Analytical thinking ability: Implementation of modified free inquiry (mfi) learning models on environmental pollution

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ARTICLE INFO	ABSTRACT
	Students' analytical thinking skills need to be developed and improved in biology learning. The lack of varied learning models used in learning makes students feel bored in learning. The modified free inquiry (MFI) learning model is one of the learning models that is thought to be suitable for improving students' analytical thinking skills. This study aims to determine and analyzed the effect of the application of the MFI learning model on students' analytical thinking skills on environmental pollution material. The method used in this research is quasi-experiment with the research design, namely pre-test and post-test control group design, and the sample used is 60 class X students. The data showed gain score in both classes is normally distributed and homogeneous. This research showed that MFI learning model effected the students' analytical thinking skills on environmental pollution. The application of the MFI learning model could be an alternative for teachers to improve students' analytical thinking skills, because this model encourages students' activeness in constructing knowledge so that it creates a meaningful learning experience.

INTRODUCTION

Learning is an interaction between teachers and students that contains educational communication to achieve learning goals (Inah, 2015). Effective learning is characterized by the learning process of students, namely there will be changes in students from ignorance to the knowing (Aunurrahman, 2014). 21st-century learning requires students to master seven skills, one of which is the ability to think analytically (Wagner, 2010). Analytical thinking ability is an ability to be able to divide and describe knowledge or problem into important parts and find the relationship of the components of knowledge (Yaumi, 2013). With good analytical skills, it can make it easier for students to understand learning materials and help students recognize problems, and find solutions to find ways to solve problems in everyday life (Dawati, 2015).

The analytical skills of Indonesian students are still quite low (Khurniawan & Erda, 2019). This also occurred in the students' pretest average data where students' analytical skills were still low, which was 54.7 for the experimental class and 58.7 for the control class. Based on data from the PISA (Program for International Student Assessment) survey results in 2018, the ability of Indonesian students in science have an average score below OECD (Organization for Economic Cooperation and Development) countries. These results state that Indonesian students are good at understanding single-text forms but weak at understanding multiple texts, meaning that students in Indonesia are good at finding information, evaluating, and reflecting on information, but weak at understanding information (Kementerian Pendidikan dan Kebudayaan, 2019). The results of research conducted by Setiawati & Corebima (2018) show that the ability of students is still in the low category, namely 40%. These results are also in line with research conducted previously by (Ilma et al., 2017) which explains that students' analytical thinking skills are still relatively low. It was also stated by Kiong et al., (2012) based on the results of their research from the five components in Bloom's taxonomy of thinking, the ability to analyze has the lowest results.

High school biology material, especially in class X regarding environmental pollution, is one of the biological materials that requires high analytical skills because this material is directly related to students' daily lives (Harahap & Harahap, 2021). Environmental pollution material contains many environmental problems that are discussed and require students to analyze the causes and formulate alternative solutions related to these problems (Sofiatin et al., 2016). Problems about environmental pollution challenge students to get used to solving problems in learning (Luthfi et al, 2019). Learners who know the concept of environmental pollution can use this ability to overcome environmental problems (Sigit et.al, 2017). However, Biology subjects in environmental material still lack imagination in analyzing the problem-solving process (Azrai & Sulistianingrum, 2017)

Based on the above problems, the analytical ability of students is still low, and environmental pollution material requires high analytical thinking skills. So teachers must be good at designing learning through the application of the right learning model and following the learning needs taken (Suryanda, 2020). The MFI learning model is one of the learning models that is thought to be suitable for overcoming the above problems and is also thought to be suitable for training students to develop their analytical thinking skills. The MFI learning model is a learning model modified from guided inquiry and free inquiry. In its implementation, the teacher first provides a topic then students formulate problems, convey hypotheses, plan and conduct experiments, analyze data, communicate, and conclude independently (Rahmi et al., 2020). Syntax of MFI has an important role in learning activities in the classroom because students will play an important and active role in practicing courage, communicating, and trying to get their knowledge to solve problems (Fatmawati, 2021).

The MFI learning process is centered on students, where students are given the freedom to search and find solutions or answers to problems so that the teacher only acts as a facilitator (Putri et al., 2022). The MFI learning model limits teacher guidance to students so that students can try independently to analyze problems and find answers or solutions (Suryaningsih &

Sugandi, 2022). This was also conveyed by Kholilurrohman & Suryadarma (2019), the minimal role of teacher guidance in learning activities using the MFI model, can trigger students to build their ideas into new experiences explored in the form of performance in a lesson. One of the advantages of the MFI learning model is that it helps the development of students' thinking in terms of processing and concluding, obtaining basic ideas and concepts (Fatmawati, 2021).

This research specifically examines the effect of the MFI learning model on students' analytical thinking skills on environmental pollution material to obtain novelty and support aspects of improving students' analytical thinking skills in learning environmental pollution material. Environmental pollution is a complex topic and requires in-depth analytical skills to understand the various causal factors, impacts, and possible solutions. Thus, this research aims to fill the gap by exploring the extent to which the MFI learning model can improve students' analytical thinking skills in the context of environmental pollution material. The MFI learning model is expected to encourage learners to be able to convey the results of their thinking in the form of analysis of environmental pollution material problems that are close to students' daily lives. Learners can analyze the efforts made in tackling environmental pollution based on the results of group discussions that have been carried out. Based on the problems that have been described in the description above, the ability to think analysis of students, especially at the high school level is very important and needs to be improved. The purpose of this study is to determine, measure, and analyze the effect of the application of the MFI learning model on students' analytical thinking skills on environmental pollution material.

METHODS
Research Design
This study used a quasi-experimental method with the research design using was pre-test and post-test control group design (Creswell, 2014). The independent variable of this research is the MFI learning model and the dependent variable is the analytical thinking ability of students on environmental pollution material (Table 1).

Table 1
Research Design

Group	Pre-test	Treatment	Post-test
Experiment	O_1	X_1	O_2
Control	O_1	C	O_2

Note: O_1 = Pre-test; X_1 = Treatment of experimental class with Modified Free Inquiry (MFI) learning model; C = Treatment of control class with Discovery Learning (DL) model; O_2 = Post-test.

Population and Samples
The research was conducted at one of the high schools in Jakarta, Indonesia in the second semester of the 2022/2023 school year. The research was conducted in one of the senior high schools in Jakarta in the second semester of the 2022/2023 school year because the school is a Sekolah Penggerak and uses the Merdeka curriculum. Class X was selected using the purposive sampling technique because environmental pollution material is studied by class X students in second semester. Determination of experimental and control classes using cluster random sampling technique, so class X-6 was obtained as an experimental class and X-7 as a control class. Research sampling using a simple random sampling technique and the formula of Slovin (1960), so 60 students were obtained as research samples.

Instrument
The research instrument was made based on the components of analytical thinking skills developed by Marzano (2007). The research instrument used an essay test of 20 items on environmental pollution material. In the instrument validity test with Pearson Product Moment (PPM) at the significance level α = 0.05, 19 questions were valid and 1 question was invalid (Putrawan, 2021).

Reliability measurement with Cronbach's alpha, the result is 0.87, meaning that the instrument has very high reliability (Miller, Linn, & Gronlund, 2009).

Table 2
Analytical Thinking Ability Test Grids

Components of Analytical Thinking	Indicators
Matching	Detail the characteristics or traits
	State similarities and differences in knowledge components (concepts, theories, etc.)
Classifying	Identify characteristics to classify and explain their relationship
Analyzing Errors	Evaluate the validity of knowledge based on explicit criteria
	Identifying an error in thinking
Generalizing	Looking for patterns or connections in the information
	Make a general statement that explains the pattern or relationship
Specifying	Identify principles that apply to specific situations
	Identify conclusions that can be described or predictions made

(Source: Marzano, 2007)

Procedure

A pre-test is given to students in both classes before learning is given which aims to determine the initial ability of students' analytical thinking. Furthermore, the experimental group will be given a MFI learning model for learning environmental pollution material. The control group will be given a Discovery learning model for learning environmental pollution material. Both classes get the same learning time which is for 2 meetings. After learning, both classes will be given a post-test to see the effect of the learning model that has been applied. The following are the learning stages in the experimental class with the MFI learning model in Table 3.

Table 3
Modified Free Inquiry Learning Stages

No	Syntax of MFI	Description
1	Orientation	Teachers provide apperception, motivation and explain learning objectives and learning outcomes to students
2	Formulate the problem	Students formulate the problem
3	Hypothesis Formulation	Students formulate a hypothesis as a temporary answer to the problem formulation that has been made.
4	Data Collection	Students design data collection and collect data through observation, exploration or experimentation.
5	Hypothesis Testing	a. Processing and analyzing the data/information obtained
		b. Discuss data/information from observation, exploration or experimentation.
		c. Present the results of the discussion
		d. Conduct a question-and-answer discussion between students
6	Conclusions	Students make conclusions from the results of the discussion

Data Analysis Techniques

Data analysis in this study used descriptive statistical analysis, gain score and N-Gain tests, and hypothesis testing. Descriptive statistics can help summarize data in the form of simple quantitative measures such as histograms (Nur et al., 2023). Gain score calculation is done to determine the improvement of students' analytical thinking skills before and after learning is done, while N-Gain is used to determine the effectiveness of the learning model used (Hake, 1999). Before testing the research hypothesis, the data will be processed using two prerequisite tests, namely normality test using the Kolmogorov-Smirnov test (K-S test) and the homogeneity test using F-test. If the data meets the prerequisites, then proceed to hypothesis testing with an independent t-test. All tests were carried out with the SPSS version 25 application.

RESULTS AND DISCUSSION

Pre-requisite analysis and hypothesis testing were carried out to see the effect of the applied learning model. Based on the results of Kolmogorov-Smirnov normality, it was found that the data is normally distributed, and based on the results of the homogeneity test, the data obtained was homogeneous. After it is known that the data meets the prerequisites, hypothesis testing is continued using an independent t-test with SPSS version 25 at a significance level of $\alpha = 0.05$. Based on the calculation results, a significance value of 0.021 was obtained (0.021 <0.05). So, this research showed that there is an effect of the MFI learning model on students' analytical thinking skills on environmental pollution topics. Based on the research conducted, the descriptive statistical results of the experimental and control classes are presented in Table 4.

Table 4
Descriptive Statistical Results of Experimental and Control Classes

	n	Minimum	Maximum	Mean	Median	Std. Deviation
Pre-test Experiment Class (MFI)	30.00	36.80	80.70	58.70	56.10	9.67
Post-tests Experiment Class (MFI)	30.00	50.90	98.20	76.40	78.90	12.01
Pre-test Control Class (DL)	30.00	28.10	84.20	54.70	56.10	15.4
Post-tests Control Class (DL)	30.00	36.80	94.70	67.30	67.50	15.8

Table 4 shows the pre-test and post-test values of the experimental class using the MFI model and the control class using the discovery learning model. The experimental class value is higher than the control class, due to differences in syntax in the MFI and DL learning models. Syntax is a stage of the learning model that can support the achievement of the desired learning outcomes and objectives to make learning more meaningful (Asyafah, 2019; Setiawati & Corebima, 2018). This is reinforced by (Rijal & Bachtiar, 2015) that learning outcomes are influenced by the experience of students. The inquiry model is a learning activity that encourages students to learn through searching and discovering concepts through observation, exploration, and experimentation (Kunandar, 2010). The discovery learning model is cognitive learning that requires teachers to be more creative in creating situations that can make students discover their knowledge. The results of the pre-test and post-test values obtained are then processed to determine the gain score which is the difference between the pre-test and post-test values. These results are presented in Figure 1.

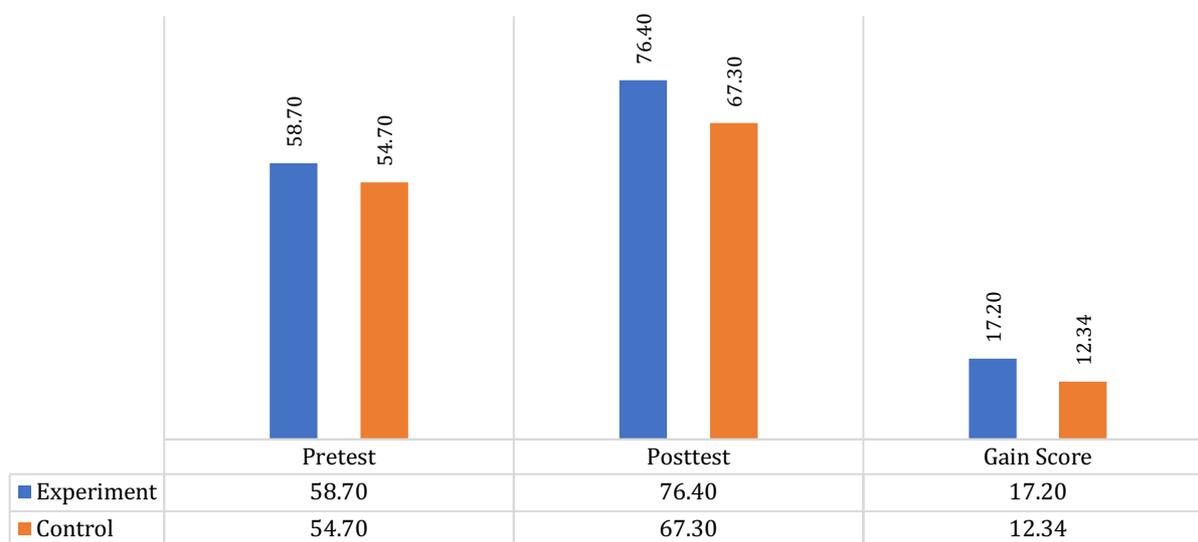|	Pretest	Posttest	Gain Score
Experiment	58.70	76.40	17.20
Control	54.70	67.30	12.34

Figure 1. Average Pre-test-Post-test and Gain Score of Analytical Thinking Ability Of Students

After that, the N-Gain calculation is carried out, namely the result of the division between the post-test value minus the pre-test value and the ideal value minus the pre-test value, this is useful for knowing the increase in students' analytical thinking skills. The experimental class has an average N-Gain of 0.45 while the control class is 0.30. N-Gain results can be seen in Table 5.

Table 5
Experimental and Control Class N-Gain Results (Hake, 1999)

Class	N-Gain	Category
Experiment Class (MFI)	0.45	Moderate
Control Class (DL)	0.30	Moderate

Based on Hake's category (1999) the N-Gain value of both classes is in the medium category but the value of the experimental class is greater than the control class. Things that make a difference in the effectiveness of learning models include the conditions of teachers and students, the nature of teaching materials, and the learning model applied (Fathurrohman, 2015). After that, the dimensions of analytical thinking ability based on Marzano (2007) are analyzed in Table 6.

Table 6
Average Component Value of Analytical Thinking Skills (Hake, 1999)

Components of Analytical Thinking	Experiment			Control		
	Pre-test	Post-test	n-Gain	Pre-test	Post-test	n-Gain
Matching	57.00	75.00	0.42	55.00	61.00	0.13
Classifying	53.00	70.00	0.36	51.00	63.00	0.24
Analyzing Errors	64.00	78.00	0.39	59.00	68.00	0.22
Generalizing	63.00	78.00	0.41	59.00	75.00	0.39
Specifying	56.00	80.00	0.55	50.00	68.00	0.36

Based on Table 6, the matching aspect of the experimental class experienced a higher increase than the control class. According to Fakhrurrazi et al., (2019), students have been able to identify similarities and differences in the knowledge component where in this case analyzing the differences in the causes of environmental pollution. The results of student answers to question number 3 are shown in Table 7.

Table 7.
Example of Experimental and Control Class Answers on The Matching Aspect

Class	Pre-test	Post-test
Experiment	The characteristics of pollution by humans tend to take a long time and are sustainable, for example, cutting down trees illegally and throwing garbage. Whereas environmental pollution caused by natural disasters usually does not take a long time and is not sustainable, for example, a tsunami that damages the surrounding environment.	1. Environmental pollution caused by human behavior can be minimized, for example by throwing garbage in its place or by properly managing waste. While environmental pollution caused by natural disasters cannot be prevented, for example environmental pollution due to earthquakes, tsunamis, volcanic eruptions. 2. Environmental pollution caused by humans has a slow or long period of time, for example when people litter in the same place frequently, during the rainy season the garbage will clog the waterways which will cause flooding, while environmental pollution caused by natural disasters has a fast period of time, for example environmental pollution due to tsunamis. 3. Environmental pollution caused by human behavior comes from humans themselves, for example when we litter, cut down trees illegally and others. Meanwhile, environmental pollution caused by natural disasters comes from nature such as environmental pollution due to earthquakes.
Control	Environmental pollution caused by human behavior has a low-scale nature and the pollution process tends to be slow. Meanwhile, pollution caused by natural disasters is large-scale and the process is fast.	Environmental pollution caused by nature is usually earthquakes, floods, and forest fires, but if environmental pollution by humans is usually littering / throwing garbage into the river causing river flow to be blocked and resulting in flooding, littering cigarette butts can cause fires.

Based on the results of the experimental class students' answers, show an increase in analysis. The increase in the matching aspect of the experimental class is due to learning with the MFI model making students explore all information about the learning material being studied (Putri Lamia et al., 2022). Thus, students can understand and convey what has been learned during learning.

The second aspect is classifying, the results of the experimental class experienced a higher increase, meaning that the ability of students to select concepts that are classified and identify various categories of knowledge material for a concept has been optimized (Fakhrurrazi et al., 2019). The classifying aspect can be seen in question number 6, students must classify the kinds of environmental pollution caused by the phenomenon presented in a picture "littering on the side of the road". The following are the results of student answers to question number 6 presented in Table 8.

Table 8.
Example of Experimental Class Answers on The Classifying Aspect

Class	Pre-test	Post-test
Experiment	Causes many virus diseases	Pollution that can be caused by random waste disposal is pollution of air, water, land, and soil. 1. Air pollution: Littering and piling up garbage can cause unpleasant odors and will create air pollution. 2. Water pollution: Disposing of trash carelessly can lead to water pollution. Trash piled up like the picture above can make waterways clogged and can cause flooding. 3. Soil pollution due to the accumulation of garbage that makes the soil polluted, damaged and infertile.
Control	Air pollution because garbage creates an unpleasant odor	1. Air pollution, because waste creates an unpleasant odor 2. Water pollution, as it can cause flooding 3. Soil pollution

The increase in the classifying aspect of the experimental class is because the MFI model trains students to formulate problems. In line with (Suyatman et al., 2021) problem orientation and formulation show the potential to empower analytical thinking skills in the aspects of matching and classifying because at this stage students compare, examine, and classify the problems being studied. Agree with Chin & Osborne (2008) formulating problems can foster students' curiosity, bring students closer to the material being studied, and invite students to explore the material so that students are active in the learning process Formulating problems can train higher-order thinking skills (Khofifatin & Yonata, 2013). The ability to formulate problems can improve and develop students' analytical skills (Fakhrurrazi et al., 2019).

Experimental class students are also trained in planning and collecting data, this activity can improve students' analytical skills in the aspects of classifying and analyzing errors. According to Suyatman et al. (2021)planning and carrying out investigations has the potential to empower analytical thinking skills in the classifying aspect because students carry out activities to integrate, find, and describe planning and investigations. Thus, students are active in obtaining basic ideas and concepts directly so that knowledge is difficult to forget (Aqib & Ali, 2016).

The third aspect is analyzing errors, Table 6 shows an increase in the aspect of analyzing errors, meaning that students can analyze conceptual discrepancies and errors in a phenomenon, this aspect can be seen in number 11. students identify whether the habit of burning garbage is the right or wrong way to manage waste and provide reasons for their answers. This can be seen from Table 9.

Table 9.
Example of Experimental Class Answer on Analyzing Errors Aspect

Class	Pre-test	Post-test
Experiment	Burning waste is not appropriate because it can pollute the environment. The solution to dealing with waste is the 3R (Reduce, Reuse, Recycle).	Waste management by burning is very inappropriate because it can pollute the surrounding environment. Some solutions to deal with waste are the 3Rs Reduce, Reuse, Recycle. Separating trash bins for organic & inorganic so that the waste can be processed properly. Making compost from organic waste. Doing Zero Waste.

| Control | Recycling waste, especially plastic waste, reducing the use of inorganic materials such as plastic etc. | the right solution: 1. Recycling waste, especially plastic waste 2. Making compost from organic waste |

The higher increase in the ability to analyze errors of experimental class students compared to the control class is because in the process of planning exploration, observation or experimentation, students with their groups will look for various sources of information to design and collect data so that literacy activities increase. This is explained by (Sharon & Baram-Tsabari, 2020) literacy must be taught to students so that students can identify false information. The increase in these two aspects is also because in the MFI model, the teacher limits the guidance to students so that it makes the development of students' thinking skills and students work harder to gain knowledge. In line with Perdanawati et al. (2017)the MFI model has characteristics, namely educators limit guidance to students so that students make more efforts independently, so that students can find solutions to problems.

The generalizing aspect in the experimental and control groups has a relatively similar increase, meaning that students can make generalizations, statements, or principles from information where these activities involve the process of finding and explaining patterns or relationships of information. This aspect can be seen in number 14, where students analyze the relationship between two pictures of phenomena, namely "air pollution due to vehicle fumes and factory fumes" with global warming. The following are the results of student answers to question number 14. This can be seen in Table 10.

Table 10.
Example of Experimental Class Answers on The Generalizing Aspect

Class	Pre-test	Post-tests
Experiment	Vehicle fumes and factory fumes can both cause air pollution. This can lead to respiratory problems.	Based on the above phenomenon. The smoke produced by vehicles and the smoke produced by factories both cause air pollution and global warming. Because vehicle fumes and factory fumes emit harmful substances, namely carbon monoxide and CO_2 gas and are able to damage the ozone layer in the atmosphere.
Control	The smoke emitted by vehicles and smoke from factories is carbon monoxide and carbon dioxide gas, which are greenhouse gases that can trap heat in the earth, resulting in global warming.	Smoke from vehicles and smoke from factories produce CO or carbon monoxide and carbon dioxide. This gas is one of the greenhouse effect gases that cause damage to the ozone layer. the destruction of the ozone layer causes global warming.

The relatively same increase in analytical thinking skills in both classes is due to the process of analyzing the results of the discovery so that the learning of both classes is learner-centered. Learners in both classes analyze the findings by discussing them in groups. Through this group discussion, students' attention will be focused on the material, because students are directly involved in the learning process (Syafruddin, 2017). When discussing with groups, can stimulate the creativity and analysis of students in the form of ideas, initiatives, and breakthroughs in solving a problem (Karyadi, 2017).

The specifying aspect of the experimental class has a much higher increase than the control class, meaning that students can reason to understand a series of situations (Chonkaew et al., 2016; Wahyuni et al., 2021). This aspect can be seen in number 20, where students identify and predict the impact that occurs from the graph showing the number of motorized vehicles in Jakarta which consistently increases every year. This is shown in Table 11.

In line with Fitriah et al. (2016) learning with MFI trains students to organize, analyze data and use their knowledge to solve the problems at hand, train students to identify, analyze, and evaluate problems carefully so that students can develop their reasoning power creatively to solve the problems at hand, make conclusions and solve problems.

The difference in the improvement of specifying ability in experimental and control classes is that in the experimental class, there are presentation activities and class discussions while the control class only presents the results and then continues verification by the teacher. So in the experimental class, there was a discussion again between students and teachers, this was able to improve analysis skills because it made students active in learning. According to Sukmawijaya & Juhanda (2019) the ability to

argue is the ability of students in the classroom to express what is in their minds, thus supporting the effectiveness of learning during class discussions. In line with Syafrina et al. (2019) students' understanding of the material will be deeper when the learning process allows discussion both with fellow students and with the teacher. This opinion is the same as Eggen & Don (2012), one way to improve analytical thinking skills in learning activities is to increase curiosity, the ability to ask and reflect from students, thus requiring students to think actively.

Table 11.
Example of Experimental Class Answers on The Specifying Aspect.

Class	Pre-test	Post-tests
Experiment	Motor vehicles continue to grow and the impact on the environment is that air pollution increases and produces CO2 which affects the greenhouse effect which will eventually increase global warming.	If the phenomenon of motor vehicle use continues to increase, the smoke from the exhaust of motorcycles using gasoline can produce pollutant gases such as CO_2 and N_2O. These greenhouse gases can absorb infrared radiation emitted from the Earth's surface, thereby reducing the amount of radiation radiated back into space and increasing the air temperature in the Earth's atmosphere. This is what causes the greenhouse effect, which is one of the factors of global warming.
Control	The impact on the environment is that air pollution increases and produces CO_2 that affects the greenhouse effect which will eventually increase global warming.	The impact on the environment is that air pollution increases and produces CO_2 that affects the greenhouse effect which will eventually increase global warming.

The implementation of the MFI learning model can make students more active in learning, this can be caused because the guidance provided by the teacher to students is very limited so students try to be active and independent to find solutions (Zar, 2018). Following Fitriah et al. (2016) with the MFI model, students are trained to understand something deeply by searching and finding themselves, so that students not only learn to remember but also understand their knowledge. The MFI model applied to the experimental class was able to foster students' ability to learn to control themselves in making and making decisions by using strategies responsibly (Putri et al., 2022).

CONCLUSION

Based on the results of the research conducted, it is found that the application of the MFI learning model influences the analytical thinking ability of students on environmental pollution material. Thus, the MFI model can be used as an alternative for teachers to increase student activeness in constructing knowledge. The MFI model can guide students in developing analytical thinking skills in biological material, especially in the environmental pollution section.

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