competence. One of the learning strategies that can lead the students to reach the learning objectives of calculus especially the integral concept is Scientific Debate. This condition is supported by the research results of [6], that the influence of the application of scientific debate strategy in the learning can provide enhancement students' understanding in integral concept during the final examination. The influence of the application of scientific debate in learning is that the majority of students reach the mastery learning in the understanding of integrals concept, also students can know the exploration technic of their knowledge where the algorithm solution is not applied [7]. The application of scientific debate strategy could include enhancement mathematical communication and connection ability better than conventional, but not yet for mathematical reasoning ability [1]. The application of scientific debate strategy can develop students' mathematical creative thinking ability better than conventional [8]. In the application of scientific debate strategy, the developed ability to be enhancement is mathematical competence include: concept understanding, fluency of procedure, strategic competence, adaptive reasoning, productive disposition, and self-regulated learning.

II. Review of the Literature

Increasing student knowledge in learning is important. Knowledge related to strengthening aspects of cognition, the importance of cognition in the learning process is highlighted. Cognition plays an important role in learning in various. Academic performance, learning performance, academic achievement, and learning achievement have the same understanding, namely student learning outcomes that are continuously through the learning process [9]. Lecturers can enhance academic performance of student by guiding self-confidence, setting goals and expectations, raising questions, offering feedback, connecting abstract concepts, and providing new experiences. Academic performance is knowledge, understanding, and skills acquired through learning experiences in formal curriculum and teaching design, namely students who acquire knowledge and skills through learning [10]. Academic performance is the result of student learning related to knowledge and skills in school through specific curricula and materials, which are usually presented with exam performance or academic tests [11]. Thus, academic performance can be specific or general. Specific academic performance is the subject's learning performance or the subject's average comprehensive performance [12]. The general academic performance is a record of student learning at school, such as assignments, quizzes, midterms, and final exams [13]. According to the term education, academic performance is the result of student performance on improving life adaptation and

physical and mental development through learning [12]. Therefore special academic performance was applied for this study.

III. AIMS

The measured mathematics competency in this research includes the five mathematical competence that is interrelated with each other. Specifically, the verification part of this study investigated:

1. Can we identify the difference in academic performance trought the enhancement of mathematical competence between students whose it calculus is learning with scientific debate strategy is compared with conventional learning?
2. Can we identify the difference in academic performance trought the enhancement of mathematical competence between students whose it calculus is learning with scientific debate strategy is compared with conventional learning based on Mathematical Prior Ability (MPA)?

IV. METHODS

A. *Participant*

The subjects of this research are three-semester students (N = 200) whose follow the courses of Integral Calculus. Groups of students with scientific debate strategy as many 106 people as the experimental class. Groups of students with learning conventional as many 94 people as the control class.

B. *Data Analysis*

Research instruments include the test of Mathematical Prior Ability (MPA) and mathematical competency test. Data analysis was performed using Statistical Package for Social Science (SPSS) software version 18 (IBM Corporation). Data of the difference of student's mathematical competence enhancement between scientific debate strategy and conventional learning is analyzed by Mann-Whitney U test.

The calculation of student's mathematical competence enhancement based MPA in the class of scientific debate strategy and conventional is analyzed by Kruskal Wallis test and ANOVA with p-value = 0.05.

V. RESULTS

A. *Academic Performance throught Enhancement of Mathematical Competence*

Enhancement of academic performance with measured mathematical competency indicators include: (1) understanding of concepts, namely: concepts understanding, operations, and relationships; (2) procedures fluency, namely: the ability to apply procedures flexibly, accurately, efficiently and precisely; (3) strategic competencies, namely: the ability to formulate, present, and solve mathematical problems; (4) adaptive reasoning, namely: the capacity to think logically, reflect, explain, propose justification; and (5) productive disposition, namely: the ability to always see mathematics in a positive, useful, and meaningful way [22]. Enhancement of academic performance of conventional classes is presented in Figure 1 below:

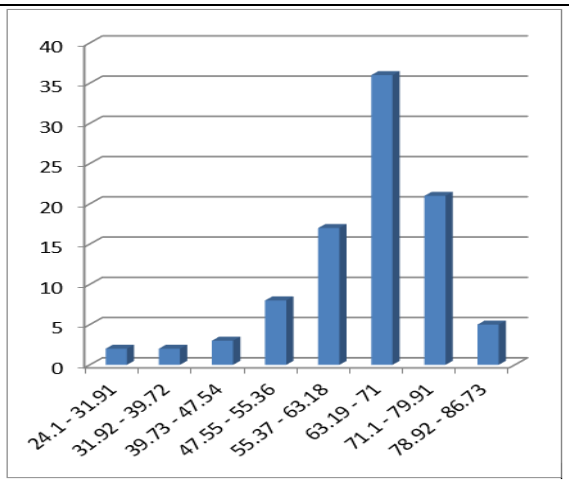


Fig. 1. Enhancement of Competence for Conventional Class.

The enhancement of academic performance of the scientific debate class is presented in Figure 1 below:

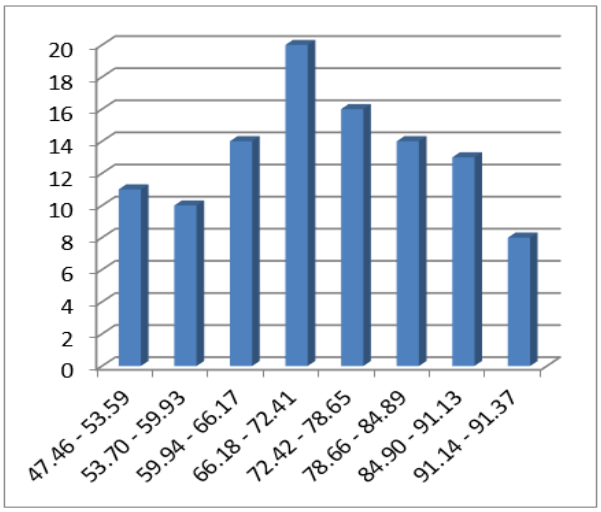


Fig. 2. Enhancement of Competence for Scientific Debate Class.

Description of academic performance data through increasing mathematical competence in scientific debate and conventional classes is presented in Table 1 below.

Table 1. Group Statistics of Academic Performance.

	Class	N	Mean	Std. Deviation
Mathematical Competency	Conventional	94	63.809	12.01871
	Scientific Debate	106	71.353	12.18661

The quantitative calculations show that the average enhancement of the mathematical competence is g = 0.47 include the medium category. Further analysis is the examination of normality and homogeneity of the score of the enhancement of mathematical competence for both classes. The results of the normality test note that the score of the mathematical competence enhancement at the control class is not normally distributed, and the experiment class is normally distributed. The testing of the hypothesis-1 to see how far the enhancement difference of students' mathematical competence at the experimental and control class is used Mann-Whitney U test. The calculation results appear in the following table 2:

Table 2. Statistics Test of Academic Performance Throught Enhancement of Mathematical Competency

	Enhancement of Mathematical Competency
Mann-Whitney U	3802.000
Wilcoxon W	8267.000
Z	-2.888
Asymp. Sig. (2-tailed)	0.004
a. Grouping Variable: Class	

From Table 2 it knew that the learning factor has a significant influence on mathematical competence enhancement. The average comparison of mean scores in the Scientific Debate class is higher than the conventional class. Students who follow Integral Calculus learning with scientific debate strategy are significantly better than students who follow conventional learning.

As a result, the implementation of learning in the experimental class, the students are seen actively involved in the process of knowledge rediscovering. They seem to think, discuss, argue to maintain opinions and explain both to other students and lecturers. This process is in line with the applied learning model that is the scientific debate. The scientific debate strategy allows students to discuss and argue so that they can be honed properly. These conditions can improve conceptual understanding, procedural fluency, strategic competence, adaptive engagement, and productive disposition. These habits provide learning outcomes in the cognitive aspects especially in the ability of high-level mathematical thinking, psychomotor aspects, and affective aspects of better learning outcomes with conventional learning.

In the scientific debate class, it appears that student activity is lively than the conventional class. Although at the learning beginning, the student looks stiff, after a few times it seems students become accustomed to arguing to maintain arguments against the answers it has.

B. *Academic Performance throught Enhancement of Mathematical Competence Based MPA*

The student academic ability can be measured through an Achievement Index (AI) or a Communal Achievement Index (CAI) what got students in the College, although sometimes it misses [14]. This AI or CAI can be assured that the student will be able to follow a certain education. Mathematical Prior Ability (MPA) held by students in this study is the student ability in the Differential Calculus material. MPA in this research is intended to see the readiness of students in the receiving of Integral Calculus materials. The success of the students receive the lessons depends heavily on the readiness of the students. This readiness is divided into two, namely mental readiness or mental development and readiness of prerequisite knowledge that has been owned. For example, students are asked to determine the Riemann number of functions $f(x) = x^2$ with n partitions. Students who do not know the limit, of course, will not be able to solve that problem. His prerequisite knowledge has not been owned, so of course, he will not understand. MPA is grouped into three groups: high, middle, and low. This grouping is intended to determine the effect of MPA on mathematical competence enhancement of students. The following table presents the condition of enhancement date of students' mathematical competence-based MPA.

Table 3. Description of Academic Performance throught Mathematical Competence Data of the Scientific Debate Class-Based MPA.

Group of MPA	Scientific Debate Class		
	Number of students	Mean	Std. Deviation
High	22	84.4955	7.57128
Middle	61	70.5885	10.31785
Low	23	60.8087	8.55421
Total	106	71.3528	12.18661

Table 4. Description of Academic Performance throught Mathematical Competence Data of Conventional Class-Based MPA.

Group of MPA	Conventional Class		
	Number of students	Mean	Std. Deviation
High	16	70.7975	14.96413
Middle	71	62.6493	9.40878
Low	7	59.6000	21.89833
Total	94	63.8091	12.01871

Furthermore, the influence analysis of learning and MPA factors on the enhancement of mathematical competence. The prerequisite test, the normality test of the data distribution and the homogeneity of the data of the variance group respectively with the Kolmogorov-Smirnov test (Z test) and Levene test (F test). From the results of prerequisite, the test is known that mathematical competence data in the control class is not normally distributed, whereas in the experiment class is normally distributed and the data groups have the same variance. The statistical test on the control class is used Kruskal Wallis Test. The calculation results are shown in Table 5 below:

Table 5. Test Statistics of Academic Performane throught Mathematical Competence Based MPA in the Conventional Class.

Chi-square	12.628
Df	2
Asymp. Sig.	0.062

Table 5 is known that the MPA factor in the conventional class has a significant influence on the enhancement of mathematical competence. The comparison of the average scores in the high group is higher than other MPA groups. The used statistical test in the experimental class is ANOVA. The calculation results are shown in Table 6 below:

Table 6. Test Statistics of Academic Performance throught Mathematical Competence-Based MPA in the Scientific Debate Class.

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	6392.774	2	3196.387	35.781	0.000
Within Groups	9201.130	103	89.331		
Total	15593.904	105			

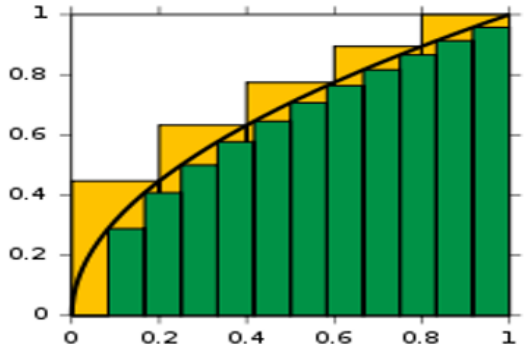
Table 6 is known that the MPA factor in the Scientific Debate class has not a significant influence on the enhancement of mathematical competence. The comparison of the average scores in the high group is higher compared to other MPA groups.

VI. DISCUSSION

Academic performance that developed were mathematical competence refers to the opinion of [15], which are five of interconnected mathematical competences with each other (intertwine). The five of competencies are:

1. Concept understanding include: concept, operation and relationship understanding.
2. Procedure fluency include: ability to apply procedure flexibly, efficiently and accurately.
3. Strategic competence include: ability to formulate, to present and to solve mathematical problems.
4. Adaptive reasoning include: capacity for logical thinking, reflection, explaining, justification.
5. Productive disposition include: the ability to constantly see mathematics in a positive, useful, meaningful way.

For example, the used problem examine the competence of students' adaptive reasoning with indicators explains the model, image, facts, nature, relationships, or patterns that exist: consider the function graph of $f(x) = \sqrt{x}$ between $x = 0$ and $x = 1$ below,



a. From the graph on the side, describe the relationship between x and y variables.
b. Describe the shaded area in green!
c. Describe the shaded area in yellow!
d. Show the area bounded by the curve $f(x) = \sqrt{x}$ between $x = 0$ and $x = 1$.

Example of indicators estimate the answers and solutions process and the using of patterns and relationships to analyze mathematical situations and generalize, the questions can be raised such as:

1. To use 5, 10, and 15 rectangle of the enclosure to estimate the area of S under parabola $y = f(x)$ between $x = 0$ and $x = 1$, with $f(x) = \sqrt{x}$.
2. To use n rectangle of the enclosure to estimate the area of S under the parabola $y = f(x)$ between $x = 0$ and $x = 1$, with $f(x) = \sqrt{x}$. Example of indicators of constructing and testing of conjectures a problem may be proposed such as, to compare the S area under the parabola $y = f(x)$ between $x = 0$ and $x = 1$, with $f(x) = \sqrt{x}$ obtained for 5, 10, 15, And n rectangle of the enclosure.

Example of indicators the rules following of inference, to construct valid arguments, and to check the validity of arguments can be raised such a problem, to prove that the S area under the parabola $y = f(x)$ between $x = 0$ and $x = 1$, where $f(x) = \sqrt{x}$ is 2/3. Another example, the problem is used to test the fluency competency of a student procedure: to estimate area below the graph of $f(x) = x^2 + 1$ from $x = -1$ to $x = 2$ use three rectangles of the enclosure and the right endpoint. Then:

1. To refine your estimates use the six rectangles of the enclosure.
2. To repeat one part by using the left endpoint.
3. To repeat one part using the midpoint. From your sketch of part one, two, three in which sections appear.

The research results show that the MPA factor in the experimental and control classes have a significant influence on the enhancement of mathematical competence. The students' ability learns new ideas to depend on their mathematical prior ability and existing cognitive structures. According to [14], the success of each student in learning is almost completely influenced by student intelligence, student prior ability, and student talent. But, the research results of [1] refer that there is no interaction between the learning model with the MPA of students in mathematical problem-solving ability.

Students who follow Integral Calculus learning with scientific debate strategy are significantly better than students who follow conventional learning. In the conventional class, Integral Calculus instructional was given spontaneously and inductively with the assumption that Calculus was a combination of some knowledge and techniques. This instructional situation emphasizes at Calculus for mathematicians. Students learn with the example (inductively). The lecturer was a belief that mathematics was a knowledge body had been found and he has a belief that students can learn spontaneously by to listen, to notice, and to provide techniques set to resolve routine problems. This condition causes the student was passive to acquire the knowledge so that mathematical competence and Self-Regulated Learning did not develop optimally. This was the created instructional error. One the effort can be made to improve the instructional error was the tailored method selection of Integral Calculus.

Debate Scientific strategy was expected can increase student activity. Students were trained to be able to solve problems, to communicate the answers both oral and to be written, to provide the refutation of different answers, to provide feedback, to evaluate, to reflect, and to conclude. These conditions can enhance mathematical competence and Self-Regulated Learning. The new getting of knowledge in the study, the students need to discuss with their teachers and peers to understand the meaning of the world and to develop academic discourse abilities, conventions, and traditions of the scientific community [16] and [17].

The principle of Scientific Debate instructional strategy refers to [18], namely:

1. Spontaneously: the presentation material was done verbally, to be written, to be presented in the drawings/ diagrams form, students listened and to recorded with confidence they can learn independently.
2. Inductively: students learn the presented examples various, the lecturer filter both generally concept part and important concepts of the student experience and he organizes the information of the student mind.
3. Constructively: the students learn to make the association of mental construction between the concept with mathematical phenomenon.
4. Pragmatically: the students learn mathematics through the response of problem or other field problems, teachers can engage the students in the several applied fields. Dubinsky opinion application was adapted to the mathematics character as knowledge, techniques, thought ability, and applications.

The process of mathematical knowledge acquiring in the Scientific Debate instructional model was based on the cognitive and didactic hypotheses [3] namely:

1. Constructivism, the theory talk that the knowledge was gained apparently with to construct own their knowledge through interaction, conflict, and re-equilibration to involves mathematics knowledge, the other students, and the problems various. The interaction was regulated the lecturers to take up the optioning of fundamental issues.
2. The strengthened knowledge when it has been established and has been applied to the proper concept order.
3. A contradiction setting.
4. The setting importance of the students grouping understand and to construct knowledge individually.
5. The influence of meta-mathematical factors such as representation system of problem-solving and the verification can be done explicitly to emphasize the teaching purposes.
6. The constructed epistemology involves issues, situations, and so on, to gives students the understanding of concept through an association for the concept formation advancement.

It implementation was carried out with the stepping:

1. The Lecturer initiate and to organize the student statement without the truth evaluating.
2. A statement was given back to be considered and to be discussed.
3. The statement was justified with show theorem or applicable rules.
4. To provide the statement modification
5. To determine the counter-example.
6. To conduct observation.
7. To generate a new conjecture.
8. To generate an argument.
9. To perform validation.

The concept part of Integral Calculus material was the must be proved theorems. The proof in Debate Scientific Instructional has the distinction between 'proofs to convince' (the proof convince other students), and the evidence was used to show at the lecturer. The involved activities in the 'proofs to convince' process was the involved fundamental difference in both the process and can produce the knowledge and the deeper understanding. Theoretically, this teaching system was used since 1984 and to be shown as a didactic situation [19]. It was a situation where students are trying to convince him and others at the same time from the formulated conjecture truth in the problem answer in which all groups are trying to solve. Students were aware that the conjecture was not always the truth, but the special conditions and the undeveloped knowledge part.

Based on the above conditions, the characteristics of the learning model can be illustrated how the process of teaching and learning takes place in the classroom. Characteristics of scientific debate strategy according to [2] are: (1) Teaching materials are packaged in the form of conceptual presentation, examples of application, and dish of the problem, so that the understanding of concepts, principles, and procedures in solving problems are expected to be studied independently through teaching materials. Understanding the concept correctly and in-depth is done through the problem solving of application done in the debate. This activity is expected to accommodate students'

opportunities to construct and discover knowledge independently. (2) Mathematical activity in a variety of thinking, thus learning activities should emphasize the process of extracting from real experience in everyday life into the world of mathematics or vice versa, in other words. There is a link between mathematics with other fields of science. So to stimulate the occurrence of debate between students with students or between students with teaching lectures began with a dish of application problems. (3) The teacher functions as a facilitator. For a debate, lecturers begin and organize student answers. These results are written on the board without evaluating the truth of the statement. The statement is given back to the student for consideration, and they must reiterate the report and have been supported by several ways, given his argument, proved, proving that something is not true, with counter-examples, and others. Statements are justified by the prevailed theorems showing or rules, while some built as improper statements are presented as "false statements," with a corresponding counter-examples. (4) Learning interaction model developed more multidirectional.

In implementing the scientific debate strategy, the lecturer prepares the teaching materials and Student Worksheet (SW) for the experimental class. The teaching materials are developed in this research are designed so that students can find the concept, procedure, principle, and able to apply it in the solving of the given problem. Teaching materials are developed in such a way that students are enabled to achieve mathematical competencies relevant to the being studied material. Also, the focus of developed teaching materials is directed so that students' mathematical competence can develop optimally. This SW is served as a reference for students to equip themselves in debates and the problems solving. SW not only contains the problems that will be solved by the students, but also provides concepts, procedures, and principles, as well as serving examples of applications that students can learn before the lecture as a preparation for the debate.

The learning model and the types of tasks given in the form of SW in the scientific debate strategy also provide opportunities for the growth of stronger mathematical power in the students. To improve mathematical conceptual understanding, students can do it by expressing their mathematical ideas to others [20]. The discussion activities with teachers and their spouses, students are expected to gain a better understanding of the basic concepts of mathematics and become better problem solvers [21]. In the conventional class indicates that the average value of concept understanding, strategic competence, adaptive reasoning, and productive disposition have category sufficient or C and the mean value of procedure fluency has category good or B. There is no difference in the competence of the mathematical understanding, strategic competence, and productive disposition between scientific debate class and conventional class. Students' competence in fluency procedures and adaptive reasoning in the scientific debate class is better than conventional class [22]. This rational support efforts to improve the quality of learning outcomes and the process of mathematics learning to develop students' high mathematics thinking ability, especially the improvement of mathematical competence. The implementation of Scientific Debate strategy can reduce the level of misunderstanding of integral concepts is lower than conventional learning [7]. Students who follow the Integral Calculus learning with scientific debate strategy are significantly better than conventional class [22].

VII. CONCLUSION

Students who follow Integral Calculus learning with scientific debate strategy are significantly better than students who follow conventional learning. The Mathematical Prior Ability (MPA) factor in the conventional class has a significant influence on academic performance throught the enhancement of student mathematical

competence. The Mathematical Prior Ability (MPA) factor in the class of scientific debate strategy did not have a significant influence on academic performance throught the enhancement of student mathematical competence.

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