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EFFECTIVENESS OF LEARNING MODEL QUANTUM LEARNING AGAINST STUDENTS' MATHEMATICAL CRITICAL THINKING SKILLS

Siti Khadijah Nasution[1], Suci Dahlya Narpila[2]
[1,2]Pendidikan Matematika, Universitas Islam Negeri Sumatera Utara
e-mail: siti0305213108@uinsu.ac.id

Abstract

Students must have critical thinking skills to face the challenges of complex mathematics learning. Howver, the fact in the field shows that study are still classified as lacking in critical thinking. The purpose of this study was to determine how effective the quantum learning model is on students' mathematical critical thinking skills in the material of arithmetic sequences. This study was conducted at Karya Utama Junior High School in Serdang Bedagai Regency. A quantitative approach was used and a quasi-experimental design using a pretest-posttest control group. The results of the study were conducted randomly, with 30 studies each in the experimental group of class VIII d and the control group of class VIII B. The results showed an average posttest score of the experimental class of 79.66, which was higher than the control class of 70.66, and a significance value of 0.003 <0.05. Therefor, H0 was rejected and ha was accepted. The results showed that the quantum learning model was effective in improving the ability to think critically mathematically.

Keywords: *quantum Learning, critical Thinking, tandur, arithmetic sequences*

Abstrak

Peserta didik haruis memiliki kemampuan berpikir kritis untuk menghadapi tantangan pembelajaran matematika yang kompleks. Namun, fakta dilapangan menunjukkan bahwa siswa masih tergolong kurang dalam berpikir kritis. Tujuan penelitian ini ialah menentukan seberapa efektif model pembelajaran *Quantum* terhadap kemampuan berpikir kritis matematis siswa dalam materi barisan aritmatika. Penelitian ini dilakukan di SMP Karya Utama di Kabupaten Serdang Bedagai. Pendekatan kuantitatif digunakan dan desain quasi eksperimen menggunakan *Pretest-Posttest Control Group*. Hasil penelitian dilakukan secara acak, dengan 30 siswa masing-masing dalam kelompok eksperimen kelas VIII D dan kelompok kontrol kelas VIII B. hasil menunjukkan skor *posttest* rata-rata kelas eskperimen sebesar 79,66, yang lebih tinggi dari skor kelas kontrol sebeesar 70,66, dan nilai signifikansi 0,003 < 0,05. Oleh karena itu, H_0 ditolak dan H_a diterima. Hasilnya menunjukkan bahwa model pembelajaran *Quantum* efektif dalam meningkatkan kemampuan untuk berpikir kritis secara matematis.

Kata kunci: pembelajaran *quantum*, berpikir Kritis, tandur, barisan aritmatika

INTRODUCTION

Education is the main element in individual development (Narpila et al., 2025). Education plays an important role in shaping future generations who are able to adapt to the dynamics of the times (Narpila et al., 2023). Improving the quality of education continues to be the main focus in Indonesia, as reflected in education needs to be designed, utilized, improved, and arranged in such a way as to support learning needs, with the aim of achieving higher quality learning (Pulungan & Rakhmawati, 2022). Various efforts have been made, such as teacher training, seminars, and workshops, with the aim of increasing the effectiveness of learning models in class, including in mathematics. Mathematics is characterized by properties such as abstraction of study objects, deductive approaches, consistent systems,

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meaningful symbols, and clear scope limits based on formal agreements (Siregar et al., 2024). Mathematics as a basic science in education now needs to be applied and developed more creatively, adjusting to the demands of the changing times (Lubis & Rahmadhani, 2023).

Mathematics does not only function as a means to hone the ability to do calculations, measurements, reasoning, and use of formulas, but also play a role in forming student thinking logically, critically, and analytically (Hasibuan et al., 2023). According to NCTM (2020), the purpose of learning mathematics includes five main aspects, namely the ability to solve problems, communication skills, connection capabilities, reasoning capabilities, and the ability of representation. One of the main aspects in achieving these goals is to practice the critical thinking skills of students, where students are guided more than just knowing the concepts on paper but are also able to examine, evaluate, and apply the concept in various real situations. In line with Maysarah et al., (2024) which states through learning mathematics, students are required to apply logical reasoning and critical thinking in dealing with various real life situations.

According to Nasution et al., (2022) , the ability to think critically includes managing, adjusting, revising, or perfecting the mindset. This means that someone who thinks critically is not only able to understand an information, but can also judge truth, relevance, and implications of an information before drawing certain conclusions or actions.

The ability to think critically includes five indicators namely Elementary Clarification (providing simple explanation), basic support (building basic skills), advanced clarification (providing further explanation), strategy and tactics (strategy and tactics), and inference (concluding) (Wardani et al., 2024).

The ability to think critical is an important aspect to support success in the world of education. The importance of critical thinking in education is also supported by various studies. Critical thinking skills encourage students to develop learning skills, solve problems effectively, and make decisions wisely (Ariadila et al., 2023). Learning models such as learning focusing problems and collaborative learning show success in honing students' critical thinking skills. Critical thinking also directs in determining rational decisions, increasing the ability to solve problems, and develop creativity in facing challenges. Therefore,

strengthening critical thinking skills in learning becomes an important aspect that cannot be ignored.

If students show optimal critical thinking skills, they will tend to be able to learn problems in a structured manner, overcome various problems with an orderly approach, arrange creative questions, and design solutions that are considered quite innovative (Zakiah & Lestari, 2019). This will increase creativity, learning independence, and the ability to face academic challenges and real situations. Students who can think critically are also increasingly active in discussions, are able to provide logical arguments, and are ready to face questions that require in-depth analysis. Therefore, mathematics lessons not only focus on memorizing the formula but also in the process of thinking critical which is useful in everyday life.

But the findings in the field are not like that, in the findings of the trial of researchers at SMP Karya Utama, it was found that during the learning process of mathematics, students tend to show the ability to think critically. Based on the test given to students, only 24% of students are able to answer questions appropriately and show a critical thought process. Meanwhile, 76% of other students have difficulty in mastering concepts, analyzing patterns, and drawing conclusions from the problems given. Almost all students only remember the formula without mastering their application, as a result when the questions given have a different pattern from the sample taught, some students seem difficult to determine the steps of completion.

According to observations, teaching and learning activities carried out by teachers contribute to the decline in critical thinking. This result also proves the learning approach used by conventional permanent teachers, with lectures and examples of questions given without giving the possibility of students studying ideas personal. This situation makes students passive in receiving information, without activities or discussions that can help them think critically. The teacher tends to focus more on the final results of answers than the thought process of students. As a result, students are accustomed to finding quick ways to answer questions without understanding the basic concepts.

To deal with this problem, a learning model is needed that can stimulate students' analytical and reflective thinking. Anggara & Rakimahwati, (2021) states that the learning approach based on direct and interactive experience has a positive effect. This model allows students to participate actively and interact with ideas directly have the ability to increase student interest in lessons, improve their critical thinking skills. As a result, choosing a good learning model is very important to get the best learning in school.

Through an innovative learning model, students are expected to be motivated in thinking more deeply and actively in the learning process. Lubis (2024) states that students are more interested in learning mathematics, teachers need to implement interactive and fun learning approaches. Trinova et al (2022) also explains that an interesting learning approach can eliminate the perception that mathematics is a subject that is considered challenging and unattractive. If students feel challenged and interested in the learning methods used, they will be more actively involved and be able to develop their critical mindset better. Therefore, innovation is needed in learning strategies to increase student critical involvement and thinking skills.

One solution that can be applied is the use of quantum learning learning models. According to Anggara & Rakimahwati, (2021), the Quantum learning model focuses on realizing a state of positive, active, encouraging learning. A comfortable and positive learning environment can trigger students' interest in learning more actively (Siregar et al., 2023).This quantum learning model is based on the principle of tandur (growing, natural, name, demonstrating, repeating, celebrating), aims to foster more meaningful active involvement and help students master the concepts more easily (Trinova et al., 2022). This learning activity allows students to actively participate in discussions, reflect on, and develop critical thinking skills more directed and sustainable. Thus, Quantum Learning gives students the opportunity not only to master the mathematical concepts but also apply the concept in a real context, thereby increasing their critical thinking skills.

Various studies have proven quantum learning both in improving students' critical thinking skills. Research Saputro (2024) found that the manifestation of quantum learning was able to improve students' significant critical thinking skills. Meanwhile, Trinova et al.,

(2022) found that the quantum learning model made learning more relaxed and fun, and improve students' critical thinking skills. However, although this approach has been proven effective, there are still a few studies that discuss the integration between Quantum Learning in learning mathematics.

Seeing the great potential of Quantum Learning in improving students 'critical thinking skills, this research was conducted to see how effective the Quantum learning model in improving the ability of students' mathematical critical thinking in arithmetic material. It is hoped that this research will find learning methods that are more creative, interactive, and successful to improve students' critical thinking skills.

Based on this background, the main purpose of this research is to find out how effective the quantum learning model is on the ability of students' mathematical critical thinking in arithmetic material. Another main goal is to find out whether there are significant differences in the critical thinking skills of students who use the Quantum learning model compared to students who learn with ordinary learning models, as well as measuring their influence on the quality of critical thinking of students.

Although critical thinking skills have long been recognized as an important competency in mathematics learning, their implementation in the classroom still faces many obstacles, primarily due to the conventional, teacher-centered learning approach. This results in students being given less space to develop the logical, analytical, and reflective thinking skills that are so essential in today's education era. Previous studies have indeed demonstrated that the Quantum Learning model can improve learning outcomes, but few have specifically linked the TANDUR steps in Quantum Learning to measurable indicators of mathematical critical thinking. Furthermore, few studies have examined the model's effectiveness on arithmetic sequences at the junior high school level, particularly in areas such as Serdang Bedagai Regency that have not received much research. Therefore, this study aims to fill this gap by exploring in detail how the implementation of the Quantum Learning model can improve students' mathematical critical thinking skills through five measurable indicators, and contributing to the development of mathematics learning that is adaptive to the demands of the 21st century.

The results of this study are expected to provide broad benefits for various parties. For students, this research is expected to be able to improve the ability to think critically, creativity, and motivation and active involvement in learning mathematics. For teachers, the results of this study are used as references to apply learning models that are more innovative, interactive, and adjust to student learning guidance. For schools, the findings of this research can be the basis for making optimal learning curriculum and learning strategies planning. As for other researchers, it becomes a contribution to the progress of education, especially in the application of learning models that can improve students' critical thinking skills at the junior high school level.

METHODS

This research is a type of quantitative research with an experimental quasi approach. This study uses the design of the pretest-posttest control group design, where two groups of students namely the experimental group and the control group each are given pretest, then the experimental group receives treatment with the quantum learning learning model with tandur steps (growing, natural, name, demonstration, repeat, and celebrate), while the control group gets ordinary learning. After treatment, the two groups were given a posttest to measure the extent of the ability of mathematical critical thinking students to increase.

This research was conducted at Karya Utama Middle School, located in Pekan Dolok Masihul, Serdang Bedagai Regency, North Sumatra Province, Indonesia. The time of research is the even semester of the school year 2024/2025, precisely in April. The population of this study covers all students of class VIII of SMP Karya Utama consisting of 4 classes namely VIII A, VIII B, VIII C, and VIII D which amounted to 120 students. Random sampling is simple, which means samples taken directly from the sample unit without considering certain groups or strata, used for sampling (Salim, 2018) and from the lottery results obtained class VII D as an experimental group and class VIII B as a control group, totaling 30 students. The research design is as follows:

Table 1. Pretest-posttest control group design

Group	Pretest	Treatment	Posttest
Experiment	O_1	Quantum Learning	O_2
Control	O_3	Ordinary learning	O_4

Description:

O_1 = Pretest for experimental class

O_2 = Posttest for experimental class

O_3 = Pretest for control class

O_4 = Posttest for experimental class

The instrument used consisted of essay questions based on five indicators of mathematical critical thinking skills: elementary clarification, basic support, advanced clarification, strategy and tactics, and inference. This instrument was validated by two experts, a lecturer and a mathematics teacher, to ensure the suitability of the indicators, level of difficulty, and readability of the questions. The validated questions were then used in the pretest and posttest.

The instrument used is in the form of a critical mathematical thinking test sheet. This instrument has gone through a validation process and contains questions based on indicators of mathematical critical thinking abilities in the context of arithmetic sequences.

Table 2. Rubric assessment ability thinking critical mathematical students

Indicator	Description	Score
Elementary clarification (providing a simple explanation)	Able to describe simply from the right problem	2
	Able to describe simply from problems but in the settlement is not right	1
	Unable to describe simply	0
Basic Support (Building Basic Skills)	Able to build basic skills from the problem properly	2
	Able to build the basic skills of the problem but in the solution is not right	1
	Unable to build basic skills	0
Advanced Calrification (providing further explanation)	Able to explain in more detail from the problem correctly	2
	Able to explain in more detail from the problem but the solution is not right	1
	Unable to explain in more detail	0
Srategy and Tactics (Developing Strategies and Tactics)	Able to develop strategies and tactics from problems appropriately	2
	Able to develop strategies and tactics from problems but the solution is not right	1
	Unable to develop strategies and tactics	0
Inference (concluding)	Able to conclude from the problem properly	2
	Able to conclude from problems but not quite right	1
	Unable to conclude	0
Total score		10

T-Test, a statistical method used to evaluate the validity of the null hypothesis, used to analyze the data of this study (Sudijono, 2018). Before conducting t-test there is a prerequisite test conducted requires a prerequisite test to ensure the analyzed data is in accordance with the basic assumptions in the parametric statistical analysis. Two types of tests, namely the normality test and homogeneity test, are needed to guarantee the accuracy and validity of the research results. The normality test, homogeneity test, and t-test (independent sample t-test) are used to assess significant differences between the experimental and control groups in the pretest and posttest data of the two groups. Researchers use Statistical Package for the Social Sciences or SPSS version 25 to help them analyze the data they get.

Before conducting the t-test, the following prerequisite tests were performed:

a. Normality test using Shapiro-Wilk, because the sample size was <50. The goal was to ensure that the data in each group was normally distributed.
b. Homogeneity test using Levene's Test, to determine whether the variances of the two groups were homogeneous.

If the results of the normality and homogeneity tests indicate that the data meets the requirements, the t-test can be conducted. The decision-making criteria for hypothesis testing are:

a. If the significance value is ≤ 0.05, then H0 is rejected and Ha is accepted.
b. If value significance > 0.05, then h_0 accepted and h_a rejected.

RESULTS AND DISCUSSION

Results should be clear and concise. The results should summarize (scientific) findings rather than providing data in great detail. Please highlight the differences between your results or findings and the previous publications by other researchers.

Before treatment, students undergo pretest to measure their initial ability to think critically. Students are tested again after learning to find out the extent of their critical thinking skills. The tools used are a matter of description, or essay, which is made based on five criteria for critical thinking skills: namely elementary clarification, basic support, advanced clarification, strategy and tactics, and inference.

Data pretest and posttest for experimental and control classes are presented below to provide a general picture of the critical thinking skills of students in both classes.

Table 3. Description ability thinking critical mathematical students

Statistics	Learning			
	Quantum (Experiment)		Ordinary (control)	
	Pretest	Posttest	Pretest	Posttest
Amount	30		30	
Average	46,33	79,66	43,66	70,66
Standard deviation	13,51	10,33	13,25	10,14

The table above shows that the average posttest score for the experimental group was 79.66, higher than the control group's average of 70.66. Furthermore, the experimental group had a smaller standard deviation, indicating more even and stable learning outcomes. This demonstrates that the Quantum Learning model has a positive impact on students' critical thinking skills.

Table 4. Average score each indicator ability thinking critical mathematical students

Indicator	Experimental class		Control class	
	Pretest	Posttest	Pretest	Posttest
Elementary Clarification	0,966	1,833	0,866	1,266
Basic Support	0,900	1,666	0,833	1,366
Advanced Calrification	0,800	1,733	0,933	1,200
Strategy and Tactics	0,900	1,666	0,833	1,233
Inference	0,933	1,766	0,900	1,166

The data in the table shows that there was an increase in all aspects of critical thinking, particularly in the elementary clarification and inference indicators in the experimental class. This suggests that steps in the Quantum Learning model, such as "Grow" and "Repeat," play a significant role in building basic understanding and the ability to draw logical conclusions.

Before conducting the t-test, a prerequisite test was conducted to ensure the data met the requirements for parametric analysis:

Table 5. Test normality ability thinking critical mathematical students

Tests of Normality						
	Kolmogorov-Smirnova			Shapiro-Wilk		
	Statistics	DF	Sig.	Statistics	DF	Sig.
Pretest experimen	,121	30	, 200*	,958	30	,275
Posttest exprimen	,136	30	,167	,960	30	,303

Control control	,155	30	,064	,953	30	,200
Posttest control	,130	30	, 200*	,959	30	,285

This data has a normal distribution because all Shapiro-Wilk's significance value is greater than 0.05.

The homogeneity test was conducted after the normality test to determine whether the variances between groups were homogeneous. The following table shows the results of the Levene's Test:

Table 6. Homogeneity test of students' mathematical critical thinking skills

Test of Homogeneity of Variations					
		Levene Statistics	DF1	DF2	Sig.
Understanding	Based on mean	.770	1	58	.384
	Based on median	.558	1	58	.458
	Based on median and with adjusted df	.558	1	54.376	.458
	Based on trimmed mean	.766	1	58	.385

With a significance value of 0.384 above 0.05, the data meets the requirements for a t-test because the variance in both groups is homogeneous. The Shapiro-Wilk test results indicate that the data are normally distributed, and the Levene's test results indicate that the data have homogeneous variance. Therefore, the analysis can be continued using an independent sample t-test. The results are presented in the following table:

Tabel 7. Hasil uji t

Independent Samples Test										
		Levene's Test for Equality of Varianes		t-test for equality of means						
		F	Sig.	T	DF	Sig. (2-tailed)	Mean Difference	STD. Error difference	95% Confidence Interval of the Difference	
									Lower	Upper
Ability	Equal varian	.770	.384	3.122	58	.003	8.167	2.616	2.930	13.403

ces assumed							
Equal variations not assumed	3.122	56.664	.003	8.167	2.616	2.927	13.406

As shown by the significance value of 0.003, H0 is rejected and Ha is accepted at a significance level of α=0.05, proving that the Quantum learning model is successful in improving students' ability to think critically mathematically.

The research results were found that the Quantum Learning learning model was effective in improving students' mathematical critical thinking skills in arithmetic material. This finding is shown through differences in the average score between the experimental class and the control class which is quite significant, from 46.33 to 79.66. Meanwhile, the control class using the usual method only increased from 43.66 to 70.66. The average score on each indicator of students' mathematical critical thinking abilities for experimental classes and control classes occurs in all indicators from pretest to posttest. In the experimental class, the pretest scores are in the range of 0.800 to 0.966 and increased to 1,666 to 1,833 in posttest. The control class shows the pretest scores between 0.833 to 0.933 with posttest scores that increased to 1,166 to 1,366. The t-test results show a significance value of 0.003 <0.05, also supports significant differences. That is, compared to conventional learning, quantum learning improves students' critical thinking skills better

The effectiveness of quantum in learning cannot be separated from the specific contributions of each step to aspects of critical thinking ability. In this study, the ability to think critically was measured based on five indicators, namely elementary clarification, basic support, advanced clarification, strategy and tactics, and inference. Each tandur step plays a role in encouraging the strengthening of these indicators during the learning process.

The first step is to grow, the teacher builds positive interactions and explains the learning objectives so that students feel attracted and motivated. This step is closely related to the elementary clarification indicator, because students who are motivated tend to have more understanding and explain the core of the problem well. Research Trinova et al., (2022)

also shows that a conducive learning environment and learning motivation greatly affects the basic understanding of students of the material.

The second step is natural, students are invited to experience the concept directly through explorative activities. This activity supports basic support indicators, because students begin to build understanding through concrete experiences. Nurjannah & Arifin (2023) through her research revealed students' involvement in the environment directly improve their ability to provide logical reasons and link information obtained with real situations.

The third step is the name, the teacher begins to introduce formal terms or concepts such as the formula and mathematical notation. This stage supports the Advanced Clarification Indicator because students learn to connect experience with a more complex logic structure. This is supported by Saputro (2024) which states that giving the term after exploratory activities strengthens the ability to think logically and in -depth students.

The fourth step is demonstration, students are given the opportunity to designate their learning outcomes, both through discussion and presentation. This process strongly supports strategy and tactics indicators, because students are required to develop systematic problem solving strategies. Annisa et al., (2024) research shows that when students are asked to show their thinking processes in front of the class, this increases their ability to compile arguments and train self -confidence.

The fifth step is to repeat, done by repeating concepts and providing exercises to strengthen understanding. This is related to the inference indicator, because repetition helps students in drawing conclusions based on the patterns and information that has been learned. Ariadila et al., (2023) emphasizes that students' critical thinking skills can be strengthened through repeated exercises, this also encourages them to make rational conclusions based on the information they have.

The last step is to celebrate, is a form of appreciation for student efforts and achievements. Although not directly related to certain indicators, this award creates a positive emotional atmosphere and arouses student learning motivation. According to Maruti & Anggraini (2022), appreciation for student efforts can increase the spirit and confidence, which supports the development of critical thinking abilities indirectly.

The results of this study align with those of Trinova et al., (2022), who stated that Quantum Learning creates an active and enjoyable learning environment, making it easier for students to understand and reflect on mathematical concepts. These findings are further supported by Saputro (2024), who stated that the "Natural" and "Demonstrate" steps in Quantum Learning are highly effective in developing students' conceptual understanding and analytical skills.

Furthermore, Quantum Learning enables students to actively engage, think systematically, and express their ideas through discussions and presentations. This finding aligns with the opinion of Ariadila et al., (2023), who emphasized that learning that encourages active participation is crucial for developing higher-order thinking skills.

The implication of these results for mathematics education practice is the importance of teachers adopting a more active and reflective learning approach. Quantum Learning through the TANDUR approach not only improves learning outcomes but also creates meaningful, enjoyable, and empowering learning experiences. This model can be implemented as an effective alternative learning strategy to foster students' critical mathematical thinking skills, which are crucial for facing the challenges of the 21st century.

Thus, it can be concluded that Quantum Learning is very suitable to be applied as an innovative learning model to improve students' critical thinking skills, especially in mathematics subjects.

CONCLUSION

Based on the results of research conducted at SMP Karya Utama, it can be concluded that the Quantum Learning Learning Model is effective in improving students' mathematical critical thinking skills in arithmetic material. This can be seen from the results of the independent sample t-test which shows a significance value of 0.003 <0.05 then H0 is rejected and Ha is accepted. That is, the quantum learning learning model has proven effective in improving students' mathematical critical thinking skills compared to ordinary learning.

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