UNIVERSITAS SEBELAS MARET
BIOEDUKASI: JURNAL PENDIDIKAN BIOLOGI
https://jurnal.uns.ac.id/bioedukasi/
1693-265X (Print) | 2549-0605 (Online)

A Meta Analysis of Inductive Learning-Based Modules to Improve Critical Thinking Skills in Science

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Submission : 25/09/2020
Revision : 17/01/2021
Accepted : 15/02/2021

ABSTRACT

Critical thinking skills in science learning can be improved by learning accompanied by learning model-based modules. Inductive learning is one of the lessons that can be integrated with the module as an alternative to empower critical thinking skills. This meta-analysis research aims to determine the effectiveness of learning with inductive learning-based modules to improve critical thinking skills, especially in science (biology, physics, and chemistry). This type of research was survey research and descriptive. Data were collected online and obtained 13 articles in the fields of biology, physics, and chemistry from 2014-2019 published in Indonesia and outside Indonesia. The calculation results show that the average effect size (E.S.) was 2.1 with the high category. These results indicate that science learning with inductive learning-based modules provides high effectiveness in improving critical thinking skills. Based on the relationship between variables, it was known that the variable in the field of study gives the greatest E.S. results (E.S. = 4.3) in the field of physics, while the variable for education level gives the largest E.S. result (E.S. = 2.14) at the high school level.

Keywords: Critical Thinking, Meta-Analysis, Modules, Science Learning

INTRODUCTION

As one of the skills needed in the 21st century (Leward & Hirata, 2011), critical thinking has an important role in making the right decisions to solve problems during studies or in everyday life (Snyder & Snyder, 2008). Critical thinking can be trained in formal schools through interactions between teachers and students in the learning process (Nafi'ah & Prasetyo, 2015). Learning science by practicing critical thinking has a specific goal, namely to prepare students to achieve competency standards set by the curriculum, be able to face life's challenges in the future (Sadia, 2008), and to handle and solve existing problems (Larsson, 2017; Thompson, 2011). Critical thinking in the learning process cannot be taught through the lecture method because critical thinking is an active process. Critical thinking skills can be taught through many models and methods, such as module-based, laboratory-based, paper-based activities, home assignments that provide various opportunities to generate critical thinking skills, and tests designed to empower critical thinking skills—learning with modules as an alternative that can train critical thinking skills. Learning with modules, students can learn independently, flexibly, and repeatedly so that their critical thinking skills can be empowered. Also, learning using modules allows students to improve optimal learning activities according to their level of ability and progress (Lunenburg, 2011).

Critical thinking skills trained by module learning can support increased thinking skills because they can accommodate students' cognitive development (Fascione, 2013). Modules applied in learning are usually based on certain approaches/models/strategies in empowering critical thinking skills. The implementation of the 2013 curriculum impacts the research carried out, especially research on the application of inductive learning-based learning modules. Inductive learning is learning that begins by presenting students with specific challenges, such as experimental data, case studies to analyze, or complex real-world problems to solve. Various forms of inductive learning include discovery learning, inquiry-based learning, problem-based learning, project-based learning, case-based teaching, and just-in-time teaching (Prince & Felder, 2007).

The results of tracing several studies in schools and colleges currently show that learning using modules has been done. Learning with integrated modules with an inquiry or scientific approach is becoming a trend to empower certain abilities, including critical thinking skills. Some learning research with modules shows that effective modules improve students' critical thinking skills (Nugroho, Prayitno, Maridi, 2017; Wijayanti, 2017; Selviani, 2019). The effectiveness of learning with this module is based on the results of inferential statistical tests, which state a significant difference in critical thinking skills between learning using modules and those without using modules. These results clearly show that learning with modules is effective in improving critical thinking skills. However, several studies that use the basis of N-Gain results show that increasing critical thinking skills with module learning can increase the results to high (Suarsana & Mahayukti, 2013) and moderate categories (Fitriani and Setiawan, 2017; Ulandari, Wahyuni, Bachtiar, 2018; Susilowati, Sajidan & Ramli, 2017). Research findings from Puspitasari, Suparmi, Aminah (2015) indicate that 46.87% (15 of 32 students) have less critical thinking skills after learning with modules. Based on some of the research results, it can be seen that learning with modules provides different impact measures.

With the large number of studies that have been carried out on learning with inquiry-based approach modules in improving critical thinking skills, it is necessary to synthesize these findings. The number of studies that continue to increase will increase the number of reference materials for further research. However, the large number of studies will make it difficult for researchers to find out the results of the research that has been carried out, so there is a need for a summary of these findings so that researchers can obtain preliminary information from various studies that have been carried out (Tumangkeng, 2018). One way to summarize research results is by using a meta-analysis method. A meta-analysis method is a

form of a quantitative summary that examines the results of research statistically. Meta-analysis methods are considered more objective (focus on available data) so that the results can be more accurate and credible. Meta-analysis states the results of the study findings with the effect size (E.S.) to answer questions concerning the problem of differences between the experimental group and the comparison group if it is based on research results that continue to increase from year to year (Sutrisno, et al.; 2007).

Based on the background description, meta-analysis research was carried out on the effectiveness of learning with modules in improving critical thinking skills, especially in biology, physics, and chemistry. This research study discusses 1) how the effect size of learning using modules on critical thinking skills; 2) how the effect size of learning using modules on critical thinking skills in terms of the field of study and the level of education units. It is hoped that the results of this meta-analysis can conclude the effectiveness of learning with modules in improving critical thinking skills and providing a uniform view of the findings as a whole.

METHODS

This type of research is survey research and is descriptive. The data was collected online by browsing articles published in national journals and national/international proceedings. The steps of this meta-analysis (Figure 1) can be specifically explained as follows (Glass, 1981),

Preparation Stage. In the preparation stage, the independent and dependent variables were determined to be a meta-analysis. The independent variable in this study is learning with modules, while the dependent variable is the ability to think critically. The type of publication is also determined at this stage, namely scientific articles published in national journals and national/international proceedings, with the research subject being students in Indonesia. The year of publication of articles is limited to 2014 - 2019. The topics of study (fields of science) specifically cover biology, chemistry, and physics at the primary, secondary, and tertiary school levels.

Implementation Stage. The implementation phase begins by browsing articles and obtaining 42 articles about learning with science modules (physics, chemistry, and biology) to improve critical thinking skills. Article searches are carried out online through the online journal portal (OJS) or online proceeding portal and google scholar. These articles are then selected and taken 13 articles that meet the requirements for calculating the effect size for meta-analysis. After that, the effect size is calculated for each article and tabulated in the table.

Analysis stage. At this stage, an average learning effect size analysis is carried out with modules to improve critical thinking skills. The relationship between variables, namely science with critical thinking skills, education level, and critical thinking skills, was also analyzed.

The following is a picture of the stages in the meta-analysis.

The data analysis technique to calculate the effect size (E.S.) uses several statistical equations in Table 1 (Becker & Park, 2011).

Table 1. Effect Size (E.S.) Formula

Statistics Data	Formula
Average in one group	$ES = \frac{\bar{x}_{post} - \bar{x}_{pre}}{SD_{pre}}$
Average in each group	$ES = \frac{\bar{x}_{eksperimen} - \bar{x}_{kontrol}}{SD_{kontrol}}$
Average in each group	$ES = \frac{\left(\bar{x}_{post} - \bar{x}_{pre}\right)_{ekspeirmen} - \left(\bar{x}_{post} - \bar{x}_{pre}\right)_{kontrol}}{\left(\frac{SD_{pre\,kontrol} + SD_{pre\,eksperimen} + SD_{post\,kontrol}}{3}\right)}$
Chi-square	$ES = \frac{2r}{\sqrt{1-r^2}};\ r = \sqrt{\frac{\chi^2}{n}}$
T-test	$ES = t\sqrt{\frac{1}{n_{eksprimen}} + \frac{1}{n_{kontrol}}}$

After obtaining the effect size (E.S.) value, the results are interpreted into small, medium, and high according to the criteria in Table 2.

Table 2. Classification of effect size (cohen's, 1988)

Effect Size (E.S.)	Standard category
$0 \leq ES \leq 0{,}2$	Low
$0{,}2 < ES \leq 0{,}8$	Medium
$ES > 0{,}8$	High

RESULT AND DISCUSSION

The meta-analysis in this study found 13 articles about learning with modules in improving critical thinking skills obtained from the search results of accredited national journals published from 2014-2019. The following is a summary of the effect size (E.S.) results for each article.

Table 3. Effect Size (ES) category for each article

No	Author	Article Code	Module base	Field of study	Level	*ES*	Category
1	Elisanti, Sajidan, Prayitno (2018)	ESB	*Inquiry*	Biology	High School	2,4	High
2	Nugroho, Prayitno, Maridi (2017)	EBM	Model *REACT*	Biology	High School	0,2	Rendah
3	Selviani (2019)	IS	*Problem Based Learning*	Biology	High School	0,1	Rendah

No	Author	Article Code	Module base	Field of study	Level	*ES*	Category
4	Ulandari , Wahyuni, & Bachtiar (2018)	FSR	*Scientific*	physics	High School	2,4	High
5	Agnafia, Sutarno, Prayitno (2017)	DSB	*Generative Learning*	Biology	High School	6,4	High
6	Ansori, Sunarno, Suparmi (2017)	MWS	*Inkuiri Terbimbing*	physics	High School	2,8	High
7	Puspitasari, Suparmi, Aminah (2015)	YSN	*Scientific*	physics	High School	7,7	High
8	Susilowati, Sajidan, Ramli (2017)	SSM	*Inquiry*	Biology	High School	2,9	High
9	Permatasari, Dwiastuti, Suwarno (2016)	PSS	*Guided Inquiry*	Biology	High School	1,1	High
10	Suryani, Prayitno, Rinanto (2018)	NBY	*Guided Discovery*	Biology	High School	1,1	High
11	Marzuki, Ramli, Sugiyarto (2017)	MMS	*Guided Discovery*	Biology	High School	ES_1 = 1,12 ES_2 = 1,3	High High
12	Nugroho (2018)	AAN	*Learning Cycle 7E*	Biology	Bachelor	1,6	High
13	Pratama, Ashadi, Indriyanti (2017)	GAN	*Problem Based Learning*	Chemistry	High School	ES_1 = 0,9 ES_2 = 0,9 ES_3 = 0,8	High High High
Average						2,1	High

The average value of the effect size (E.S.) in Table 3 can be seen that is 2.1 in the high category. However, two articles (Nugroho, Prayitno, Maridi, 2017; Selviani, 2019) show the E.S. score is in a low category. This score is possible because of the learning base used in the module, the material used, or other factors that influence it. Overall the results in Table 3 show that learning with effective modules increases critical thinking skills in the high category. The average effect size representation of the ability to think critically based on the field of study can be seen in Figure 2.

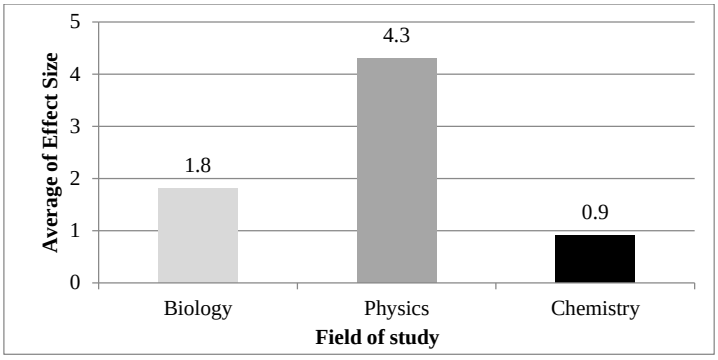

Figure 1. Average Effect Size of Critical Thinking Ability by Field of Study

Effect Size based on the field of study shown in Figure 2, namely in the field of physics, learning with modules has a larger effect size (E.S. = 4.3, high category) compared to the field of biology (E.S. = 1.8, high category) and chemistry (E.S. = 0.9, high category). When viewed from the number of articles, physics has only three articles based on two scientific models and one guided inquiry article. There is only one article based on problem-based learning in chemistry, while in biology, there are nine articles with various learning bases (see Table 3). The learning base for the various modules (in biology) allows for variations in E.S. results. The representation of the average effect size based on education level can be seen in Figure 2.

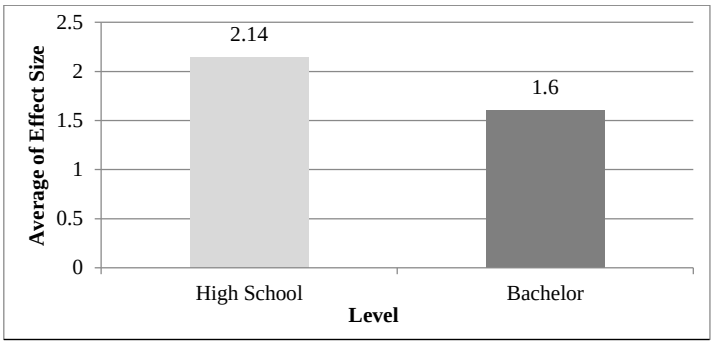

Figure 2. Average Effect Size of Critical Thinking Ability based on Education Level

Based on Figure 2, it can be seen that it has a larger effect size (E.S. = 2.14) compared to the undergraduate level (E.S. = 1.6). The number of articles at the high school level is 12, with details of 7 articles of class X and five articles of class XI. At the bachelor level, there is only 1 article (see Table 3). When viewed from the source of the thinking skills used, it can be seen that seven articles using Facione's critical thinking skills, two articles from Ennis, 1 article from Marzano, and three articles do not include their sources. Researches in Indonesia on the ability to think critically still refer to Facione, which is possible by the characteristics of students or indicators of critical thinking from Facione, which researchers easily understand.

From the overall results of calculating the average E.S. learning effectiveness with inductive learning-based modules in improving critical thinking skills, an E.S. score of 2.1 is obtained with a high category. These results indicate that learning with inductive learning-based modules provides high effectiveness in increasing critical thinking skills. Learning with modules based on certain models/methods/approaches has the potential to train students' critical thinking skills so that learning not only spurs students to get facts and knowledge from the text but also supports students to get new ideas, knowledge, and perspectives so that they can improve results student learning (Hazeli & Rezali, 2013; Khatib & Alizadeh, 2012). The model/method that is the basis of the module also affects students' critical thinking. Agboeze and Ugwoke (2013) state that critical thinking can be improved by a learning model that

facilitates interaction between students, such as debates, group discussions, asking open-ended questions, solving problems, then evaluating and applying new concepts to solve problems in new situations.

Instructions and exercises in the module can make students think critically. Sudarmini, Kosim, & Hadiwijaya (2014) state that critical thinking skills can develop because of the habit of doing exercises. If students study the module consistently and continuously, they can practice their thinking skills. Mahmudi (2009) states that the habit of critical thinking that is carried out consistently and sustainably by students will have implications for forming critical thinking skills.

CONCLUSION

Based on the data analysis that has been done, several conclusions can be made as follows: 1) The calculation results show that the average effect size (E.S.) is 2.1 with the high category. These results indicate that learning with modules provides high effectiveness in improving critical thinking skills. 2) Based on the relationship between variables, it is known that the field of study variable gives the result that in the field of physics, learning with modules has a larger effect size (E.S. = 4,3, high category) compared to the field of biology (E.S. = 1,8, high category) and chemistry (E.S. = 0.9, high category). In comparison, the variable level of education at the high school education level has a larger effect size (E.S. = 2.14) compared to the level at S1 (E.S. = 1.6).

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