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## Exploring the Influence of the Evidence-Based Reasoning Model in the Inquiry Approach to Enhancing Students' Scientific Reasoning

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### Abstrak

Scientific reasoning becomes a prerequisite skill for studying science. The fact is that this ability, especially at the junior high school level, is relatively low. One learning model that can be applied to overcome this problem is inquiry-based, evidence-based reasoning. This type of research is a one-group pretest-posttest design with a sample of 102 students taken by the purposive sampling technique. The research instrument was a two-tier multiple-choice test based on scientific reasoning indicators. The results of the study were analyzed using the N-gain test, and a value of 0.6 was obtained, or it could be concluded that there was an increase in students' scientific reasoning in the moderate category. An ANOVA test was also carried out, and a significance value of  $0.258 > 0.05$  was obtained, which indicated that there was no significant difference between groups or that the EBR model had a consistent impact on increasing students' scientific reasoning. Each indicator of scientific reasoning also experienced an increase in the moderate category. The existence of this research can be of particular concern to educators as they continue to train scientific reasoning abilities in various natural science materials so that a scientific mindset is formed in students.

**Keywords:** Evidence-Based Reasoning, Inquiry, Scientific Reasoning

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## INTRODUCTION

Scientific reasoning is a person's ability to think logically based on scientific concepts and evidence already possessed to acquire new knowledge (Firdausi et al., 2020; Hadi et al., 2021; Sari et al., 2020). In line with this, some researchers interpret scientific reasoning as the ability to apply logical principles to a scientific process, starting from finding problems, formulating hypotheses, determining predictions and solutions, determining variables, applying experiments, analyzing data, and draw a conclusion (Balqis et al., 2019; Hanson, 2016; Nasir, 2023). Based on the opinion of several scientists, scientific reasoning skills are needed in learning natural sciences to understand and construct drafts independently (Tala & Vesterinen, 2015; Basri, 2019). This is because science is knowledge that learns all phenomena or symptoms of nature in the form of facts, concepts, and laws based on experiments or research to obtain the truth. Scientific reasoning abilities are included in one part of thinking skills in the 21st century, which can be implemented in science learning as a provision for students to adapt to the challenges of globalization, (Handayani et al., 2020; Utami et al., 2019; Yulianti & Zhafirah, 2020). In agreement with this viewpoint, it is well known that the 2013 curriculum includes a requirement that students develop their capacity for scientific reasoning as part of their study of science (Anjani et al., 2020; Fitriyani et al., 2017; Wasoso, 2018)

According to Karplus et al., scientific reasoning has two patterns: concrete reasoning and formal reasoning. In concrete reasoning, there are four dimensions: class inclusion, serial ordering, and reversibility. Additionally, formal reasoning consists of five dimensions: theoretical reasoning, combinatorial reasoning, functional and proportional reasoning, control variables, and probabilistic and correlational reasoning (Karplus, 1977; Shofiyah & Wulandari, 2018). Based on Piaget's theory of cognitive development, the operational stage of concrete reasoning is owned by children aged 6–12 years, while the operational stage of formal reasoning is owned by children aged 12–14 years, (Ibda, 2015; Rahmaniar et al., 2021; Sansena, 2022). In this study, scientific reasoning is defined as students' cognitive abilities in five dimensions: class inclusion (ability to classify data), serial ordering (ability to sort data sets), theoretical reasoning (ability to

interpret data based on relevant theories), functional and proportional reasoning (ability to analyze a functional relationship), and control of variables (ability to determine and control variables).

The ability of scientific reasoning has an important role in learning science. The existence of scientific reasoning that is owned by students will affect learning achievement in the fields of science and physics (Laily et al., 2018; Prastiwi et al., 2018; Rimadani et al., 2017). Students with high levels of scientific reasoning can explain concepts correctly; they are able to create an argument in developing understanding as well as be active in principle in using scientific methods to explain phenomena in the real world. This makes students' understanding and mastery of concepts more in-depth. This is inversely correlated to students' level of scientific reasoning in science since they will have trouble correctly understanding and mastering concepts, which can have an impact on student achievement. Similarly, students with strong scientific reasoning skills may perform better than average students in solving complex problems (Fawaiz et al., 2020; Koes-H & Putri, 2021; Musyaffa et al., 2019).

The significance of scientific reasoning is not consistent with the state of affairs. It was discovered that students in SMPN 15 Sukabumi still had very poor levels of scientific reasoning skills, particularly in the area of hypothesis-deductive skills, similar to the findings of the research by (Firdaus et al., 2021). The same is true of the study of Handayani et al., which discovered that class IX students at SMAN 1 Sukabumi lacked the capacity for scientific reasoning (Handayani et al., 2020). This problem was also found in SMP Negeri 1 Tanggulangin. This was proven by the results of a preliminary scientific reasoning test with six indicators given to class VIII students of SMPN 1 Tanggulangin. The results showed that 81% of students had the ability on the reversibility indicator, 50% of students had the ability on the class inclusion indicator, 29% of students had the ability on the theoretical reasoning indicator, 28% of students had the ability on the functional and proportional reasoning indicators, as many as 8% of students had the ability on the serial ordering indicator, and 0% or none of the students had the ability on the control of variables indicator. This shows that there is only one indicator of scientific reasoning that is mastered by more than 50% of students. Students stated that they found it

difficult to complete the test because they had not been fully trained in scientific reasoning abilities. Teacher expected can choose a model learning Which appropriate to train scientific reasoning abilities.

Inquiry is one of the lessons that can improve students' scientific reasoning abilities because it is oriented to the scientific method (Sundari & Rimadani, 2020; Sutarno, 2014; Utami et al., 2019). In line with this, Daryanti's research results show that there is an optimal increase in the scientific reasoning abilities of SMPN 1 Malang students after the application of inquiry learning, which is marked by an N-gain value of 3.56 or in the high category (Daryanti et al., 2015). In this study, it was explained that with inquiry learning, students were given the opportunity to actively build their own knowledge, like researchers (Daryanti et al., 2015). However, Zimmerman et al. noted that some students continued to struggle with using the scientific method in inquiry learning, particularly when it came to forming hypotheses and fusing prior knowledge and data or evidence with these assumptions (Anjani et al., 2020). In this case, a learning design is needed that is able to coordinate between theory and evidence, which is a set of scientific reasoning skills (Schiefer et al., 2019). Evidence-based reasoning (EBR) is thought to be a solution to this problem.

The Evidence-Based Reasoning (EBR) learning model is a learning model that applies an inquiry-based framework that is capable of producing scientific reasoning in experimental and predictive activities (Erlina et al., 2018). This learning model shows two inputs in the form of statements (predictions) and data that are processed through three processes, namely analysis, interpretation, and application to make claims. The process is contained in five phases of EBR learning. The first phase is to define a problem. The teacher involves students in making a statement about a real phenomenon, which is then developed by making a problem formulation. In the second phase, develop a hypothesis. The teacher involves students in making hypotheses and determining variables before doing proof. In the third phase, search for evidence, the teacher engages students to look for evidence for predictions made through experimental activities and analyzes the results obtained. In the fourth phase, draw a conclusion, students and the teacher make a conclusion, and state claims from statements

(predictions) and evidence. In the fifth phase, test the adequacy of the conclusion, allowing students to apply their knowledge or concepts to a new phenomenon or problem to test the conclusion reached. Based on research by Hardy et al., it states that the EBR learning model can develop scientific reasoning based on phenomena (Hardy et al., 2010). Similar to this, the results of research by Erlina et al. stated that the application of the EBR learning model was effective in increasing the scientific reasoning abilities of SMAN 3 Jember students, especially in learning physics, as evidenced by increasing the scientific reasoning abilities of students who were in the medium to high criteria (Erlina et al., 2018). This research only focuses on formal scientific reasoning, which is adapted to the research subjects used. It is for this reason that researchers conduct research with some updates, namely indicators of scientific reasoning that are used not only in formal patterns but also in concrete patterns; the natural science materials used are different; and the research subjects are also different. Based on the existing background, the aims of this study were to (1) describe the effect of the EBR learning model in the inquiry approach on students' scientific reasoning abilities in junior high schools and (2) describe students' scientific reasoning abilities based on the improvement of each indicator.

## METHOD

This research includes quantitative research, which is a type of structured research and is synonymous with the use of numbers in presenting research data and using a larger sample size (Sahir, 2021). The type of research used is a pre-experiment with the one-group pre-test-posttest design (Fraenkel et al., 2011; Sugiyono, 2022).

Table 1. Research Design

Class	Pretest	Treatment	Posttest
Experiment	O <sub>1</sub>	X	O <sub>2</sub>
Replication 1	O <sub>1</sub>	X	O <sub>2</sub>
Replication 2	O <sub>1</sub>	X	O <sub>2</sub>

The research was conducted in three classes, namely the experimental class, replication 1 and replication 2. In the early stages of the study, a pretest (O<sub>1</sub>) was given to determine students' initial scientific reasoning abilities. The research was continued by applying the same learning model to the three classes. The learning model is Evidence Based

Reasoning in the inquiry approach, for the three classes according to the existing syntax (X). In the final stage of the research, students' scientific reasoning abilities were tested by giving a posttest to the three classes (O<sub>2</sub>).

the research started on 21 February to 18 March 2023. The research population used was class VIII students at SMPN 1 Tanggulangin Samples were taken using a purposive sampling technique, with a total sample of 10% of the population calculated using the Slovin formula (Sugiyono, 2019). So that three class groups were obtained, namely the experimental class of 34 students, replication class 1 of 35 students, and replication class 2 of 33 students. The technique of collecting data is done by administering a test. The test instrument is in the form of 20 two-tier multiple-choice questions on substance stress, with five indicators of scientific reasoning: class inclusion, serial ordering, theoretical reasoning, functional and proportional reasoning, and control of variables. Every indicator has four questions. Before use, the instrument was assessed for validity and reliability by two professional validators. The research process begins by giving a pre-test to each class, then conducting treatment applying the EBR learning model to each class, and a post-test. The results of the pre-test and post-test were analyzed using N-gain to determine students' scientific reasoning abilities for each indicator. The following table shows the criteria for increasing N-gain.

Table 2. Criteria for N-gain Increase

Average	Criteria
$g > 0.7$	Tall
$0.3 \leq g \leq 0.7$	Currently
$0 < g < 0.3$	Low
$g \leq 0$	Fail
$g > 0.7$	Tall

Source: (Wahab et al., 2021)

In addition, a one-way ANOVA statistical test was carried out to determine whether there was a significant influence from the application of the EBR learning model in each group. There is a prerequisite test before the ANOVA test is carried out, which includes the normality test and homogeneity test of variance. The statistical test was carried out using SPSS.

## RESULTS AND DISCUSSION

### 1. Analyze the influence of EBR in the inquiry approach on students' scientific reasoning ability.

The results of the pretest and posttest were used to conduct the N-Gain and Anova tests to determine the influence of the EBR learning model on scientific reasoning.

Table 3. N-Gain Results for All Samples

N	Pretest	Posttest	N-Gain	Category
102	19,6	73,1	0.6	Currently

Based on Table 3, it shows that there is an increase between the pretest and posttest values. Of the 102 existing samples, the average student score before the EBR (pretest) model was applied was 19.6, and the score increased after the EBR model (posttest) was applied, namely 73.1. Existing posttest scores are used in the N-gain test to find out how much of an increase in scientific reasoning ability is produced. The N-gain score obtained was 0.6. This score indicates an increase in the moderate category. This shows that EBR in inquiry learning has a positive influence on students' scientific reasoning abilities.

In addition to the N-gain test, an ANOVA test was also carried out. This Anova test uses SPSS. The prerequisites for the ANOVA test are the normality test and the homogeneity test. The normality test was carried out to find out whether the data obtained was normally distributed or taken from a normal population. If the data is normally distributed, then the homogeneity test can be continued. A homogeneity test was conducted to find out whether the sample used came from a homogeneous (same) population. If both conditions have been met, then the ANOVA test can be carried out. The type of Anova test used is one-way Anova. The purpose of the ANOVA test is to test whether there is a significant difference between two or more classes that are affected by one independent variable in the study. If the p value is  $> \alpha$ , it can be said that there is no significant difference in the data, and vice versa. The following are the results of the normality test, homogeneity test, and ANOVA test obtained from the study.



Table 4. Normality Test Results

Data	Class	Significance Value
Score N-Gain	Experiment	0.296
	Replication 1	0.140
	Replication 2	0.110

Table 5. Homogeneity Test Results

Data	Class	Significance Value
Score N-Gain	Experiment	0.701
	Replication 1	
	Replication 2	

The results of tables 4 and 5 are the results of the prerequisite tests of the one-way ANOVA, namely the normality and homogeneity tests. Based on Table 4, it shows that the normality test for the three classes is taken from the N-gain scores of all samples. In succession, the experimental classes, replication 1, and replication 2, had significance values of 0.296, 0.140, and 0.110. This shows that the significance value, or p-value, of the three classes is  $> 0.05$ . So it can be concluded that the data is normally distributed or that it is taken from a normal population. The data that has been normally distributed is subjected to another prerequisite test, namely the homogeneity test. Based on Table 5, it shows that the homogeneity test of the three classes was taken from the N-gain scores of all samples. The results showed that the experimental classes, replication 1 and replication 2, had a significance value or p-value  $(0.7) > \alpha (0.05)$ . This shows that the data obtained comes from a homogeneous population. The results from tables 4 and 5 can be concluded that the data has fulfilled the prerequisite test for the Anova test, according to table 6.

Table 6. ANOVA test results

Data	Class	Significance Value
Score N-Gain	Experiment	0.258
	Replication 1	
	Replication 2	

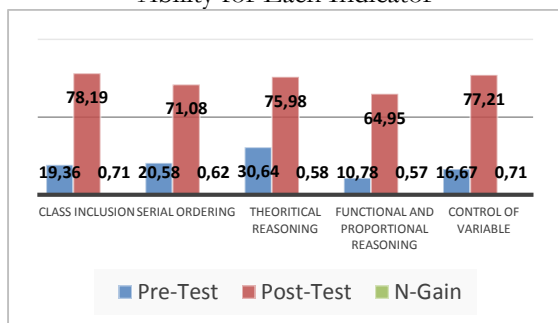
Based on Table 6, it shows that the third-class ANOVA test is taken from the N-gain score of all samples. The results showed that the

experimental classes, replication 1 and replication 2, had a significance value or p-value  $(0.2) > \alpha (0.05)$ . It can be concluded that there is no significant difference between the three classes tested. The EBR learning model in the inquiry approach becomes an independent variable that affects the absence of these differences. So that it can be said that there is an increase in scientific reasoning abilities really influenced by the EBR learning model in the inquiry approach. Inquiry-based learning, including EBR, can actually help develop the natural development of scientific reasoning (Schlatter et al., 2022). This shows that students are able to have the skills to think logically based on the concepts and evidence they already have. This is consistent with the claims of Slavin in Erlina et al. (2018) that inquiry-based EBR helps students understand the connection between evidence and theory or concepts so they can solve problems easily.

In the search for evidence phase of the EBR learning model, students are asked to look for evidence through an experiment and analyze it. As a result, providing opportunities for students to be actively involved both physically and mentally in understanding a concept. This is in line with the research results of (Qamariyah et al., 2021) who found that implementing learning that actively involves students in constructing conceptual understanding can improve students' scientific reasoning abilities. It was further explained that activities that involve physical activity (experimental) can develop students' methodological and technical abilities, thus enabling them to concretize theoretical knowledge with existing realities (Bouzit et al., 2023). In addition, the activity of looking for evidence of a concept is important for training students in making reasonable conclusions. In the test of the adequacy of the conclusion phase, the EBR model also provides an opportunity for students to test the adequacy of their understanding by solving or providing solutions to a new problem accompanied by relevant reasons based on evidence and conceptual understanding that has been previously obtained. As a result, students will have a deeper understanding. This trains students to argue correctly. All of these evidence-based learning activities are the key to scientific reasoning (Murtonen & Balloo, 2019).

## 2. Improvement Test for Each Indicator of Scientific Reasoning

Graph 1. Improvement of Scientific Reasoning Ability for Each Indicator



The improvement of each indicator was tested by calculating the average pretest, posttest, and N-gain values of the three classes on the five indicators of scientific reasoning, namely Class inclusion, Serial Ordering, Theoretical Reasoning, Functional and Proportional Reasoning, and Control of variables. Based on graph 1, it shows that each indicator has increased both from the pretest-posttest score and the N-gain score. N-gain average score for each indicator is 0.7. This shows that the increase in students' scientific reasoning abilities on each indicator is in the medium category.

The class inclusion indicator is the indicator with the highest posttest score among other indicators. This shows that students are already able to classify data. The resulting N-gain score is also included in the medium category (0.71). Basically, class inclusion is an initial ability to concretely form patterns in scientific reasoning. Thus, students at the junior high school level have actually passed the concrete reasoning stage. According to Piaget, the concrete reasoning stage has been owned by children aged 6–12 years (Ibda, 2015; Sanghvi, 2020). Similar to the class inclusion indicator, the control of variables indicator is also the indicator with the highest increase in both the pretest, posttest, and N-gain scores, which shows that students are able to determine or control variables. This is because EBR presents an initial statement through a phenomenon that has a relationship between variables (Erlina et al., 2018). In addition, the Develop a Hypothesis phase in the EBR model trains students to determine variables in seeking evidence through an experiment. The existence of experimental activities and stimulation of cognitive problems

is effectively used to study the ability to control variables (Schlatter et al., 2022).

The functional and proportional reasoning indicators are indicators with the lowest pretest and posttest scores among other indicators. This shows that students have not maximized their ability to analyze a functional relationship. The fundamental cause is that teachers are not used to teaching these abilities to students, which makes them less perceptive in evaluating how a concept (a mathematical equation) relates to the proper explanations. (Ash-Shiddieqy et al., 2018) states that proportional reasoning ability refers to students' sensitivity to situations that involve proportional relationships. This ability is one that can be built, not purely from one's expertise. In addition, students' knowledge of scientific reasoning has improved in the medium category, as measured by the N-gain score. Basically, EBR facilitates students making proportional and probabilistic predictions by asking questions as an elaboration of premises.

## CONCLUSION

Based on the results of the research that has been done, it can be concluded that there is a significant effect of applying the EBR learning model in the inquiry approach to students' scientific reasoning abilities in junior high schools. This is obtained from the average value of the N-gain score (0.6) which is in the medium category. In addition, the ANOVA test results with a sig value (0.258). Besides that, there is an increase in the ability of each indicator of students' scientific reasoning in the medium category after the application of the EBR learning model in the inquiry approach.

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