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Effects of Inquiry Learning on Students' Science Process Skills and Critical Thinking: A Meta-Analysis

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ABSTRACT

Skills of a student are needed to achieve success in learning and everyday life. However, their skills were still low. Solution to solve this problem is to apply an inquiry learning model during learning. This research aims to determine the effect of the inquiry learning model on students' science process skills and critical thinking which is reviewed based on the level of education, subject matter and type of inquiry learning model. This type of research is a meta-analysis. Meta-analysis is research conducted by summarizing research data, reviewing and analyzing research data from several pre-existing research results. The articles of this research consisted of 20 articles that already had an ISSN. The instruments used were category codes and effect size calculations. The steps of meta-analysis are conducting a literature review, collecting data, researching and assessing articles, analyzing and interpreting articles and compiling report results. The data analysis technique in this study is to calculate the magnitude of the effect using the formula (1981) based on the mean, standard deviation, and t-test. From the data analysis carried out, it can be stated that four research results. First, the application of the inquiry learning model has a significant effect on science process skills and critical thinking skills based on level education, learning materials, and types of inquiry learning model.

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INTRODUCTION

The 21st century is a century of rapid progress in science and technology. The development of science and technology is developing quickly and rapidly (Habibah, 2017; Mulyani, 2021). This can be seen from the fact that technology and science have become a necessity in society. The development of this technology can be utilized by the wider community in various fields, especially in the field of education. The development of increasingly advanced technology has caused the world of education to be in the era of the

industrial revolution 4.0.

The era of the industrial revolution 4.0 will bring benefits if it can be put to good use. Supporting skills are needed in order to survive in this era. Skills that can answer this need are science process skills and critical thinking (Nugraha, 2017). Science process skills and critical thinking can be built early in education (Sulistiyono, 2020). School is a place to hone and improve these skills. Both of these skills can be improved through learning at school.

The learning process at school directs to student activity. Students do more activities in learning. Student activity during the learning process can develop students' intelligence and skills, both conceptually and procedurally (Pandiangan, 2019). Learning activities with active students in it will be able to make learning meaningful and can develop student potential. In this case the teacher acts as a director or facilitator so that the learning process in the classroom is more directed.

The facts found are not in accordance with the expected conditions. Based on the results of the analysis of several journals, several real conditions were found. The first real condition found was a problem at the education level. The process of learning science in junior high school is still rote. Students tend to be passive during the learning process at school (Jiwanto, 2017). Learning in class is less active and only focuses on the material provided by the teacher (Falahudin, 2016). At the high school education level during student learning also tends to be passive (Sitinjak, 2018). High school student learning outcomes are still low (Tampubolon, 2017).

The second real condition found is related to the subject matter. The concepts that students get tend to be only from the teacher, not based on student experience (Hakim, 2016). The use of models is not adapted to the subject matter. Subject matter obtained by students only comes from the teacher, not supported by other learning sources. This makes students tend to be passive and students are less able to absorb lessons properly.

The third real condition found is related to the learning model used. Learning still uses lecture and rote methods (Ardiana, 2018). Learning in schools tends to use conventional models (Sinaga, 2018). The use of the lecture method makes communication in learning tend to be only one way so that students can only get material from the teacher. Students are less trained to get concepts based on their own experience.

The fourth real condition found is related to student learning outcomes. Science process skills and critical thinking of students are less trained and developed. Students are not trained enough to carry out activities to analyze, solve problems and provide solutions (Ardiana, 2018). Students also lack the ability to develop critical thinking skills and lack the ability to solve problems (Kristanto, 2015). Learning models are rarely applied, so students are passive during the learning process and students' science process skills do not develop (Jiwanto, 2017).

The learning model analyzed in this study is the inquiry learning model. The inquiry learning model is an arrangement of activities in learning that makes students think in an inquisitive, structured, and thorough manner. The inquiry learning model involves students to seek and investigate systematically, critically, logically and analytically, so that they can formulate their own findings (Kudiastuti, 2016). Inquiry contains higher level mental processes, for example formulating problems, designing experiments, conducting experiments, collecting and analyzing data, drawing conclusions, having objective attitudes, being honest, curious, being open, and so on.

The use of inquiry models during the learning process has advantages and disadvantages. The advantages of using the inquiry learning model are as follows. First, it can provoke students' interest in learning science. Second, it can improve students' understanding of concepts. Third, lead to an understanding of the nature of scientific knowledge. Fourth, facilitate collaboration between students. Fifth, help develop student skills (Usman, 2019). In addition to the advantages, the inquiry learning model also has disadvantages. The

disadvantages of inquiry learning are that it takes time to change students' habits in the learning process, requires learning resources and suggestions that are not always available, and is less efficient to practice with a large number of students and limited teachers.

The types of inquiry models discussed in this study are guided inquiry models and inquiry training. The first type of inquiry learning model is guided inquiry. The guided inquiry model is a learning model that can train students' skills to collect and process data so that students can make their own conclusions to answer questions posed by the teacher (Smetana, 2005). In the guided inquiry process, the teacher poses a problem and encourages students to develop procedures and solve them.

The second type of inquiry learning model is inquiry training. Inquiry training is expected to bring students to the scientific stage through exercises that shorten the scientific process (Joyce, 2011). The inquiry training learning model is a learning process that involves students to be active in formulating questions, investigating and forming new knowledge (Hakim, 2016). Inquiry learning model activities train students to do many things. The activities that are trained are conducting an experiment, including formulating problems, conveying hypotheses, testing hypotheses, determining variables, designing experimental steps, collecting, calculating and analyzing data, drawing conclusions and communicating experimental results. These skills can also be called science process skills (Susilawati, 2015).

Science process skills (KPS) are skills in discovering knowledge by observing, conducting experiments, interpreting data and so on. Science process skills are basic abilities for learning that are useful for forming concepts in each student in self-exploration (Evan, 1990). Science process skills must be trained during the learning process. Learning must begin with activities that encourage each student to think so that they can develop skills in solving problems, making decisions and analyzing experimental results.

Science process skills consist of basic skills and integrated skills. The basic science process skills are observing, classifying, estimating, calculating, formulating, and presenting. On the other hand, integrated science process skills are identifying, displaying data in graphical or tabular form, explaining relationships between variables, calculating data, analyzing experiments, making hypotheses, designing and carrying out experiments. In addition to science process skills, skills that are also needed in this era are critical thinking

Critical thinking is a high-level skill in thinking (Adyana, 2012). The results of thinking from critical thinking can be accounted for. Critical thinking is a skill that allows one to analyze the arguments, facts and logic that underlie other people's ideas (Sudarti, 2015). Critical thinking is a person's skill in analyzing and investigating evidence from other people's knowledge or ideas (Sastra, 2023). Critical thinking indicators include explaining simply, namely analyzing questions and focusing questions, improving basic skills, concluding, conveying in-depth explanations, designing strategies and techniques (Qibtiyah, 2023).

Based on the problems that have been described, the solution to this problem is to do a meta-analysis of the influence of the inquiry learning model on students' science process skills and critical thinking. Meta analysis research was chosen as the method in this study for several reasons. First, previous research has only determined the effect on science process skills or critical thinking. Second, previous research only discussed one subject matter. Third, previous studies covered only one level of education. Fourth, previous studies only used one inquiry learning model. The purpose of the meta-analysis research is to see the effect of the inquiry learning model on students' science process skills and critical thinking.

METHODS

The method used in this research is meta-analysis. Meta-analysis is a quantitative analysis using quite a lot of data by applying statistical methods to organize data from large

samples (Nengsih, 2021). Meta analysis is a procedure for making summaries of several studies quantitatively (Putri, 2023). Meta-analysis uses statistical data from several related articles and then analyzes it to fulfill the research objectives. Meta-analysis is defined simply as analysis above analysis.

The processes that involve meta-analysis are setting research partners, choosing the type of publication sources, collecting sources, recording statistical data, determining effect sizes, interpreting summaries and making reports. Previous studies were grouped based on the publication of each article, sample, experimental class, control class and other groupings (Wati, 2022). Meta-analysis has a different goal from other research, namely to increase statistical value for primary research, to obtain effect size values for the magnitude of the differences between variables or the strengths between variables.

Meta-analysis has several advantages when used as a research method, namely meta-analysis can combine several previous research results quantitatively, meta-analysis is able to provide a good picture between studies and can minimize differences in the results of these studies. The meta-analysis is very objective and focuses on research data obtained from research articles, while the literature review focuses on the final conclusions of various meta-analyses, and the method of meta-analysis is quantitative and very easy to do.

Weaknesses in meta-analysis research, this research uses a large sample so that it allows for bias and unnecessary data. Meta-analysis often results in only the significant ones being published. This method is averaging something so that something different can be seen as the same in this method. Meta-analysis is less precise applied to a small sample. In conducting this meta-analysis research, you must have statistical data that can be analyzed according to the effect size formula.

This study uses a meta-analysis of several articles related to the influence of inquiry learning. The analysis technique uses a quantitative approach through calculations and analysis of the data already in the article. The number of articles analyzed was 20 articles on the influence of the inquiry learning model from 2010-2020. The effect size can be determined, within the following statistical parameters.

a. Mean and standard deviation pretest-posttest

$$ES = \frac{\overline{X}_{post} - \overline{X}_{pre}}{SD_{pre}} \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The mean and standard deviation of the pretest-posttest according to formula (1). The explanation of the formula above the ES value is the effect size, represents the posttest average, represents the pretest average and the SD value represents the standard deviation. Statistical data for the average value of the experimental class, control class and standard deviation of the articles will then be entered into the formula above.

b. Mean and standard deviation of two groups posttest only

$$ES = \frac{\overline{X}_{E} - \overline{X}_{C}}{SD_{C}} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The mean and standard deviation of the two group posttest only are in accordance with formula (2). Explanation of formula (2) states that the ES value is an effect size, states the average experimental group, states the average value of the control group and states the standard deviation of the control class. Statistical data for the average value of the experimental class, control class and standard deviation of the control class are included in formula (2) to obtain the effect size value.

c. Mean and standard deviation of two group pre-posttest

$$ES = \frac{\left(\bar{X}_{post} - \bar{X}_{pre}\right)_E - \left(\bar{X}_{post} - \bar{X}_{pre}\right)_C}{SD_{preC} + SD_{preE} + SD_{postC}} \quad \text{.....(3)}$$

The mean and standard deviation of the two pre-posttest groups according to formula (3). The ES value represents the effect size, represents the average posttest of the experimental group, represents the mean of the pretest of the experimental group. states the average posttest value of the control group, states the average pretest value of the control group, states the standard deviation value of the experimental group and states the standard deviation value of the control group.

d. If the standard deviation is not known, it can be done with the t-test.

$$ES = t\sqrt{\frac{1}{n_E} + \frac{1}{n_C}} \quad \text{.....(4)}$$

The standard deviation is unknown, so it can be done with the t-test according to formula (4). The ES value represents the effect size, the t value represents the t test result, and ne represents the number of experimental groups. The t-test value and the value of the number of experimental groups were obtained from related articles, so they were entered into formula (4) to obtain the effect size value.

RESULTS AND DISCUSSION

Results

The first result of this study is related to the effect of inquiry learning on student learning outcomes in terms of educational level. Twenty articles correspond to the first objective. There are ten articles on the effect of inquiry learning on science process skills. The average value of the effect size can be seen in Table 2.

Table 2. Effect of Inquiry Learning on Science Process Skills Based on Education Level

Level of Education	Journal Code	Effect size	Average Effect size	Note
Junior High School	K1	0.53	0.65	Medium
	K2	0.31		
	K3	0.99		
	K4	0.78		
	K5	0.41		
Senior High School	K6	0.84	0.99	High
	K7	1.84		
	K8	0.82		
	K9	0.54		
	K10	1.50		

Based on the data in Table 2, it is stated that there are 4 articles at the junior high school level and 6 articles at the high school level. From Table 2 it can be described that the inquiry learning model has a high effect on the science process skills of high school students with an average of 0.99. The inquiry learning model at the junior high school level obtained an effect size value of 0.65 in the medium category. At the junior high school level, the effect of the inquiry learning model is in the moderate category, and at the high school level, the effect is

at a high level. This shows that students' science process skills at the senior high school level can be improved by applying the inquiry learning model.

Researchers grouped ten articles regarding the influence of the inquiry learning model on critical thinking skills. Critical skill is a moderator variable in the research. The effect size of the effect size of the inquiry learning model on critical thinking skills is calculated. The average value of the effect size on critical thinking can be seen in Table 3.

Table 3. Effect of Inquiry Learning on Critical Thinking Based on Education Level

Level of Education	Journal Code		Effect size	Average Effect size
Junior High School	B1	0.74	0.72	Medium
	B2	0.90		
	B3	0.52		
	B4	0.73		
	B5	0.52		
Senior High School	B6	0.71	1.11	Very high
	B7	3.37		
	B8	0.23		
	B9	0.80		
	B10	1.01		

Based on the data in Table 3 it is stated that there are 4 articles at the junior high school level and 6 articles at the high school level. From Table 3 it can be described that the inquiry learning model has a very high effect on the critical thinking of high school students with an average of 1.11. At the junior high school level, it was stated that the inquiry learning model had a moderate effect on critical thinking skills with an average effect size value of 0.72. This shows that students' critical thinking at the high school level can be improved by applying the inquiry learning model.

The second result is related to the effect of inquiry learning on student learning outcomes in terms of subject matter. The moderator variable for further research is subject matter. There are six junior high school science articles that are suitable for the second objective. Effect size values based on junior high school science subject matter can be seen in Table 4.

Table 4. Effect of Inquiry Learning Based on Middle School Science Subject Materials

Journal Code	Subject matter	Effect Size	Note
K1	Optical Tool	0.53	Medium
K3	Circulatory Tool	0.99	High
K11	Optical Tool	0.20	Low
K12	Pressure	0.50	Medium
B1	Classification of objects and their changes	0.74	Medium
B2	Environment	0.90	High

From the data in Table 4 it can be seen that inquiry learning has a different effect on junior high school science subject matter. The size of the effect of critical thinking can be seen in the code journal B which to increase students' critical thinking is more effectively applied to environmental material. The size of the effect of science process skills can be seen in the K journal code which to improve students' science process skills is more effectively applied to the circulatory system material. Ten high school physics subject matter articles that fit the

second objective. The moderator variable of this research is the subject matter. The effect size values based on the high school physics subject matter used can be seen in Table 5.

Table 5. Effect of Inquiry Learning Based on High School Physics Subject Materials

Journal Code	Subject matter	Effect Size	Note
B5	Electricity	0.52	Medium
B6	Global warming	0.71	Medium
B8	Harmonic Vibration	0.23	Low
B9	Momentum and Impulse	0.80	High
K5	Harmonic Vibration	0.41	Medium
K6	Temperature and Heat	0.84	High
K7	Gas kinetics	1.84	Very High
K8	Elasticity and Hooke's Law	0.82	High
K9	Static Fluids	0.54	Medium
K10	Temperature and Heat	1.50	Very High

From the data in Table 5 it can be described that the inquiry learning model has a different effect on high school physics subject matter. The size of the effect of critical thinking can be seen in the code journal B which is to improve students' critical thinking more effectively applied to the material of momentum and impulse. The size of the effect of science process skills can be seen in the code of the journal K where to improve students' science process skills it is more effectively applied to material on temperature and heat, gas kinetics and elasticity and Hooke's law. The third result in this study is related to the effect of inquiry learning on student learning outcomes in terms of the types of inquiry learning models. The next moderator variable is the learning model. The average value of the effect size of the inquiry learning type in Middle School Science can be seen in Table 6.

Table 6. Effects of Inquiry Learning Based on Types of Inquiry Learning Models in Middle School Science

Types of inquiry learning models	Journal Code	Effect size	Average Effect Size	Note
Inquiry Training	K2	0.31	0.47	Medium
	K11	0.20		
	K12	0.50		
	B11	0.86		
Guided Inquiry	K1	0.53	0.78	High
	K3	0.99		
	K4	0.78		
	B1	0.74		
	B2	0.90		
	B4	0.73		

From the data in Table 6, there are four articles of inquiry training type and six articles of guided inquiry type. The type of inquiry training has a moderate effect on student learning outcomes with an average effect size of 0.47. The guided inquiry type has a high effect on student learning outcomes with an average effect size of 0.78. Fourteen articles on types of inquiry learning models in high school physics. The average value of the effect size of student learning outcomes in terms of the type of inquiry learning model can be seen in Table 7.

Table 7. Effect of Inquiry Learning Based on Types of Inquiry Learning Models in High School Physics

Types of inquiry learning models	Journal Code	Effect size	Average Effect Size	Note
Inquiry Training	K5	0.41	1.25	Very High
	K6	0.84		
	K7	1.84		
	K10	1.50		
	B7	3.37		
	B8	0.23		
	B9	0.80		
	B10	1.01		
Guided Inquiry	K8	0.82	0.94	High
	K9	0.54		
	K13	1.08		
	K14	1.98		
	B5	0.52		
	B6	0.71		

From the data in Table 7 it can be seen that there are 8 articles on the type of inquiry training and 6 articles on guided inquiry. In high school physics, the inquiry training type has a very high effect on student learning outcomes with an average effect size of 1.25. The guided inquiry type has a high effect on student learning outcomes with an average effect size of 0.94. The fourth result in this study is related to the effect of inquiry on students' science process skills and critical thinking. Ten articles on the effect of inquiry learning on science process skills. The effect size value of each article can be seen in Figure 1.

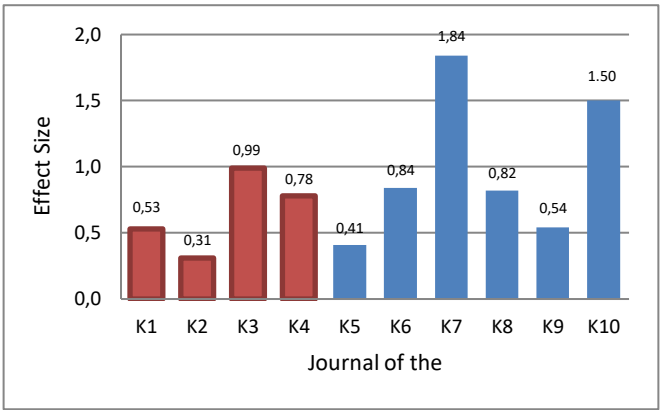

Figure 1. Effect Size of each Science Process Skills Article

Based on the data in the Figure diagram, the color indicates the effect size for junior high school education level and the blue color indicates the effect size for senior high school education level. From Figure 1, the average effect size of the inquiry learning model on science process skills is 0.87. The average effect size describes that the inquiry learning model has a high effect on science process skills.

Ten articles on the influence of inquiry learning on critical thinking. The average effect size value is obtained from the calculation of the effect size of each article. The value of the effect size of the influence of inquiry learning on critical thinking can be seen in Figure 2.

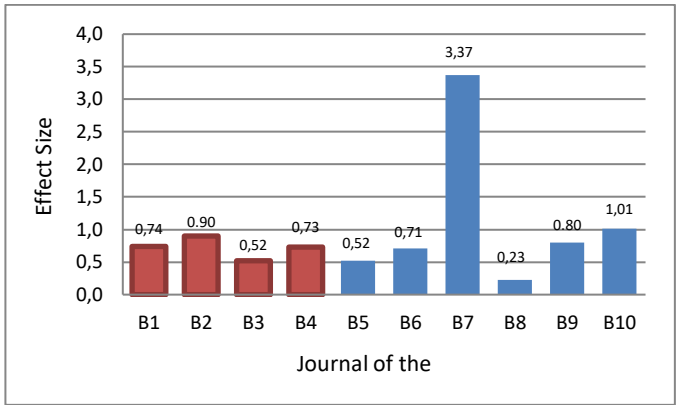

Figure 2. Effect Size of Each Article on Critical Thinking

Based on Figure 2, it can be seen that the colored diagram indicates the effect size of junior high school level of education and the blue color indicates the effect size of high school education level. From Figure 2, the average effect size of the inquiry learning model on critical thinking is 0.95. The average effect size describes that the inquiry learning model has a high effect on critical thinking.

Discussion

This research was conducted to see the effect of applying the inquiry learning model seen from several moderator variables. The results of the first study are based on educational level. The inquiry learning model has a high effect on students' science process skills at the high school education level. On the other hand, the inquiry learning model has a very high effect on critical thinking at the high school education level. This is because in high school physics learning there are more experiments so that the inquiry learning model is more effectively applied at the high school education level.

The inquiry learning model is one of many learning models that train students to discover their own knowledge. The inquiry learning model trains students to be active in learning so that students are able to develop critical thinking skills (Kristanto, 2015). Inquiry learning model activities train students to experiment. The experimental stages that were trained on students were formulating problems, putting forward hypotheses, testing hypotheses, setting variables, compiling and assembling tools, collecting and working on data, making conclusions, and presenting experimental results. These skills can also be called science process skills (Evan, 1990). Through process skills, students can develop skills to analyze natural phenomena to gain knowledge and can be developed further (Harsani, 2020).

The results of the second study are based on the subject matter. According to the effect size calculation results, there are several learning materials that have a high effect on science process skills when the inquiry learning model is applied, namely gas kinetics and temperature and heat. When viewed from the learning material, all material is included in physics subjects. It can be interpreted that this inquiry learning model is very influential when applied to physics material. Many physics materials contain things related to everyday life that can also be carried out in learning experiments.

The results of the third study are based on the types of inquiry learning models. The types of inquiry learning models analyzed were inquiry training and guided inquiry. Based on the results of calculating the effect size of the type of inquiry learning model that has a high influence on students' science process skills and critical thinking is the type of inquiry training. According to Joyce (2009) this inquiry training model can train students to get used to scientific research so that it is expected to arouse and develop curiosity, improve thinking skills, research, argue and develop theories in students (Joyce, 2011). Therefore, in this study the

application of this inquiry training model has a higher effect on science process skills and critical thinking compared to the application of the guided inquiry model in the learning process.

The results of applying the inquiry training model can make students able to carry out scientific processes. Students can also have creativity in carrying out research. In addition, the inquiry training model can also bring out creativity and independence in learning, can accept differences of opinion and temporary knowledge (Joyce, 2011). This shows that by applying the inquiry training model, students' science process skills have increased.

The results of the four studies influence the inquiry learning model on science process skills and critical thinking. The high influence of the inquiry learning model on students' science process skills and critical thinking. This states that the inquiry learning model is effectively applied to improve students' science process skills and critical thinking. This is in accordance with the syntax of the inquiry learning model which leads to experimental activities during the learning process.

CONCLUSION

From the data analysis conducted, four conclusions were obtained. First, the inquiry learning model is effective to be applied at the senior high school level of education compared to junior high school. Second, the application of the inquiry learning model to students' scientific process skills and critical thinking in junior high science has a high effect on environmental and circulatory learning materials, while high school physics has a high effect on gas kinetics, temperature and heat as well as elasticity and material Hooke's law. Third, the type of inquiry learning model that has a significant effect on students' science process skills and critical thinking is the inquiry training learning model. Fourth, the inquiry learning model is equally effective in improving students' scientific process skills and critical thinking.

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