The Implementation of an Inductive Model on Science Students' Critical Thinking Skills during Online Learning

Afifah Jazilah Arjunaidi and Nurulwahida Azid

***Abstract*—For almost two years now, the world has faced the COVID-19 pandemic whereby face-to-face learning has changed to online learning. The most crucial component is that science students' abilities have not appropriately developed, particularly in critical thinking skills. Hence, this research aimed to examine the effectiveness of an Inductive Model during online learning to enhance science students' critical thinking skills. This quasi-experimental with explanatory mixed-method design involved pre-test and post-test sessions followed by a focused group interview. Sixty science students were divided into two groups: the control group and the treatment group. The control group (n = 30) was taught via online learning without using an Inductive Model, while the treatment group (n = 30) was taught via online learning using an Inductive Model. The results showed that the science students' critical thinking achievement in the treatment group significantly improved based on the post-test results. The Levene's test showed that the pre-test scores of the two experimental groups were homogeneous before the experiment was conducted [F (1, 58) = 2.757, p > 0.05]. In the qualitative aspect, this study also found that students had an enjoyable session and were motivated (more interested, and fascinated) through the inductive learning session, and improved their critical thinking skills. In conclusion, science teachers need to be creative and competent in teaching and learning strategies to reinforce students' critical thinking skills.**

***Index Terms*—Inductive model, science, COVID-19, critical thinking skills, online learning.**

I. Introduction

Due to the COVID-19 pandemic, governments all over the world have decided to close all educational institutions. This decision is affecting 80% of the world's population where almost 1.37 billion students from 138 countries and 60.2 million teachers cannot be in the classroom because of the closing of schools and academic institutions [1]. The Coronavirus if infected can cause severe acute respiratory syndromes (SARS-CoV-2) and it has caused epidemics worldwide and resulted in millions of deaths [2]. Significantly, it has resulted in a sudden change of working methods and everyone is familiarized with the new norms; including students in educational institutions. The Malaysian Education Ministry has taken the initiative to replace face-to-face learning with online learning. This initiative is aimed at all educational institutions, including kindergartens, private schools, public schools, and tertiary educational institutions. This makes it difficult for students who take science subjects because these subjects are complex and require a high understanding of theory and concepts [3]. Teachers need to be creative in delivering the teaching and learning content during online learning to stimulate students' thinking skills [4]. The National Education Philosophy touches on the importance of education which is to develop the intellectual aspects by improving thinking apart from the moral, social, and emotional aspects. Among the essential elements of the curriculum is building the intellect and developing the thinking ability to describe, analyze, reason, formulate, and produce thoughtful ideas [5]. The value of critical thinking skills applied in the learning curriculum aims to produce versatile students who think critically, and creatively and possess moral excellence in real life. Using an Inductive Model in the teaching and learning process can enhance these skills for science students. The rationale for using the Inductive Model to enhance students' critical thinking skills is supported by previous research findings [6], [7]. The previously research finding showed that using inductive model increased students' result in Jordan (pre-test = 12.45; post-test = 16.25) [7] and in Indonesia (pre-test = 52 and 100; post-test = 72 and 100) [8].

Due to the worldwide spread of COVID-19 and its alarming situation, all education, including science education at the primary to tertiary level, is implemented via online learning [2]. As a result of the sudden change in teaching and learning methods, teachers often hear students' complaints of not understanding what the online learning session was about; especially the science subjects. The most critical aspect due to the shift from traditional learning to online learning is that students' skills could not develop well, especially in critical thinking skills [9]. Coman *et al*. [10] stresses that students' skills development is poor because of online learning. Students find science subjects as complex because of the memorization method as the main approach to remembering various terms and facts [11]. Furthermore, several studies stated that science subjects do not challenge thinking because its understanding is more on memorization [12]. The Education Policy Planning and Research Division found that, in general, students only use memorization techniques in the science subject [13]. Critical thinking skills are expected in only 9.61 percent of problem-solving ability in the science test [14]. Thus, this has resulted in science students lacking mastery in critical thinking skills [15]. In a study, 75% of students' critical thinking skills in science were not fully integrated with the lessons during the pandemic [16]. It is clear that the emphasis on the need for thinking skills,

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especially critical thinking skills deserves special attention during online learning. Furthermore, science learning emphasizes the developmental pattern of students' thinking which is the critical thinking skills that include its processes such as understanding problems, planning strategies, implementing plans, and reviewing the outcomes. Features such as gathering ideas or information, interpreting things, and providing effective explanations are skills that are introduced in the Inductive Model [17].

II. Research Background

A. Critical Thinking Skills

Critical thinking skills emphasize analytical abilities, especially examining arguments, analyzing, categorizing, and reasoning in reaching information or conclusions. Critical thinking establishes the authenticity, precision, and value of information or knowledge claims [18]. It is also added that critical thinking has two main elements which are the frame of mind and some specific mental operations. The importance of thinking skills is in the ability to transfer skills that have been learned to other or new situations. Thinking skills are essential in improving the ability to deal with problems. Through it, an individual can control, determine the direction, and measure the progress of actions [19]. He can also use the knowledge learned more productively. Teachers' teaching strategies or methods and classroom conditions are factors to the effectiveness of critical thinking skills concurrent with problem-solving skills in science education. Fadhlullah and Ahmad [15] stated that teacher strategies and reflective pedagogy stimulate students to practice critical thinking. In addition, students' critical thinking skills can be developed when teachers use various learning activities in the classroom [20]. Santos [21] suggested that further research and analysis are needed to elucidate the impact of using critical thinking in science teaching and learning activities to enhance students' critical thinking skills. Indeed, these skills are vital in science education and must be implemented in teaching and learning, especially during online learning.

B. Online Learning

Online learning is a method of learning that can be done in or out of the classroom using the medium of the internet. Online learning refers to the use of internet technology to convey information that can enhance one's knowledge and skills [10]. It is in line with the use of the internet in education as interactive learning [22]. Specific challenges such as critical thinking skills in science subjects become more challenging to teach and learn online. Nevertheless, critical thinking skills are vital in science education. One of the main reasons for the decline in online science learning is that the environment is not suitable for science subjects [23]. Based on the researchers' experience, science learning is not suitable for implementation because students cannot interact with teachers directly while the teaching and learning process is in progress. Students are usually more likely to ask poorly understood questions. The OECD [24] agreed that effective online science learning requires teachers to use appropriate and effective forms of online learning pedagogy to develop students' skills, especially in critical thinking skills.

C. Inductive Model

The Inductive Model is a learning model that relates to the processing of information through an inductive thought process. Through the Inductive Model, educators can apply learning that facilitates students to get involved in finding patterns, procedures, and formulas. The Inductive Model is a planned strategy and is very suitable for developing students' thinking skills through observation, comparison, pattern discovery, and generalization [6]. It is also a high reasoning process approach where students are not directly exposed to the teaching process [17]. This means that they are not exposed to other problems related to the topic of discussion and the topic being taught. Instead, they are encouraged to explore, investigate, and study independently [7]. The Inductive Model approach starts from the specific to the general, which begins with a cause or example and moves toward a generalization [25]. The teacher directly presents information that will illustrate the topics that students will study. Then, the teacher guides students to find specific patterns from the illustrations provided. This model will lead students to make logical conclusions with the existing evidence [26]. Thus, the learning process through the Inductive Model is not about memorization by students but the learning is understood in depth.

D. Research Questions

- What are the students' profiles in critical thinking skills based on the pre-test and post-test results for the control and treatment groups?
- Are there any significant differences in science students' critical thinking skills between online learning using an Inductive Model and online learning without using an Inductive Model?
- What are the students' views of using an Inductive Model during online learning?

E. Research Hypothesis

Ho: There is no significant difference between the use of an Inductive Model on science students' problem-solving and critical thinking skills during online learning.

III. Methodology

A. Research Design

The research design is a specific method of obtaining the data and information needed to respond to the research questions and accomplish the study's objectives [27]. In this study, quasi-experimental with explanatory mixed-method design was used. For quantitative, the researchers used pre-test and post-test instruments for the control group (online learning without using an Inductive Model) and treatment group (online learning using an Inductive Model). To support the quantitative findings from the post-test, the researchers employed the focus group interview for the qualitative approach [28]. The dependent variable in this study was critical thinking skills while the independent variable was the teaching method for the two groups. The

design of this study is illustrated in Table I.

TABLE I: QUASI-EXPERIMENTAL DESIGN

Group		Teaching Method	
Control Group	Pre- Test	Online learning without using Inductive Model	Post-Test
Treatment Group	Pre- Test	Online learning with using Inductive Model	Post-Test

B. Sampling Design

The study was conducted at the secondary school in Selangor. A total of 60 science students studying at secondary schools around Shah Alam participated in this study. The gender difference was not examined in this research. Sample selection was made based on the non-probability sampling method through a convenience sampling procedure [29]. Hence, the sample was selected as it was accessible to the researchers. In the control group, thirty students (n = 30) underwent online learning without using an Inductive Model while another thirty students (n = 30) in the treatment group went through online learning with an Inductive Model.

C. Instrumentation

A research instrument is essential to achieve the objectives of a study. It is also a measuring tool used to measure the variables studied [28]. A good measuring tool accurately measures the variable to be measured [30]. The research instrument used in this research was a set of nine open-ended questions namely Science Achievement Test targeting students' critical thinking skills in answering the questions. The Science Achievement Test was formed referring to the form one (age of 13) Science textbook on the topic of air pollution. This test question contained higher order thinking skill questions based on the elements measured in the high-level of Blooms' Taxonomy; applying, analysing, evaluating, and creating. Critical thinking is referred to as higher order thinking [31]. The total score was 30 marks (100%). The four elements of higher order thinking were marked as; (i) Apply- 4 marks, (ii) Analyse - 4 marks, (iii) Evaluate- 16 marks, and (iv) Create- 6 marks.

D. Experimental Protocol

Teaching sessions were conducted by a science teacher using an online learning video platform called Cisco Webex. Pre-test for the control and treatment groups implementation period was within a week. The post-test for the control and treatment groups was also conducted within a week after the pre-test. Hence, the total duration of this study was two weeks. For the control group, the teaching session was without using the Inductive Model. This meant that the teacher conducted a standard teaching technique. Meanwhile, for the treatment group, the teaching session was with the use of the Inductive Model. An Inductive Model has four phases, namely introduction, open-ended phase, closure, and application phase. The four phases of an Inductive Model are illustrated in Fig. 1 below.

Table II below explains the process of an Inductive Model in online learning including the open-ended questions given to the students.

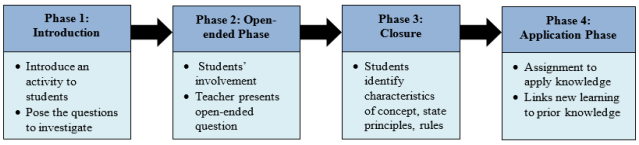

Fig. 1. The phase of an inductive model.

TABLE II: THE PROCESS OF AN INDUCTIVE MODEL IN ONLINE LEARNING SETTING

Phases of an Inductive Model	
Phase 1: Introduction	• Students looked at the pictures of smoke from factories, car exhausts, and open burning given by the teacher. • Students made observations and gave opinions based on the given pictures by the teacher. • Students answered the posed question given by the teacher, which was: - How and why did the smoke come out from this factory, car exhaust, and open burning? - What are the effects of this smoke on our health?
Phase 2: Open-ended	Students were divided into groups to do a discussion session. Each group consisted of three to four members. • Students brainstormed the open-ended questions given by the teacher: - Identify the pollutant substances that came out from the factory smoke, car exhaust, refrigerator, and open burning. - Pollutants harm our environment. Explain two causes and two harmful effects of air pollution on human health, buildings and infrastructure, plants and animals, and the earth's climate. - Explain two methods to overcome open burning. • Students wrote their answers on the chat box. • Each group presented their findings and gave their opinions on the effects of air pollution. • Teacher acted as a facilitator and guided students during the process.
Phase 3: Closure	• Students reflected on the lesson: - Students determined the concept of air pollution in terms of what pollutant substances cause air pollution. - Students stated the characteristics of a good citizen preventing air pollution. - Students stated the rules on preventing air pollution.
Phase 4: Application	• Teacher gave reinforcement exercises as students' homework. • Students applied prior knowledge to give an idea/opinion on preventing air pollution and controlling air pollution through laws, education, and science and technology.

E. Statistical Analysis

Two types of statistics were used to analyze the data obtained in this study, namely descriptive statistics to measure the achievement of critical thinking skills referring to students' profiling, and inferential statistics for ANCOVA test analysis. The pre-test and post-test assessed whether the mean of two-sample distributions for the control and treatment groups were significantly different [29]. Students' critical thinking analysis for pre-test and post-test-only are as follows; i) 80%-100%: Excellent, ii) 60%-79%: Good, iii) 30%-59%: Satisfactory, and iv) 0%-29%: Weak. Meanwhile, thematic analysis was used to address the third research question which was to identify the students' views of using the Inductive Model during online learning. Thematic analysis is a way to identify patterns of a phenomenon [32]. This thematic analysis began with the initial stage of analyzing data and was followed by an advanced process that

involved the code construction section and ended with the data display section. A code in qualitative research is mainly a word or concise phrase that symbolically gives a summative, prominent, essence-capture, or redolent feature to a part of language-based or visual data [33]. The qualitative analysis involved ten respondents (n = 10) randomly selected for the focus group interview session. The focus group interview session was purposely to get the students' views on using the Inductive Model during online learning. The interview session was conducted through Cisco Webex for 30 minutes after the learning session.

IV. Findings

The findings are reported in two parts, namely quantitative and qualitative.

A. Quantitative Result

The descriptive analysis is reported based on [Fig. 2 (a); Fig. 2 (b); Fig. 3 (a); Fig. 3 (b)] below which showed the overall scores. The results of the pre-test and post-test for the control and treatment group in the Science Achievement Test contributed to the science students' profiling based on their critical thinking skills. Based on Fig. 2 (a) and Fig. 2 (b), the findings from the pre-test for the control group showed that the highest science students' Critical Thinking Achievement was the satisfactory score at 33% (n = 10), while the post-test for the control group showed the highest science students' Critical Thinking Achievement was the satisfactory score at 77% (n = 23).

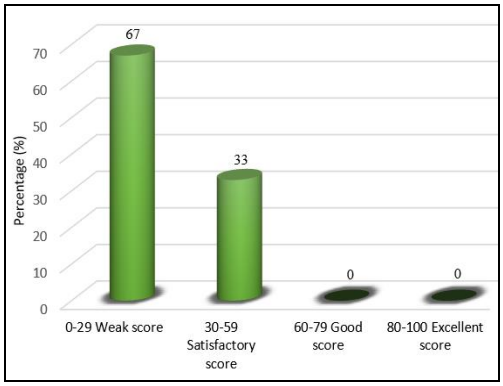

Fig. 2 (a). Pre-test for control group.

Fig. 2 (b). Post-test for control group.

Meanwhile, Fig. 3 (a) below shows the findings from the pre-test for the treatment group which showed that the highest science students' Critical Thinking Achievement was the satisfactory score at 60% (n = 18), while Fig. 3 (b) showed the findings from the post-test for treatment group which showed the highest science students' Achievement Test was the excellent score at 30% (n = 9).

Fig. 3 (a). Pre-test for treatment group.

Fig. 3 (b). Post-test for treatment group.

ANCOVA test analysis was performed to investigate the differences in Critical Thinking Achievement between control and treatment group post-test scores. The preliminary analysis results showed that the data met the normality and equal variance assumptions of the ANCOVA test. This test showed that for the post-test scores the treatment group with a mean score of 67.13 outperformed the control group with a mean score of 36.13. The ANCOVA test required that one of the data undergo Levene's test to verify that both groups were homogeneous before treatment was administered.

TABLE III: Levene's Test

F	df1	df2	Sig.
2.757	1	58	0.102

Table III of Levene's test showed that the pre-test scores of the control and treatment groups were homogeneous before the experiment was conducted [F (1, 58) = 2.757, p > 0.05]. Based on Table IV, after equalizing the pre-test score using the ANCOVA test, the results showed a significant difference in the post-test scores between the control and treatment groups [F (2, 57) = 192.584, p < 0.05]. The research hypothesis was accurate, and the null hypothesis was rejected. Hence, the inductive model has significantly affected the science students' critical thinking skills during online learning. This means the Inductive Model has effectively enhanced the critical thinking skill of the science students. The large partial eta squared value 0.772 (refer Table IV) revealed that the Inductive Model strategy has

significantly enhanced the science students' critical thinking skills.

TABLE IV: ANCOVA TESTS (METHODS OF TEACHING)

Dependent variable: Post-test

Source	Type III Sum of Squared	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	19140.186[a]	2	9570.093	221.769	0.000	0.886
Intercept	10162.084	1	10162.084	235.487	0.000	0.805
Pre-test	4725.186	1	4725.186	109.497	0.000	0.658
Methods of teaching	8310.671	1	8310.671	192.584	0.000	0.772
Error	2459.747	57	43.153			
Total	181560.000	60				
Corrected Total	21599.933	59				

[a]. R Squared = 0.886 (Adjusted R Squared = 0.882)

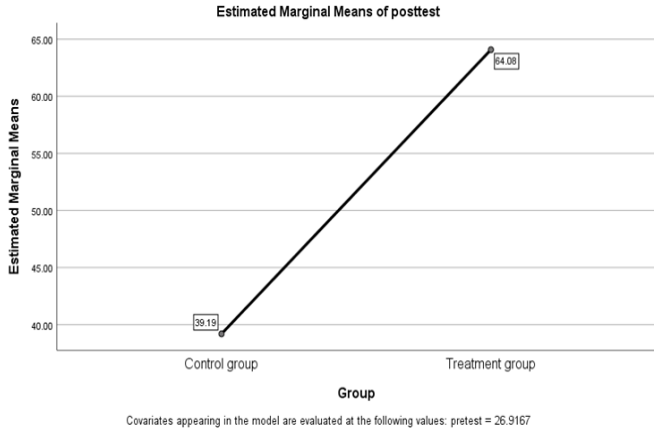

Fig. 4. The graph of estimated marginal means of post-test.

Fig. 4 showed that the mean value for treatment group (M = 64.08) was higher than control group (M = 39.19).

B. Qualitative Result

The overall outcome of the interview findings extracted two themes namely the sessions were more enjoyable and had improved their critical thinking abilities. According to the interview data, all students believed that using the Inductive Model in science online learning was successful, entertaining, and had inspired them to learn science further. Some of the science students' (S) responses from the interview session are as follows:

Theme 1: Teaching using Inductive Model made students enjoy the session and felt motivated

"I feel motivated after the teacher used this model. Teacher constantly monitored and guided this learning. Likewise, it has boosted my interest in learning science." (S1)

"Through this model, it makes me more interested in science subjects and to think outside the box. This teaching method makes online learning enjoyable and I feel motivated. (S2)

"I enjoyed learning through this Inductive Model, and it increased my interest in science….because it was the first time my teacher has taught using this method in the online classroom." (S4)

"This is the first time I have been taught to use this Inductive Model and it was fascinating and enjoyable. I had a hard time understanding the higher order thinking questions, but the teacher has guided me throughout the learning process. I felt motivated to learn science subjects through this model." (S5)

Theme 2: Enhance students' critical thinking skills

"I can answer high-level questions clearly after the teacher used this model. My critical thinking has improved, where I previously had difficulty understanding and answering high-level questions." (S7)

"After the teacher used this model of instruction, I could answer the questions well. This model enhanced my critical thinking skills compared to previously as, before this, I could not cater to higher-order thinking questions and quickly gave up when I could not answer the questions." (S8)

"My critical thinking skills were enhanced when the teacher implemented the Inductive Model in the online class as I can answer higher-order thinking questions in the test confidently." (S10)

Students reported that utilizing the Inductive Model in online learning was enjoyable, and it pushed them to master the science subjects mainly to improve their critical thinking skills. As used in an online learning setting, the Inductive Model has been beneficial to teachers and students. It has also provided students with relevant learning and experience in science disciplines from various perspectives, particularly in an online learning situation. Students' motivation in science disciplines and critical thinking skills have also improved based on the interview responses.

V. DISCUSSION

The findings of this study were able to answer three research questions, namely i) the students' profiling in a pre-test and post-test for control and treatment group based on their critical thinking skills, ii) significant differences in science students' critical thinking skills between without the use of the Inductive Model and with the use of the Inductive Model during online learning, and iii) the students' views of using an Inductive Model during online learning. Furthermore, the researchers delved into the three findings obtained using a mixed-method research design.

The findings were that the science students' critical thinking achievement in the control group in the pre-test and post-test showed a significant improvement in overall students' critical thinking skills. In fact, the post-test results showed that students have improved to moderate, good, and excellent for the treatment group. The pre-test results showed that the two groups comprised of medium and low achievers.

There was a significant difference between the control group compared to the treatment group. The achievement test of the treatment group using the Inductive Model was better than the control group. This is in line with Sari's [6] findings that the Inductive Model strategy has a significant impact on developing students' critical thinking skills. This circumstance demonstrated that using the Inductive Model in an online learning context positively influenced the treatment group's critical thinking skills.

This study found a significant difference between the control and treatment groups in critical thinking skills. This shows that the teaching method using an Inductive Model was better than the standard teaching method. This is because interview data with students showed that learning using the Inductive Model has successfully enhanced their critical thinking skills (S7, S8, and S10). This response also was supported by their motivation and interest in a science subject (S1, S2, S4, and S5). With the effectiveness of using the Inductive Model in online learning, the teacher was able to deliver meaningful learning and implement student-centered teaching strategies to improve their critical thinking skills. Students were able to answer the higher order thinking skills in the online learning setting. This aligns with Obeidat and Alomari [7] that the students are encouraged to explore, investigate, and study independently with guidance from teacher and peer discussions when an Inductive Model is implemented in the teaching strategy. Hence, the Inductive Model has enhanced students' higher order thinking to discover, investigate, and draw conclusions from a critical thinking question.

Teaching using the Inductive Model was seen to impact students' critical thinking skills positively. This finding aligns with the findings of Fadhlullah and Ahmad [15], which showed that the teaching strategies and approaches as well as reflective pedagogy can stimulate students to practice critical thinking when they are answering the critical thinking questions. When the Inductive Model was used in the online classroom, the researchers discovered several benefits. The benefits of this model include: i) students became active with their learning activities by engaging their minds in exploring and investigating the questions, ii) boosting students' motivation based on the development of high curiosity while conducting the Inductive Model learning, and iii) increasing students' engagement in the activity by asking about science concepts which meant that students are more active in learning. Some of the limitations faced in implementing the Inductive Model in online learning were that the effectiveness of this learning model depended on the teacher's skills in questioning and directing learning students. Some of the students have difficulty using the internet. These findings are supported by Kapilan *et al.* [34] findings that internet access is often an issue that is often raised in online learning.

Exciting learning methods are one of the vital aspects that teachers need to consider. This is because students who learn the science subjects have the belief that these subjects are complex and require a high understanding of theory and concepts [3]. If students' motivations are not elevated in the online learning session, students tend to lose interest and this will result in the students not improving their critical thinking skills in the science subject. Hence, using the Inductive Model is one of the alternatives that can increase students' motivation and enhance their critical thinking skills.

This study is intended to help teachers modify the way science is taught in the classroom, particularly in an online learning environment. The provision of higher order thinking questions that cater to the critical thinking skills of the students will assist the teacher in increasing the degree of both abilities [35].

VI. Conclusion

In conclusion, the quantitative findings of this investigation revealed that the effectiveness of the Inductive Model has a positive impact on students in terms of i) students' critical thinking achievement scores, ii) achievement comparison between control and treatment groups proved that using the Inductive Model in online learning has stimulated students' critical thinking skills. This conclusion means that the null hypothesis was rejected. Meanwhile the qualitative findings obtained from students' interviews proved that the use of the Inductive Model in an online learning setting has i) helped students learn concepts that can be used to organize information to facilitate them to apply the concepts more effectively, ii) to provide the experience of scientific methods specifically for the critical thinking, and iii) fostering cooperation and fun engaging learning among science students during online learning. The effectiveness of the Inductive Model can be implemented in an online learning setting by science teachers to help students investigate, decide, and solve problems effectively through critical thinking skills. The effectiveness of this teaching model in online learning contributes to the improvement of science students' achievement in critical thinking skills, interest, and motivation in learning science subjects to cater to both abilities has been proven in this study. Even though this study does not indicate the enhancement of students' critical thinking achievement across the country, researchers believe that teaching strategy using the Inductive Model needs to be continued to ensure students increase their critical thinking skills. This study has only been conducted through an online learning platform. Hence, it is recommended that other researchers conduct a study implementing the Inductive Model in a face-to-face classroom setting to get in-depth data, especially for science subjects. There is a need for training for the science teachers to be more creative and competent in implementing the model of instruction to enhance critical thinking skills.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Afifah Jazilah Arjunaidi was the main researcher, and she suggested related literature review, involved in the data collection, and provided the accurate data analysis. Nurulwahida Azid was the advisor in the research process to be implemented. She has conducted the review editing of this paper to make sure it was related to the aims and scope of the

journal. All authors were committed to review the final manuscript.

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