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## Rasch Model for Analysis of Scientific Attitude Instruments in the Context of Secondary School Science Education

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**ABSTRACT**

*This study aims to analyze the psychometric quality of a scientific attitude questionnaire instrument for secondary school students using the Rasch Model. The instrument, developed based on Harlen's theory, includes four key dimensions: curiosity, respect for data, critical thinking, and open-mindedness/cooperation. A survey method was employed with 30 seventh-grade students in Bandung City as respondents. Data were collected through a four-point Likert scale questionnaire and analyzed using Winsteps 4.6.0 software. The Results revealed that 16 out of 23 items fit the model based on Outfit Mean Square, Z-Standard, and Point-Measure Correlation indicators. The instrument also demonstrated high overall validity and reliability, with an Outfit MNSQ of 1.00, ZSTD of -0.17, an item separation index of 2.91, and a reliability coefficient of 0.89, indicating good discrimination and stable measurement structure. In conclusion, the scientific attitude instrument exhibits strong psychometric properties and can serve as a valid tool for assessing student attitudes in science education. However, revisions are needed for seven misfitting items to enhance clarity and construct alignment. Further validation on broader populations is recommended to ensure generalizability.*

## INTRODUCTION

Natural Science learning is designed not only to instill scientific concepts, but also to shape ways of thinking and behaving that reflect the character of a scientist. The learning process includes observation, experimentation, drawing conclusions, and formulating theories, which provide students with direct experience in understanding nature scientifically (Widiyatmoko, 2023). Through this experience, students not only learn to understand facts, but also develop scientific attitudes such as curiosity, openness to data, and objectivity in thinking. These three aspects are important foundations in authentic scientific practice, because they can encourage students to actively ask questions, evaluate information, and engage in problem solving (Berkmans & Renuka, 2024).

The scientific character that is to be formed through science learning often faces challenges, especially when the approach used is still oriented towards memorizing concepts. Without a connection to concrete experiences and everyday life, students tend to have difficulty internalizing scientific values (Carleial & Soares, 2022; Jokic, 2024). Therefore, science learning needs to be aligned with a curriculum approach that emphasizes character building and 21st-century competencies. The Merdeka Curriculum, for example, through the Pancasila Student Profile, encourages integration between science learning and strengthening contextual character values (Durasa & Suastra, 2024). This integration has been shown to increase student engagement and overall learning outcomes (Fauzan et al., 2023).

Optimal scientific attitude formation requires measuring instruments that can provide an accurate picture of the development of these characters in students. The instruments developed must be able to reveal important aspects such as curiosity, critical thinking, and openness to new ideas in the context of science learning (Shinta & Rosana, 2017). Schools that have valid and reliable instruments are better able to measure scientific attitude achievements objectively, so that the evaluation results can be used to develop learning programs (Gading & Rohaeti, 2024). Unfortunately, many instruments used in education, especially in the form of questionnaires, have not gone through an adequate validation process. When the quality of the instrument is low, the resulting data becomes inaccurate and can even be misleading (Ramadhan et al., 2024).

The use of questionnaires without valid statistical tests raises doubts about the validity of research findings and educational evaluations. Many teachers and researchers rely on instruments that have not been psychometrically analyzed, even though instrument validation is an important stage in educational research (Hu & Xu, 2024). This process is not just a formality, but an essential step to ensure that the measurement results truly reflect the conditions that are to be known (DeCoster et al., 2024). Validated instruments can provide a strong basis for designing learning interventions and data-based educational policies.

Classical approaches such as classical test theory (CTT), including the use of Cronbach's Alpha, are still widely used in instrument testing. This method is indeed useful in assessing the internal consistency of a questionnaire (Wong Shao Yun et al., 2023; Malapane & Ndlovu, 2024). However, internal reliability alone is not enough to ensure the overall quality of the test items. CTT does not consider the unique information of each item, such as the level of difficulty and item discrimination, in depth (Ventura-León & Peña-Calero, 2020). As a result, the overall quality of the test becomes less accurate in reflecting the variation in student abilities (Ciptari et al., 2024).

Another difficulty arises when the instrument is unable to accommodate differences in test taker abilities. An item that is very easy for most students or too difficult for others does not provide optimal information in the assessment (Davier, 2024). Instruments that are not adaptive to respondent diversity tend to fail to map scientific abilities accurately. This situation indicates the need for a more robust and flexible approach to evaluating instrument quality, especially on an item-by-item basis.

The Rasch model is a promising solution in assessing instrument quality as a whole. This model is able to provide detailed information regarding the suitability of items and respondents, their respective reliability, and ensure the unidimensionality of the construct being measured (Yim et al., 2024; Rahman et al., 2023). Previous studies have shown that Rasch produces high reliability indices, both on the item and respondent sides, reflecting the stability and reliability of the instrument (Loh et al., 2022). In addition, the Rasch Model is able to identify items that do not conform to theoretical constructs through analysis of response patterns and fit statistics (Elfira et al., 2024).

Another advantage lies in the use of a logit scale that allows measurement results to be on an interval scale. This scale provides certainty that differences between scores have the same meaning across the range of values, thus strengthening the quality of further analysis (Suryani, 2018; Burevtsev et al., 2020). In practice, the Rasch Model is able to distinguish student abilities with a high level of precision, making measurements more objective and valid than conventional approaches (Darmana et al., 2021). This capability makes Rasch increasingly used in educational research because it is probabilistic and provides fair measurements (Khine, 2020).

This study aims to analyze the quality of secondary school students' scientific attitude instruments using the Rasch Model approach. The evaluation was conducted in the context of science learning, which is relevant to the citizen science approach, namely student involvement in real scientific practices to improve motivation and scientific communication skills (Lüsse et al., 2022). The results of the study are expected to provide real contributions in the form of psychometrically tested instruments that can be used by teachers, researchers, and science education policy makers. In addition, the existence of this instrument will strengthen data-based evaluation practices, enrich understanding of student achievement, and support a more accurate decision-making process in the school environment.

## METHOD

### Research Design

This study uses a quantitative approach with a survey type, which aims to develop and test a scientific attitude questionnaire instrument on students. The quantitative approach was chosen because it provides the possibility to measure variables systematically and objectively through a measuring instrument in the form of a questionnaire. The survey design provides a comprehensive picture of students' scientific attitude tendencies based on data obtained from the questionnaire.

Data analysis in this study was carried out using the Item Response Theory (IRT) approach, especially the Rasch Model, which allows researchers to review the extent to which each statement item on the questionnaire functions in measuring scientific attitudes. The Rasch Model is considered appropriate because it is able to explain the relationship between respondents' latent abilities and the level of item difficulty, as well as providing detailed information about the validity and reliability of the instrument (Fajrianti et al., 2016).

### Research Subjects

The questionnaire trial was conducted on 30 seventh-grade students from one of the Secondary schools in Bandung City. Students were selected purposively, namely based on the consideration that they had received basic science learning that was relevant to the scientific attitude indicators to be measured. The data collection process was carried out directly in class using questionnaire paper.

Before the implementation, students were given a brief explanation of the purpose of the study, the importance of answering honestly, and a guarantee that the data collected was anonymous and used only for academic purposes. This step was taken to ensure that respondents felt safe and understood the purpose of the activity (Ilfiandra et al., 2022).

### Instrument Development and Validation

The scientific attitude questionnaire in this study was developed based on the theory of Harlen (2018), which divides scientific attitudes into four main aspects: curiosity, respect for facts/data, critical thinking skills, and openness and cooperation. These four aspects are translated into 23 specific indicators, as listed in Table 1.

The statements in the questionnaire were designed in positive and negative forms using a four-point Likert scale, consisting of: strongly disagree (1), disagree (2), agree (3), and strongly agree (4). The four-point scale was chosen to encourage students to provide firm responses without a neutral option, so that the results obtained are clearer and can be analyzed properly (Heiberger & Holland, 2015).

**Table 1.** Statements of Scientific Attitudes Questionnaire Based on Harlen's Dimensions (2018)

No.	Dimension	Statement
1	Curiosity	During the citizen science project, I asked the teacher about things I wanted to know. (A1) The internet is my tool to learn about scientific phenomena I want to know. (A2) During the citizen science project, I did not ask the teacher even though there was something I wanted to know. (A3) I observed the weather very carefully. (A4) I was not serious when conducting weather observations. (A5) Although it took quite a long time, I still carried out the investigation earnestly. (A6) I did not conduct the investigation thoroughly because it required a long time. (A7)
2	Respect for data/facts	I altered the weather investigation data to obtain conclusions that match scientific concepts. (B1) I checked the facts first before taking action. (B2) I acted based on facts and opinions from people who are not experts. (B3) I compared my weather investigation data with that of others to verify inconsistent parts. (B4)
3	Critical thinking	If a friend presented conclusions from their investigation, I accepted it without question. (C1) I repeated the weather measurements to obtain accurate data. (C2) When conducting the investigation, I reflected on whether the data obtained was accurate or not. (C3)
4	Open-mindedness and cooperation	During discussion, I considered others' opinions. (D1) I only wanted my own opinion to be accepted by the group. (D2) If the data is lacking, I will redo the investigation. (D3) I insisted on my opinion even though it lacked scientific evidence. (D4) I accepted feedback from peers during investigation, even if it did not match my expectations. (D5) I admitted my own mistakes during the investigation process. (D6) I believed everything I did in the investigation was correct. (D7) I helped group members carry out the weather investigation. (D8) I didn't share anything with group members during the investigation. (D9)

Before being used for data collection, the questionnaire went through a content validation stage. Two experts in the field of science education and instrument evaluation were asked to provide an assessment of the clarity, suitability, and measurability of the statement items with the targeted indicators. The results of this validation became the basis for refining the content and wording of the items in the questionnaire to suit the context of learning at the secondary school level.

### Data Analysis Techniques

The questionnaire data were analyzed using Winsteps software version 4.6.0 through the Rasch Model approach. This analysis provided in-depth information regarding the quality of the items and students' responses. Several aspects were examined, including the item fit to the model, the reliability and separation indices of items. By employing the Rasch approach, the instrument was evaluated not only

based on descriptive statistics but also on its precision in accurately measuring the construct of scientific attitudes (Wibisono, 2016).

## RESULTS AND DISCUSSIONS

### Item Fit

Based on the results of the analysis using the Rasch model, the evaluation of the feasibility of 23 items was carried out by considering three main indicators: Outfit Mean Square (MNSQ), Z-standard (ZSTD), and Point-Measure Correlation (Pt Measure Corr). An item is said to fit the model if it meets at least two of the following three criteria: the MNSQ value is in the range of 0.5–1.5, ZSTD between –2.0 to +2.0, and item correlation (Pt Measure Corr) between 0.4–0.85 (Sumintono & Widhiarso, 2015). Item Fit obtained from the Rasch model analysis can be seen in Table 2.

**Table 2.** Results of item fit analysis based on the Rasch model

Item	JMLE Measure	Outfit MNSQ	ZSTD	Pt Measure Corr	Category
C1	2.39	0.84	-0.70	-0.18	Fit
D7	1.59	0.66	-1.66	0.09	Fit
B4	1.34	1.37	1.47	0.43	Fit
<b>B1</b>	1.14	<b>1.88</b>	<b>2.89</b>	<b>0.25</b>	Misfit
B3	0.94	1.08	0.39	0.40	Fit
D5	0.87	0.46	-2.54	0.48	Fit
<b>C2</b>	0.35	<b>1.68</b>	<b>2.17</b>	<b>0.24</b>	Misfit
D3	0.27	0.90	-0.29	0.20	Fit
<b>A3</b>	0.11	0.42	<b>-2.70</b>	<b>0.20</b>	Misfit
D4	0.11	1.38	1.35	0.24	Fit
<b>D1</b>	0.02	<b>1.62</b>	<b>2.05</b>	<b>0.19</b>	Misfit
D2	0.02	1.29	1.07	0.71	Fit
<b>A1</b>	-0.24	<b>0.37</b>	<b>-3.17</b>	<b>0.33</b>	Misfit
<b>A4</b>	-0.51	<b>0.49</b>	<b>-2.45</b>	0.40	Misfit
A5	-0.60	0.95	-0.10	0.45	Fit
<b>D6</b>	-0.60	<b>1.59</b>	<b>2.12</b>	<b>0.34</b>	Misfit
D8	-0.60	1.26	1.06	0.48	Fit
B2	-0.80	0.81	-0.78	0.32	Fit
A7	-0.90	0.84	-0.64	0.36	Fit
A2	-1.00	0.76	-1.06	0.21	Fit
A6	-1.22	0.82	-0.73	0.26	Fit
D9	-1.22	0.90	-0.36	0.35	Fit
C3	-1.45	0.70	-1.34	0.52	Fit

Based on the results shown in Table 2, the items are arranged from the most difficult to the easiest based on the measure value. Item C1 has the highest measure value of 2.39 logit, indicating that this item is the most difficult statement, only agreed or answered correctly by students with the highest ability level. Conversely, item C3 with a measure of -1.45 logit is the easiest item, because even students with low abilities tend to be able to answer or agree with it.

Table 2 also shows that 16 items are declared fit to the Rasch model because they meet at least two of the three criteria. These items show that they function consistently and relevantly in measuring students' scientific attitude constructs. For example, item C3 shows an Outfit MNSQ value of 0.70, ZSTD of 1.34, and Pt Measure Corr of 0.52, all of which are within the acceptable range so that they can be said to be very stable statistically.

However, there are 7 items that are declared misfit to the model, namely items A1, A3, A4, B1, C2, D1, and D6. Item A3, for example, has an Outfit ZSTD value of -2.70 and a Pt Measure Corr of 0.20, both of which exceed the tolerance limit. This indicates that the item behaves inconsistently with

the model, and may contain ambiguity of meaning or be irrelevant to the construct being measured. Items A1, B1, C2, D1 and D6 even fail all three criteria, so they must be revised or eliminated from the instrument.

These results indicate that although most of the items are in accordance with the Rasch model, there are still some items that need further attention. The mismatch in items such as B1 and C2 could be caused by ambiguous sentence formulation, statements that are too normative, or a lack of relevance to students' concrete experiences in scientific activities. Students tend to give unstable responses to items that are too abstract or idealistic, because they answer based on personal moral perceptions (Wang & Ziano, 2023), not based on real experiences. Reño (2024) stated that items with low Pt Measure Corr values tend to be unable to distinguish between students with high and low scientific attitudes.

Interestingly, some items that are classified as difficult based on the measure value are actually included in the fit group, such as C1 and D7. This shows that even though the item requires a high level of scientific ability or attitude, students are still able to respond to it consistently. This can be interpreted that the scientific attitude construct in some students has developed sufficiently. This phenomenon supports the findings of Muaziyah et al., (2023) which states that secondary school students who are often involved in scientific discussion activities show higher consistency in answering statements that require an in-depth understanding of scientific methods.

Thus, the revision process needs to be focused on items that show inconsistencies based on fit indicators. Revisions can be in the form of simplifying the wording, changing the context to make it more relevant to the student's experience, or deleting items if the improvements do not improve their statistical quality. It is also important to carry out further content validation through discussions with experts or qualitative trials so that the revisions made maintain the theoretical meaning of the scientific attitude construct itself.

### Instrument Analysis

To obtain a comprehensive picture of the quality of the instrument, an analysis of all statement items was conducted using the summary output of the Rasch model shown in Figure 1. This analysis aims to assess how the instrument performs in measuring the scientific attitude construct in general, not just at the per-item level. Several important indicators used in the interpretation of these results include the Outfit Mean Square (MNSQ) and Z-Standard (ZSTD) values in the Mean column, as well as the Separation and Reliability indices in the Real RMSE section. These indicators provide information about the accuracy, consistency, and discriminatory power of the instrument as a whole.

	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT		OUTFIT	
					MNSQ	ZSTD	MNSQ	ZSTD
MEAN	91.1	30.0	.00	.29	.99	-.22	1.00	-.17
SEM	2.7	.0	.21	.01	.09	.36	.09	.36
P.SD	12.5	.0	.98	.03	.42	1.69	.42	1.68
S.SD	12.8	.0	1.00	.03	.43	1.73	.43	1.72
MAX.	107.0	30.0	2.39	.35	1.83	2.82	1.88	2.89
MIN.	57.0	30.0	-1.45	.25	.35	-3.24	.37	-3.17
REAL RMSE	.32	TRUE SD	.93	SEPARATION	2.91	ITEM	RELIABILITY	.89
MODEL RMSE	.30	TRUE SD	.93	SEPARATION	3.16	ITEM	RELIABILITY	.91
S.E. OF ITEM MEAN = .21								

Fig 1. Results of Instrument Validity and Reliability

Based on Figure 1, the Outfit MNSQ value in the Mean column is 1.00, and ZSTD is -0.17. Both of these values are within the recommended range for Rasch model analysis, which is between 0.5 to 1.5 for MNSQ and -2.0 to +2.0 for ZSTD (Sumintono & Widhiarso, 2015; Boone et al., 2014). This indicates that in general, the pattern of student responses to all items in the instrument is consistent and does not show any significant deviation from the Rasch model expectations. Thus, there is no general tendency for students to answer these items randomly or inconsistently. Furthermore, the Item

Separation value of 2.91 indicates that the statement items in the instrument are able to group students into more than five different ability strata. A separation value greater than 2.0 indicates a good level of discrimination, meaning that the items in this instrument are not only suitable for students with average ability levels but are also able to effectively distinguish students with low and high scientific attitudes (Fitrah et al., 2024).

Meanwhile, item reliability reached a value of 0.89, which reflects the high consistency of the item difficulty level estimate. In the context of Rasch-based psychometric measurement, reliability with a score of 0.89 is considered high (Lohgheswary et al., 2022). This means that if this measurement is repeated on an equivalent group of students, the arrangement of item difficulty levels will remain consistent. This high reliability is an important indicator that the measurement structure in the instrument is stable (Kaul et al., 2025).

This finding is in line with research conducted by Fitrah et al. (2024), which emphasized that high reliability and separation index reflect good item construction quality and strong representation of the construct being measured. Thus, the scientific attitude instrument in this study can be considered to have solid structural validity, as well as adequate psychometric performance to measure the scientific attitudes of secondary school students accurately and meaningfully.

## CONCLUSION AND SUGGESTION

Based on the results of the overall item and instrument analysis using the Rasch model, it can be concluded that this student scientific attitude instrument has quite good quality in terms of validity and reliability. Most of the items (16 out of 23) were declared fit to the model because they met at least two of the three main indicators (Outfit MNSQ, ZSTD, and Pt Measure Corr), which indicates that the items work consistently and are able to represent the scientific attitude construct well. The overall analysis also indicates that the instrument has a stable student response pattern (MNSQ = 1.00, ZSTD = -0.17), high discriminatory ability (Item Separation = 2.91), and strong reliability (0.89). This shows that structurally, this instrument is able to group students based on the level of scientific attitude accurately, and can be used in the assessment or research of science education at the secondary school level.

However, there are still seven items that do not fit the Rasch model (A1, A3, A4, B1, C2, D1, and D6), so they need to be reviewed. Revisions to these items can be done by simplifying the wording, adjusting the context to be more relevant to students' concrete experiences, or even eliminating items if the improvements do not improve statistical quality. Further validation is also needed, either through expert review or qualitative approaches, to maintain the theoretical meaning of the scientific attitude construct. This instrument has great potential to be used in various contexts of science learning evaluation, but it is still recommended to be retested on a wider population to ensure consistency of its performance.

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