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Senior High School Students' Scientific Habits of Mind Profile on Chemical Equilibrium: Case of Health and Environmental Topics

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Abstract

The rapid development of science and technology is a challenge for the era of disruption in the 21st century. These phenomena cannot be separated from the hard work of scientists who have scientific habits of mind (SHOM). Science learning that focuses on SHOM can be indicated by the scientific attitude of students during learning, so the benefits of SHOM are to bring out scientific attitudes in students. In addition, SHOM needs to be taught to students so they can solve problems in a structured and systematic way. This study aims to describe the SHOM profile of high school students on chemical equilibrium with the topic of health and the environment. This research includes quantitative descriptive research. The number of samples from this study was 80 students taken from one of the high schools in Magelang City. The data collection technique in this study was a questionnaire. The data research instrument used was a student questionnaire sheet which was a closed questionnaire with five choices namely SD (Strongly Disagree), D (Disagree), QA (Quite Agree), A (Agree), and SA (Strongly Agree). The number of statements that students have to answer is 25 items with details of 14 statements with positive meaning and 11 statements with negative meaning. Then, the data were analyzed by ideal criteria assessment The results of the research that has been done can be seen that the SHOM profile on chemical equilibrium material is 66.74%. These results indicate that the students' SHOM profile on chemical equilibrium material is classified as fair. So learning modifications are needed such as modification of learning activities, use of learning models and strategies that encourage students to think scientifically, as well as selection of appropriate learning media in order to improve scientific habits of mind.

Keywords: *Chemical equilibrium, Environmental, Health, SHOM*

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INTRODUCTION

One of the challenges of the era of disruption in the 21st century is the rapid development of science and technology in various fields of life (Pratama & Rohaeti, 2023; Pratama *et al.*, 2023). This development cannot be separated from the hard work of scientists who have a habit of mind (HoM). HoM is a dimension of long-term learning outcomes (Marzano, 1994). This opinion is supported by the results of research conducted by Hayat in 2019 which shows that habit of mind will give birth to a number of scientific attitudes and also develop values in them (Hayat *et al*., 2019). Another definition of habit of mind was put forward by Burgess in 2012 which stated that habit of mind is a person's intelligent and effective behavior when facing a problem in learning. Habits of mind can be encouraged and nurtured through appropriate curriculum, pedagogy and assessment in the learning process (Burgess, 2012).

One example of a habit of mind is the scientific habit of mind (SHOM). SHOM is a useful way to characterize the way scientists think (Gauld, 2005; Çalik & Coll, 2012). The main characteristic of learning science which focuses on SHOM can be seen in whether or not there is a scientific attitude in learning. Knowing an idea or theory about science is not enough to be considered successful in understanding science, but there must be motivation to use the idea or theory and apply it in the right way to solve a scientific problem, even one related to technology (Gauld, 1980). Therefore, students must be equipped with SHOM skills in order to survive the challenges of life development (Gauld, 1982). There are seven aspects of SHOM, namely open disclosure, skepticism, rationality, objectivity, distrust of

argument authority, suspension of belief and curiosity (Gauld, 2005).

In the aspect of open disclosure, scientists must have an open mind toward new ideas that may not be in accordance with pre-existing knowledge. The aspect of skepticism in SHOM referring to new ideas must be assessed critically. Therefore, scientists must make a critical and in-depth assessment of what is new. In the rational aspect, scientists must examine rationally where every phenomenon that occurs can definitely be explained using scientific facts. In the aspect of the goal, scientists must be able to stick to the results of their research and must not be influenced by personal opinions or views. The aspect of not easily believing in the authority of an argument can be used as an example of skepticism. Scientists do not consider authority figures to be true figures just because they hold important positions or titles. If a problem is found and there is not enough evidence to make a decision, the scientist will suspend the conviction. Suspension of belief by scientists so that they are not in a hurry and draw conclusions too quickly which can lead to errors in solving a problem. That is what is meant by the aspect of suspension of faith. Whereas in the last aspect studied, the aspect of curiosity can be defined as an interest in seeking novelty, socializing, paying attention to new things or experiences, seeing various things or topics as interesting things, exploring, and trying to find something. Great interest causes scientists to want to fulfill their curiosity about the knowledge that is being explored so that taking action, namely finding out things that are not yet known, will raise the interest of scientists to study harder (Çalik & Coll, 2012; Gauld, 2005; Çalik *et al*., 2014; Prihastoto *et al*., 2019; Noviyanti *et al*., 2021; Wiyarsi *et al*., 2021)

Some of the aspects of SHOM that have been described seem to contradict each other, such as aspects of having an open mind with aspects of skepticism (Wiyarsi & Çalik, 2019). However, this aspect turns out to create HoM interactions that lead to scientific attitudes. For example, these two aspects that seem contradictory if put together can mean that someone who has SHOM abilities will not easily make a decision or conclusion just because someone else has said it, but must be supported by strong and relevant evidence (Wiyarsi & Çalik, 2019).

SHOM as part of the habit of thinking can solve it in learning by way of discussion, debate or case discussing an issue in class (Çalik *et al*., 2014; Zeidler *et al*., 2005). As part of learning, individual SHOM can be assessed. The instruments used to measure SHOM include Likert scales, surveys, and interviews (Çalik at al., 2014; Wiyarsi & Çalik, 2019; Çalik & Karatas, 2019; Coll *et al*., 2009; Steinkuehler & Duncan, 2008). However, it is possible that SHOM is measured using other forms of instruments.

Chemical equilibrium was chosen as the chemical concept discussed in this study because chemical equilibrium is one of the chemical concepts that has many contexts in everyday life (Eny & Wiyarsi, 2019). Another reason is that the concept of chemical equilibrium is often considered a complex and difficult concept to study (Kousathana & Tsaparlis, 2002; Tyson *et al*., 1999). This is thought to be related to the characteristics of this topic which includes defined concepts, abstract concepts, mathematical calculations, and graphs (Tyson *et al*., 1999). These characteristics make students tend to have difficulty understanding concepts and think that the topic of chemical equilibrium has no relation to everyday life (Tyson *et al*., 1999). whereas if explored more deeply, many phenomena or events in everyday life can be developed from the concept of chemical equilibrium. Examples of phenomena or events in everyday life that involve the concept of chemical equilibrium include dental health (tooth enamel), coral reefs, hypoxia, ammonia production, atmospheric pollutant gases, ocean acidity, and cutting vegetables (Eny & Wiyarsi, 2019; Sadhu *et al*., 2019; Fadly *et al*., 2022). In this research, the general topic taken is about health and the environment. Based on this description, the appropriate research question posed for this research is "What is the SHOM profile of high school students on chemical equilibrium material in the field of health and the environment?". So the purpose of this study was to find out the SHOM profile of high school students on chemical equilibrium material in the health and environmental fields.

RESEARCH METHOD

Research Design

This research is descriptive research using a quantitative approach which is done in one of the senior high schools in Magelang City. The subjects of the research are based on the description of the data (Cresswell, 2012). The subject of quantitative research should be in a representative way so that the chosen individual could represent the whole population (Cressweell, 2012). A population is a group of individual who has the same characteristic. The samples of this research are the 80 students of senior high school in Magelang.

Descriptive research aims to give the image of a population characteristic based on the collected data from the samples (Lochmiller & Lester, 2017). In this research, the data were collected from the result of questionnaires given to the students of grade 11^{th} who had the chemical equilibrium materials. The data then were analyzed quantitatively using descriptive statistics by counting the average of the result. It was made in form of a percentage (%) and then described in the form of a table and graphic to help the decision-making.

Data Collection Technique and Instruments

The data collecting technique in this research was using questionnaires. A questionnaire is a written statement used to get information from the participants consists of an individual report or other information they know (Lochmiller & Lester, 2017). The questionnaires were given to 80 students of grade 11th who had been taught about chemical equilibrium materials.

The questionnaire in this study was adapted from research conducted by Calik and Cobern, 2017. The questionnaires used measured seven aspects of scientific habits of mind, namely open-mindedness, skepticism, rationality, objectivity, not easily believing in authority arguments, suspension of belief in curiosity. Total number of statements that must be filled in is 25 statements. The scales used in the questionnaire were the Likert scale with five alternative options. The scales were arranged in the form of a question and followed by the responses in which the level was shown. The response options are SD (Strongly Disagree), D (Disagree), QA (Quite Agree), A (Agree), and SA (Strongly Agree). The scoring of the Likert scale options is based on the character of the question. SA has 5 points, A has 4 points, QA has 3 points, D has 2 points, and SD has 1 point if the statement is positive. There is a value reversal if the statement is negative.

Data Analysis Technique

The data analysis technique used was to determine the chemical literacy ability of senior high school students based on their questionnaire results. The analysis steps done in the research are counting the score collected by the questionnaire calculation, counting the average score of students' chemical literacy ability, and deciding the percentage of chemical literacy ability using ideal assessment criteria (Widoyoko, 2009). The description of the SHOM category is described in Table 1.

Table 1. Category of SHOM

Score Range	Category of Ability
$\bar{X}$> 84%	Excellent (E)
68% < $\bar{X}$≤ 84%	High (H)
52% < $\bar{X}$≤ 68%	Fair (F)
36% < $\bar{X}$≤ 52%	Low (L)
$\bar{X}$≤ 36%	Very Low (VL)

RESULT AND DISCUSSION

The students of grade 11th in one of the senior high schools in Magelang who had been taught the chemical equilibrium were chosen as the participants of the research. At the early of the research, the researchers explained the aims and objectives of this research to the teachers and students. Students who are reluctant to participate in this research are allowed not to fill out the questionnaire. Researchers and teachers promise to always protect the data obtained from this research (including the identities of students) are kept secret and not be used outside of the research interest. After doing the explanation, all students are willing to become respondents. The research results for each aspect of scientific habits of mind are shown in Table 2

Table 2. The result of each aspect of SHOM

Number	Aspect	Percentage
1	Open mindedness (OM)	73.67%
2	Scepticism (SC)	57.50%
3	Rationality (RA)	76.55%
4	Objectivity (OB)	82.87%
5	Mistrust of arguments from authority (MT)	55.69%
6	Suspension of belief (SO)	54.75%
7	Curiosity (CU)	66.16%
	Average	66.74%

The average result of scientific habits of mind is 66.74%. These results indicate that the profile of scientific habits of mind in high school students is still in the fair category. Furthermore, the score data was analyzed using descriptive statistical analysis techniques. Based on the results of the analysis, it is known that the average ability of students in each indicator for each aspect is as follows.

A. Open Mindedness (OM)

The first aspect consists of three statement items matched with the indicator. The indicator used to describe OM's attitude is showing an open-minded attitude by accepting the newest information from research or facts in the field. The explanation of OM's statement is summarized in Table 3.

Table 3. Statements of OM aspects

Number	Statements
1	If the latest scientific research yields evidence that the use of fluoride in toothpaste can cause damage to tooth enamel, then enter sense to consider the use fluoride-free toothpaste.
2	If new evidence is obtained that swimming and diving activities carried out by humans are causing damage to coral reefs, it makes sense to close these swimming and diving tourism destinations.
3	If the facts say that climbers with respiratory disorders are more likely to be exposed to hypoxia, then it makes sense to carry out medical tests before carrying out climbing activities.

The result of the responses from students are described in Figure 1.

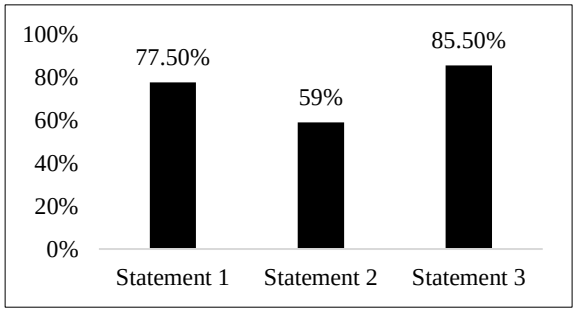

Figure1. SHOM profile in OM aspect

Based on Figure 1. the percentage of statement 1 is 77.50% and is included in high category (H). There was a decrease in yield in statement 2, which was 59%, so it was included in fair category (F). The statement that has the highest result is statement 3 which gets a percentage of 85.50% and is included in the excellent category (E). The average percentage on the OM aspect is 73.67%. From these results it can be shown that students' open-mindedness towards new things in the field of health and the environment is high (H). However, the open-mindedness of students has not been fully matched by the ability to make the right decisions. This is evidenced by the results of statement 2, where statements related to environmental issues are presented that are complex and have negative meanings, but students tend to support these statements. Students are advised to carry out more scientific activities in order to be able to make the right decisions as a result of the open-mindedness they have.

B. Scepticism (SC)

The second aspect consists of three statements developed from two indicator items. The first indicator is showing the attitude of being able to compare the effects of the pros and cons of a phenomenon on a national scale. The second indicator is showing the attitude of being able to compare the effects of the pros and cons of an action. The description of the SC aspect statement items is shown in Table 4.

Table 4. Statements of SC aspects

Number	Statements
1	We need to find out more about the increase in carbon dioxide in the atmosphere that has disrupted the state of the sea by lowering the *p*H so that it has a major impact on the growth of coral reefs in Indonesia.
2	We need to find more information before stating that the Benoa Bay reclamation project in Bali has more benefits in various fields than rejecting the project due to the preservation of coral reefs.
3	We need to look for more scientific evidence before claiming that giving artificial respiration to victims of hypoxia is faster to help victims than the side effects of contracting dangerous diseases from rescuers.

The result of the responses from students are described in Figure 2.

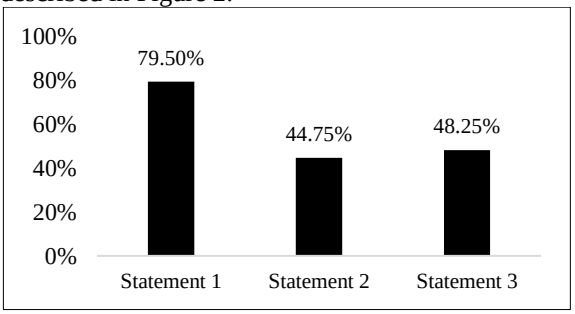

Figure 2. SHOM profile in SC aspect

Based on Figure 2, statement 1 has the highest percentage of 79.50% so it is included in the high category (H). Meanwhile, the other two statements in this category only obtained percentages of 44.75% and 48.25%, so they were included in the low category (L). Based on these results, the level of student's SC is 57.50% and is included in the Fair category (F). These results certainly show that there are still many students who do not show skepticism in addressing scientific problems in the health and environment sector. Providing stimulus to students is highly recommended so that students want to seek the truth of information by connecting it with the understanding of concepts that have been obtained from learning in class.

C. Rationality (RA)

The RA aspect statement were developed from one indicator, namely demonstrating an attitude of using rational reasoning to relate a set of facts on the topic of chemical equilibrium. The description of the RA aspect statement items is shown in Table 5.

Table 5. Statements of RA aspects

Number	Statements
1	Reducing pollution generated by motorized vehicles may be a good way to protect coral reef growth; because pollution directly affects the acidity of the ocean.
2	Accidentally consuming fluoride from toothpaste not only has an impact on tooth enamel damage, but can have an impact on bone health because it inhibits the absorption of calcium by the body.
3	Pressure in the human body plays an important role in the process of transporting and distributing oxyhemoglobin.
4	Mangrove ecosystems can indirectly reduce CO_2 levels in the sea so that it can have a positive impact on the growth of coral reefs.
5	Calcium hydroxyapatite is a tooth enamel-forming compound that can form a chemical equilibrium into calcium ions, phosphate ions and hydroxide ions.

The result of the responses from students are described in Figure 3.

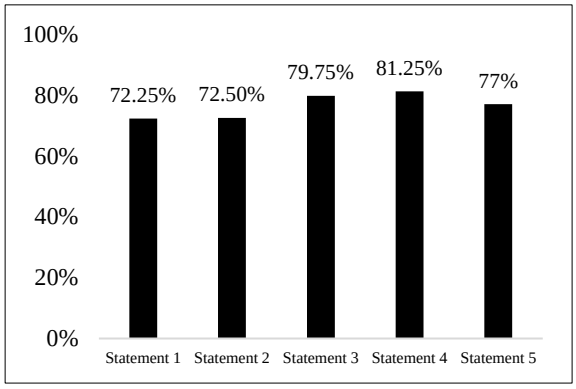

Figure 3. SHOM profile in RA aspect

All results from the RA aspect fall into the high category (H) as shown in Figure 3. Based on these results, it can be concluded that students are able to demonstrate an attitude of using rational reasoning to relate a set of facts on the topic of chemical equilibrium properly.

D. Objectivity (OB)

The OB aspect statement were developed from one indicator, namely demonstrate an objective attitude like that of scientists in solving a problem at hand. The description of the OB aspect statement items is shown in Table 6.

Table 6. Statement of OB aspect

Number	Statements
1	Chemical equilibrium research using the scientific method is research that can be trusted.
2	Researchers must minimize the emotional aspect so that their findings can be trusted by the public.
3	Research variables in chemical equilibrium experiments need to be controlled as much as possible to ensure the influence of the variables we are testing.
4	Researchers must pay attention to temperature when conducting an experiment on chemical equilibrium research.

The result of the responses from students are described in Figure 4.

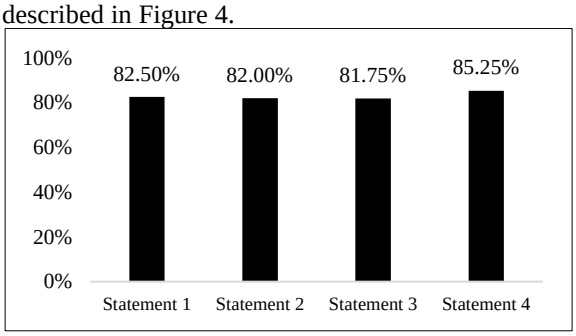

Figure 4. SHOM profile in OB aspect

The OB aspect is the aspect with the highest percentage obtained in this study. Three statements in this aspect are included in the high category (H) with a percentage of 82.50%, 82%, and 81.75%. One statement in this aspect is included in the excellent category (E) with a percentage of 85.25%. This shows that students can be objective like that of scientists in solving a problem they face.

E. Mistrust of arguments from authority (MT)

The fifth aspect consists of four statements matched with the indicator. The indicator used to describe MT's attitude is demonstrates distrust of information provided by those holding positions of authority in Indonesia. The explanation of MT's statement is summarized in Table 7.

Table 7. Statement of MT aspect

Number	Statements
1	The Indonesian Dentists Association should be believed if they say that the fluoride contained in toothpaste can improve dental health.
2	The Ministry of Environment should be credible if they say that global warming will not cause damage to Indonesia's coral reefs.
3	The Ministry of Health should be believed when they say that the higher up a person is in the mountains, the less likely he or she is to experience hypoxia.
4	The Ministry of Communication and Informatics should be trusted if they say that wearing a mask while climbing will increase a person's potential for hypoxia.

The result of the responses from students are described in Figure 5.

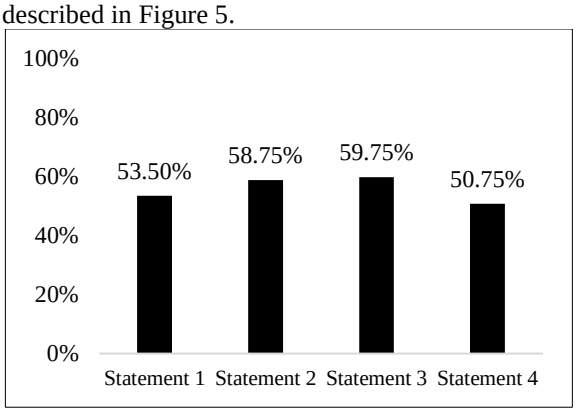

Figure 5. SHOM profile in MT aspect

Based on **Figure 5**, three statements are included in the Fair category (F) with a percentage of 53.5%, 58.75%, 59.75% and one statement is included in the Low category (L) with a percentage of 50.75%. Therefore, the MT aspect has a percentage of 55.69% and is included in the Fair category (F). Students still easily believe the information provided by the holders of positions of authority or certain positions in Indonesia without checking the truth of the information from scientists or research institutions. Students also tend to easily accept incorrect information because they absorb information raw if the information contains the logo of a certain government institution. The active role of the Indonesian government is also needed to eradicate this incorrect information.

F. Suspension of belief (SO)

The three SO aspect statements were developed from one indicator, namely showing caution before presenting arguments on the topic of chemical equilibrium in the environmental and health fields. The results of measuring this aspect are shown in Table 8.

Table 8. Statement of SO aspect

Number	Statements
1	We don't know enough to be certain that greenhouse gas emissions play a significant role in coral reef damage.
2	There is not enough evidence to say that hypoxia occurs when more hemoglobin binds to carbon dioxide to form the compound $HbCO_2$.
3	There's no reason enough to say that drinking sugar-free carbonated drinks can damage tooth enamel.

The result of the responses from students are described in Figure 6.

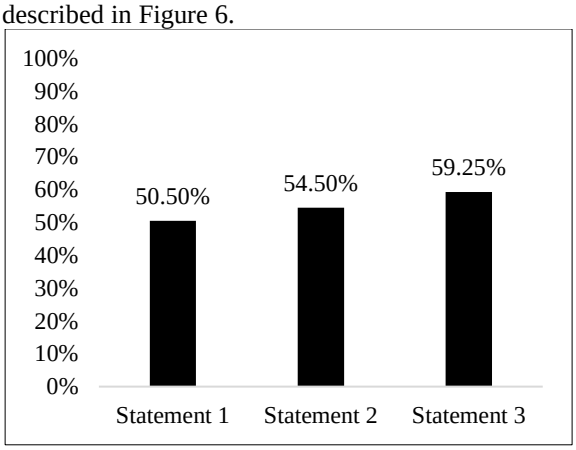

Figure 6. SHOM profile in SO aspect

Based on Figure 6, two statements are included in the Low category (L) with a percentage of 50.50% and 54.50%, and one statement is included in the Fair category (F) with a percentage of 59.35%. Therefore, the SO aspect has a percentage of 54.75% and is included in the Fair category (F). Even though it is included in the Fair category (F), the SO aspect is the aspect that has the lowest percentage in this study. These results mean that students are still lacking in showing caution before presenting arguments on the topic of chemical equilibrium in the environmental and health fields.

G. Curiosity (CU)

Students who have high curiosity will definitely find out the cause of a phenomenon. They seem more active in learning in class. This is what will develop their SHOM. The last aspect in this study is the CU aspect which was developed from three different indicators. One indicator is then developed into one statement item which is described in Table 9.

Table 9. Statement of CU aspect

Number	Statements
1	Hypoxia is a disease phenomenon that has a relationship with the chemical balance that exists in the human body, whereas hypoxemia is not.
2	We can find the concept of chemical equilibrium in cases of damaged and porous tooth enamel due to the influence of the food and drink we consume.
3	Carbon dioxide gas from industrial combustion has an effect on the preservation of coral reefs in the Indonesian seas.

The result of the responses from students are described in Figure 7.

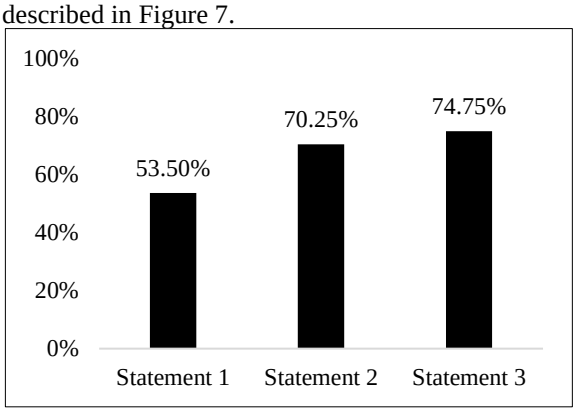

Figure 7. SHOM profile in SO aspect

Based on Figure 7, the first statement is included in the Fair category (F) with a percentage of 53.50% while the other two statements are included in the High (H) category with a percentage of 70.25% and 74.75%, so the SO aspect has a percentage of 66.16% and is included in the Fair category (F). From these results, it can be interpreted that students are quite curious about the relationship between chemical equilibrium and cases in the health and environmental fields. However, this result can be said to be not optimal. The level of curiosity of students must still be increased by linking learning with the phenomena of everyday life, especially in the fields of health and the environment.

If all aspects are reviewed as a whole, the percentage of students' chemical literacy abilities in chemical equilibrium material is 66.74%. The results of this study indicate that the ability of students is in the fair category (F). This indicates that students are not quite familiar with learning activities that use scientific steps and are not yet able to apply the way of thinking like a scientist to solve the problems they face. Therefore, educational modifications are needed, such as modifying learning activities, using models and approaches that encourage students to have scientific thinking habits, and using appropriate media. Through this educational modification, students are

stimulated to be able to build their knowledge and be able to discover the fact that there is a relationship between the phenomena that occur and the subject matter being studied at school.

CONCLUSION

The Scientific Habits of Mind (SHOM) profile of 11th-grade students on chemical equilibrium material in the field of health and the environment at a public high school in Magelang City is in the Fair category (F) with a percentage of 66.74%. Indications from the results of this study are that students are not yet accustomed enough to think scientifically like scientists, so learning modifications are needed such as modification of learning activities, use of learning models and strategies that encourage students to think scientifically, as well as selection of appropriate learning media to improve scientific habits of mind. Further studies for other researchers can use a wider range of research subjects to be able to measure students' SHOM more accurately.

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