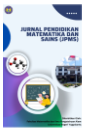

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Developing the Chemical Equilibrium-Scientific Habits of Mind Scale: Validity and Reliability Analysis

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Abstract

One of the challenges of the 21st century disruption era is the fast development of science and technology which was initiated by the hard work of scientists who have habits of mind. Habits of mind can be deepened into scientific habits of mind (SHOM) and encouraged to be used by students at the high school level. This research aims to develop and validate the SHOM questionnaire in chemical equilibrium. Modified 4D becomes an adapted development model. The questionnaire developed has 25 statement items originating from seven aspects of SHOM. Content validity was calculated using the Aiken V equation and involved seven expert judgments with 4 categories of answer choices and produced an average of 0.90, so the questionnaire tested content validity. Construct validity was assessed using the Pearson correlation coefficient with a sample of 300 respondents from seven public high schools. The resulting mean correlation of 0.581 exceeded the r table value of 0.113, thereby satisfying the criteria for construct validity. The reliability of the questionnaire was calculated using Cronbach Alpha and got a mean score of 0.915. The reliability of the questionnaire also was included in the very high category. Based on these findings, the SHOM questionnaire developed can be declared suitable for measuring SHOM for high school students.

Keywords: *Chemical equilibrium, Scientific habits of mind, Reliability, Validity*

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INTRODUCTION

The era of disruption in the 21st century has become a reality that must be faced by the world community (Pratama & Rohaeti, 2023). The effect of this era is the development of educational goals to produce a generation with quality and 21st-century skills (Pratama & Rohaeti, 2024). This aims to enable young people to meet the demands of their future work and life success (Asrizal et al., 2018; Ball et al., 2016). Young people must acquire life skills such as life and career skills, learning and innovation skills, and information media and technology skills (Pratama et al., 2023).

One of the challenges in the era of disruption is the development of science and technology in various fields of life (Pratama et al., 2024). This development cannot be separated from the hard work of scientists' Habits of Mind (HoM) (Pratama et al., 2024). HoM is a person's smart and effective behavior when faced with a problem in learning. HoM encouraged and nurtured the learning process through appropriate curriculum, pedagogy, and assessment (Burgess, 2012).

One part of HoM is Scientific Habits of Mind (SHOM). Griffin, et al. (2012) stated that SHOM is one of the skills that must possess to answer the challenges of the 21st century. Therefore, SHOM needs to be taught to students to solve problems structurally and systematically (Wiyarsi & Çalik, 2019). Marzano (1994) suggests that SHOM is a dimension of long-term learning outcomes. This opinion is supported by the results of research conducted by Hayat et al (2019) which shows that SHOM develops some scientific attitudes. SHOM is useful for characterizing the way scientists think (Gauld, 2005; Çalik & Coll, 2012). Gauld and Hukins (1980) identified the main feature of science learning that emphasizes SHOM we can see in the presence or absence of scientific attitudes in learning. Understanding a scientific idea or theory is not enough for success, we also need the motivation to apply it correctly to solve scientific problems, including those related to technology.

There are seven aspects of SHOM:

- Open-minded. Scientists must be open-minded to new ideas that may not be in line with pre-existing knowledge (Gauld, 2005).

- Skepticism. Scientists must make a critical and in-depth assessment of the new things (Çalik & Coll, 2012).
- Rational which means being rational where every phenomenon that occurs can definitely be explained using scientific facts (Gauld, 2005).
- Objective is the actual situation without being influenced by personal opinions or views (Gauld, 2005).
- Distrust of arguments from authorities can be used as an example of skepticism. Scientists do not regard authority figures as always correct simply because the authority holds an important position or title (Gauld, 2005; Çalik & Coll, 2012).
- Suspension of belief. If a problem is found and there is not enough evidence to make a decision, scientists will suspend belief. Suspension of belief is done by scientists so as not to rush and too quickly draw conclusions that cause errors in solving a problem (Gauld, 2005; Çalik et al., 2014).
- Curiosity. Curiosity is an interest in seeking novelty, openness, paying attention to new things or experiences, seeing various things or topics as interesting things, exploring, and trying to find something (Pratama et al., 2024). A great sense of interest causes scientists to want to fulfill their curiosity and desire for knowledge that is being explored so that taking action, namely finding out things that are not yet known, will arouse scientists' interest in learning more actively (Çalik et al., 2015).

Some of the SHOM aspects seem to contradict each other such as the aspect of having an open mind with the aspect of skepticism (Wiyarsi & Çalik, 2019). However, these aspects create HoM interactions. For example, two aspects that seem contradictory to each other if put together can mean that someone who has SHOM ability will not easily make decisions, but must be supported by strong and relevant evidence. (Wiyarsi & Çalik, 2019). The end of the HoM interaction can produce to many scientific attitudes (Gauld, 2005). In addition, there is a positive relationship between SHOM and one's chemical literacy skills (Wiyarsi et al., 2021).

Although SHOM can produce to scientific attitudes, in reality not many students have SHOM. When the teacher presents chemistry material in class, many students are indifferent to the explanation from the teacher. As a result, many students are less interested in participating in learning, feel bored, and are not motivated to improve their learning achievement (Pratama et al., 2024). This is exacerbated by the many perceptions of students who think that chemistry is one of the most difficult subjects because it is abstract and complex (Yakmaci-Guzel, 2013). The difficulty of learning chemistry is caused by the student's misleading concept of connecting the implementation of the chemistry concept with daily life. (Quílez, 2019).

SHOM should be trainable and measured using appropriate instruments. Çalık & Cobern (2017) have developed a SHOM scale containing 32 items with four answer choices. However, the SHOM scale measures the Common Knowledge Construction Model of undergraduate students in chemistry courses. Some SHOM scale items are also adapted to the characteristics and culture of Turkey. Another article shows the development of the SHOM scale with characteristics and culture in Indonesia, but it is still aimed at students (Wiyarsi et al., 2023). The SHOM scale that has been developed if tested on students at a lower level will cause measurement inaccuracies. This is because SHOM can develop according to one's level of education. A study of SHOM differences based on education levels has been conducted by observing SHOM differences between graduate students and undergraduate students (Alfiana & Wiyarsi, 2023).

Therefore, SHOM measurement instruments that used in high school students need to be developed. In addition, the instrument developed must meet its validity and reliability. To be more accurate, the instrument developed is specific to one chemical material. The author took the topic of chemical equilibrium because the characteristics of chemical equilibrium are abstract and complex but many are found to be relevant in everyday life (Belayneh & Belachew, 2024; Pratama & Rohaeti, 2024). Therefore, chemical equilibrium material can be one of the materials that can affect students' SHOM. Based on the description above, the purpose of this study is to develop a valid and reliable SHOM scale on chemical equilibrium material.

RESEARCH METHOD

Research Framework

This research is a type of development research with a quantitative approach. This instrument development research uses the 4-D model developed by Thiagarajan, Semmel, and Semmel (1974). In this study, the SHOM assessment instrument was developed in three stages as follows:

Define

The first stage in developing a SHOM assessment instrument is "defining". The first thing to do is to analyze the characteristics of students following the SHOM assessment instrument development design related to chemical equilibrium material and indicators that will be used to achieve learning objectives. The second is to analyze the front end based on previously developed assessment literature. Third, concept analysis is carried out to identify the subject matter to be used. The fourth is task analysis to identify SHOM indicators to be achieved.

Design

The second stage in the development of the SHOM assessment instrument was to design and construct the statement items. The first part includes describing the SHOM indicators, designing the initial questionnaire, and the conversion rubric for scoring. The second part is about statement writing. All statements were written in Bahasa Indonesia.

Development

The third stage is to develop a SHOM assessment instrument which is completed with a review by expert judgment. The content validity of the questions was determined by presenting them to 7 expert judgement who are chemistry education lecturers from 2 leading educational universities in Indonesia. The expert judgment was selected based on their experience in education, knowledge of chemical equilibrium materials, and knowledge of research. Expert Judgement will be asked to review each statement item based on the criteria of statement item substance, statement item information construct, and statement item language according to correct Indonesian grammar rules. Expert Judgement is also asked to provide feedback, comments, or revisions that are used for item refinement. The initial product results from the review will be used in the implementation of the trial.

After combining all expert comments, the instrument trial was conducted with a group of students who had studied chemical equilibrium material before. The purpose of the paper-pencil administration was to test the construct validity and reliability of the questionnaire. Before the paper-pencil administration, learners were given verbal instructions on the purpose of the questionnaire, how to answer, and a request to complete the questionnaire with seriousness and caution.

Research Participants

300 students in the 12th grade were randomly selected from several senior high schools in Magelang City. The same characteristics of this student are in the age range of 16–18 years old and having previously studied chemical equilibrium material.

Research Instrument

The research instrument used was the SHOM questionnaire. The questionnaire in this study was adapted from research conducted by Çalik and Cobern (2017). The questionnaires measured seven aspects of scientific habits of mind: open-mindedness, skepticism, rationality, objectivity, not easily believing in authority arguments, and suspension of belief in curiosity. Total number of statements that must be filled in is 25 statements. The scale used in the questionnaire was 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. The final version of the questionnaire is shown in the Appendix.

The initial version of the SHOM assessment instrument was assessed by seven expert judgments using the Delphi technique. From the assessment sheet, assessment data and suggestions or revisions for further instrument development are obtained. The assessment data that has been obtained is then analyzed using Aiken V, while the suggestion or revision data is taken into consideration for revising the instrument. After the SHOM instrument was revised, a trial of the instrument was carried out to obtain empirical validity and reliability. The Pearson Correlation Coefficient (PCC) equation is used to obtain empirical validity, while the Cronbach's Alpha equation is used to obtain the reliability of the SHOM instrument. There are guidelines for determining reliability criteria, namely if it is below 0.20 it is considered very low, in the range 0.21 to 0.40 is considered low, 0.41 to 0.60 is considered medium, 0.61 to 0.80 is considered high, and above 0.81 is included in the very high category (Nunnaly, 1967). To process and analyze the data obtained, researchers used the help of the SPSS version 25 application.

RESULT AND DISCUSSION

Content Validity

The SHOM questionnaire that had been assessed by expert judgment was analyzed using Aiken V calculations. The expert judgment responses revealed that the SHOM questionnaire that had been developed had very good scores in every item. The results of the Aiken V calculation are shown in Table 1.

Table 1. Content validity result

Item Number	Aiken V Value	Decision	Item Number	Aiken V Value	Decision	Item Number	Aiken V Value	Decision
1	0.90	Valid	11	0.90	Valid	21	0.90	Valid
2	0.90	Valid	12	0.90	Valid	22	0.90	Valid
3	0.90	Valid	13	0.90	Valid	23	0.90	Valid

Item Number	Aiken V Value	Decision	Item Number	Aiken V Value	Decision	Item Number	Aiken V Value	Decision
4	0.90	Valid	14	0.90	Valid	23	0.90	Valid
5	0.90	Valid	15	0.90	Valid	25	0.90	Valid
6	0.90	Valid	16	0.90	Valid			
7	0.90	Valid	17	0.90	Valid			
8	0.90	Valid	18	0.90	Valid			
9	0.90	Valid	19	0.90	Valid			
10	0.90	Valid	20	0.90	Valid			

Based on Table 1, all statement items in the SHOM questionnaire received an Aiken V Value of 0.90, so the average content validity score for the questionnaire was 0.90. These results indicate that the SHOM questionnaire developed meets the content validity criteria and teste on students to obtain construct validity and reliability results.

Construct Validity

The function of calculating construct validity is to state the extent to which the questionnaire that has been developed is valid for measuring students' SHOM. The construct validity of the SHOM questionnaire is calculated using the Pearson correlation coefficient (PCC). The results of the PCC calculation for the SHOM questionnaire are shown in Table 2.

Table 2. Construct validity results

Item Number	*Pearson Correlation*	R table	Decision	Item Number	*Pearson Correlation*	R table	Decision
1	0.538	0.113	Valid	16	0.610	0.113	Valid
2	0.575	0.113	Valid	17	0.581	0.113	Valid
3	0.619	0.113	Valid	18	0.564	0.113	Valid
4	0.625	0.113	Valid	19	0.583	0.113	Valid
5	0.573	0.113	Valid	20	0.601	0.113	Valid
6	0.119	0.113	Valid	21	0.604	0.113	Valid
7	0.586	0.113	Valid	22	0.533	0.113	Valid
8	0.598	0.113	Valid	23	0.589	0.113	Valid
9	0.632	0.113	Valid	24	0.609	0.113	Valid
10	0.696	0.113	Valid	25	0.458	0.113	Valid
11	0.666	0.113	Valid				
12	0.677	0.113	Valid				
13	0.742	0.113	Valid				
14	0.584	0.113	Valid				
15	0.568	0.113	Valid				

Based on Table 2, all PCC calculation results are above the minimum r table limit of 0.113. Based on these findings, we can conclude that all the items in the SHOM questionnaire that were developed are included in the valid category and there are no items that have been excluded.

Reliability

Apart from validity, reliability is also an important thing that must be known when developing an instrument. Reliability is used to determine the consistency of the SHOM questionnaire in measuring SHOM. Reliability measurement in this research uses Cronbach's Alpha equation. The results of the reliability calculations are seen in Table 3.

Table 3. Reliability result

Item Number	Cronbach Alpha	Decision	Item Number	Cronbach Alpha	Decision
1	0.912	Very High	16	0.911	Very High
2	0.912	Very High	17	0.912	Very High
3	0.911	Very High	18	0.912	Very High

Item Number	Cronbach Alpha	Decision	Item Number	Cronbach Alpha	Decision
4	0.911	Very High	19	0.912	Very High
5	0.912	Very High	20	0.911	Very High
6	0.918	Very High	21	0.911	Very High
7	0.912	Very High	22	0.912	Very High
8	0.913	Very High	23	0.912	Very High
9	0.911	Very High	24	0.911	Very High
10	0.909	Very High	25	0.914	Very High
11	0.910	Very High			
12	0.910	Very High			
13	0.908	Very High			
14	0.911	Very High			
15	0.912	Very High			

The Cronbach's Alpha calculation results for the SHOM questionnaire are 0.915. From these results, we can conclude that all the SHOM questionnaire statement items developed have very high reliability and it is can use to in further research.

Discussion

The development of SHOM measurement instruments is carried out in 3 stages, namely define, design, and development. At the define stage, it means that the characteristics of students who are in accordance with the SHOM scale development design related to chemical equilibrium material are in grade 11 at the senior high school unit level and have studied chemical equilibrium material which includes definitions, basic concepts, factors that affect chemical equilibrium shifts, and the role of chemical equilibrium in everyday life. Analyze the indicators used to achieve the learning objectives by consulting with the chemistry teacher who teaches the class.

At the design stage, the SHOM scale grid was developed from the 7 aspects of SHOM proposed by Gauld (2005). Chemical equilibrium content is included in each indicator item. Furthermore, a conversion table that can convert answers in the form of qualitative data into quantitative data is prepared. Based on the lattice and conversion table, the author can write the SHOM questionnaire as a whole and systematically.

The development stage contains validity and reliability tests of the developed SHOM questionnaire. The questionnaire was submitted to expert judgment to assess its content validity. Based on Table 1. All questionnaire items showed an Aiken V value of 0.90 and were declared valid. The Aiken validity index used to determine the agreement of the expert judgment (Retnawati, 2016). In addition to quantitative data, the authors also obtained some suggestions and input on the development of the SHOM scale such as (1) Correcting errors in writing words that are not standardized or less effective; (2) Paying attention to the effectiveness of each statement item; and (3) Revising statement items that have the potential for ambiguity.

Next, the author tested the construct validity and reliability of the revised SHOM questionnaire by testing it with 300 grade 12 students attending public high schools in Magelang City. The 300 students came from all public high schools in Magelang city. Construct validity was analyzed using the Pearson Correlation Coefficient.

The results of construct validity state that all statement items in the SHOM questionnaire have an R-value that is more than the R table value. The smallest R-value obtained is 0.119 on statement item 6 and the largest R-value is 0.742 on statement item number 13. Therefore, the SHOM questionnaire developed has met the construct validity and is declared valid in measuring the SHOM of high school students.

After testing the construct validity, SHOM questionnaire reliability was tested using Cronbach Alpha. The results of the Cronbach Alpha test state that all statement items have an alpha value of more than 0.9 with an average of 0.915. When looking at the category classification according to Nunnally & Bernstein (1994), this value is in the very high category. Therefore, the SHOM questionnaire developed is declared reliable and trustworthy in measuring SHOM in each experiment.

CONCLUSION

This study confirms that the SHOM scale on chemical equilibrium material that has been developed has relatively high validity and reliability values. The average content validation result is 0.90, the average construct validation result is 0.581, and the average reliability using Cronbach's Alpha measurement averages is 0.915. Thus, the SHOM questionnaire that has been developed can measure the scientific thinking habits of high school students in future research. If used in research that has the aim of improving SHOM, certain learning models and methods may play a role in changing students' SHOM.

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