Using Rasch Model Analysis to Analyze Students' Scientific Literacy on Heat and Temperature

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Abstract. This research to investigate the scientific literacy ability of the eleventh-year students in the topic of heat and temperature by using Rasch model analysis. This was a case study research by applying a post-test only group research design. The samples of the research were 31 students consisting of 11 male students and 20 female students. Multiple choice test consisting of 25 items were used in this research. The test items were adapted from the PISA framework constructed (r= 0.82). The result of analysis by using the Rasch model in form of Wright map display where the students 10P had high ability rate and students 04L, 07P, and 16L with the response pattern considered unfit. The MNSQ outfit value accepted was out of the limit. Generally, the percentage of students' scientific literacy ability in the three competencies was categorized low.

Keywords: Rasch Model Analysis, Scientific Literacy, Heat and Temperature

1 Introduction

Rasch model has a probability principle for every option in the classic theory test e.g. [1-2]. Analysis by using the Rasch model needs the use of an application as the processing software which is winstep 3.7 version. Winstep is software mostly used to help people in processing the Rasch model especially in education assessment, behavior survey, and assessment scale analysis. **Figure 1** is menu bar visual on Winstep. The model is the logit-linear model. The model of Rasch operated in winstep is as the following form.

The dichotomus model:
loge(Pni1 / Pni0) = Bn – Di

The polytomous "Rating Scale" model:
Log(Pnij/ Pni(j-1) = Bn –Di – Fj

The polythomus 'Partial Credit" model:
Log(Pnij/ Pni(j-1)) = Bn – Di – Fij = Bn – Dij

The polythomus "Grouped response-structure"model:
log(Pnij/ Pni(j-1)) = Bn – Dig – Fgj

Known that:
Pnij is the person probability *n* and the item of *i* was observed in the category of *j*,

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Bn is "the ability" of person measurement *n*.

Di is the measurement "level of quality" item *i*, where there is a probability of being similar in the highest and the lowest category item.

Fj is the "calibration" category of *j* to the category of *j-1*, where the category *j-1* and *j* have the same relativity in the category of item measurement [3].

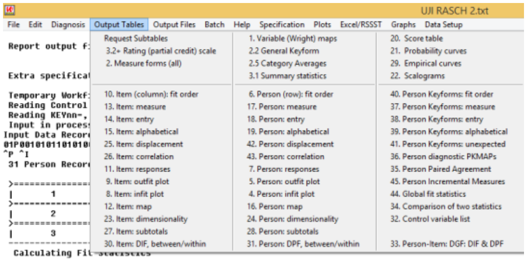


Fig. 1. Menu bar visual on Winstep.

The output part of the table is one of the bar menus that would be used in this research analysis. Analysis that can be used with the output table was the analysis of the test item, research sample, and the graph relation between them. If one of the index choices the table output is chosen, then the minstep would display the analysis result as expected automatically and simply. In this case, we used Table 1. Variable (Wright) map, Table 17. Person: measure, and Table 6. Person fit to order.

Rasch model analysis would be used to identify students' scientific literacy. Scientific literacy is important in national and international scale to help the students face the development of science and technology. Moreover, the environment becomes the biggest challenge faced by the students. Scientific literacy is the main key to contribute to what is needed by the students to be involved in society [4]. The previous research [5-6] showed that the students' scientific literacy profiles were only presented in the form of the diagram without detail analysis about the scientific literacy competence of the students. There were only a few discussions about the measurement of scientific literacy by using Rasch model analysis. Therefore, this research aimed to describe the scientific literacy competence of the eleventh-year students by using Rasch model analysis in the topic of heat and temperature.

There are three dimensions interrelated in scientific literacy according to PISA, are concepts, scientific process, and scientific situation. In physics, we know heat and temperature that involved these three dimensions. Physics is needed in the developed science and technology in the modern era. One of the basic concepts in Physics is heat and temperature which is learned at Elementary School until University [7-8]. Generally, heat and temperature are related to real-life for example, abstract concept, physical environment, and technology e.g. [9-11]. This makes the students understand heat and temperature easily. Temperature is not the number of heat energy in a thermodynamic system, but the number of average kinetic energy contained in a molecule or atom [12-13]. Heat energy can be defined as the transfer of the energy caused by the changing temperature from one thing to another in the process of heating and cooling [14-15]. Correlation between temperature change on the mass of a particular substance and heat can be described in equation (1).

$$\Delta Q = mc\Delta T \tag{1}$$

2 Research method

2.1 Participants

In this research, the samples used were 31 students in the eleventh year taking the natural science department at one of senior high school in Jambi. The sampling technique used was a random sampling technique from seven groups of students. The sample consists of 11 male students and 20 female students who had learned the material of heat and temperature. The average of the students, age taken as the research sample was 17 years old. The samples were the students registered for the even semester in the 2018/2019 learning period.

2.2 Research design

This research was a case study research. Students join the Physics class for 90 minutes divided into two learning hours; 45 minutes for each. In the first 45 minutes, the researcher did observations towards the learning by the Physics teacher in the classroom. In the next 45 minutes, the researcher gave an item instrument item in form of test of heat and temperature that had been constructed based on the PISA framework. The test results were analyzed by using Rasch model analysis to find the students' scientific literacy competence (**Figure 2**).

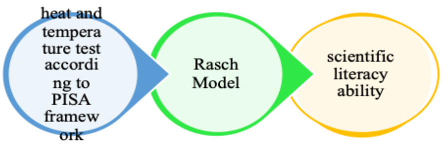


Fig. 2. Process of analysis of students' scientific literacy abilities.

2.3 Instrument

Multiple choice test consisted of 25 items and validated by using Rasch. The Item was considered valid if the MNSQ outfit is between 0.5<outfit MNSQ<1.5. The Result of validity analysis through the Rasch model for all test items was valid. The result of the students' reliability was 51 and the test item reliability was 82. Those indicated the consistency of the students' answers was low but the quality of the test instrument was categorized as good. the items test distribution for each scientific literacy indicators can be seen in Table 1.

Table 1. The domain of scientific literacy competence on instruments.

Competence domain	Item number
Explaining phenomena scientifically	1, 7, 8, 12, 18, 19, 22,
Evaluating and designing scientific inquiry	2, 9, 13, 15, 16, 17, 23
Interpreting data and evidence scientifically	3, 4, 5, 6, 10, 11, 14, 20, 21, 24, 25

2.4 Research Analysis

Analysis of the person fit using the Rasch model has criteria. The purpose of this analysis is to detect whether there are individuals who have inappropriate response patterns. The criteria for individual suitability levels are shown in Table 2 [1].

Table 2. Level criteria of person fit.

Person Fit Criteria	
Nilai Outfit mean square (MNSQ)	0.5 < MNSQ < 1.5
Outfit Z-standart (ZSTD)	-2.00 < ZSTD < +2.0
Point Measure Correlation (Pt Mean Corr)	0.4 < Pt Measure Corr < 0.85

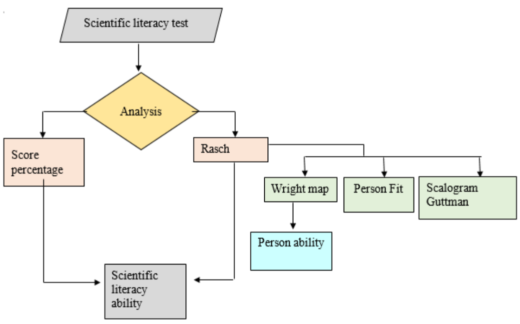


Fig. 3. Flowchart of research analysis.

3 Result and Discussion

One of the features of the Rasch model with the Winstep program is that it produces a map illustrating the distribution of students' abilities and levels of difficulty on the same scale called the Wright map, this map is also called the construct map [1]. The results of the distribution of students' abilities can be seen in **Figure 4**.

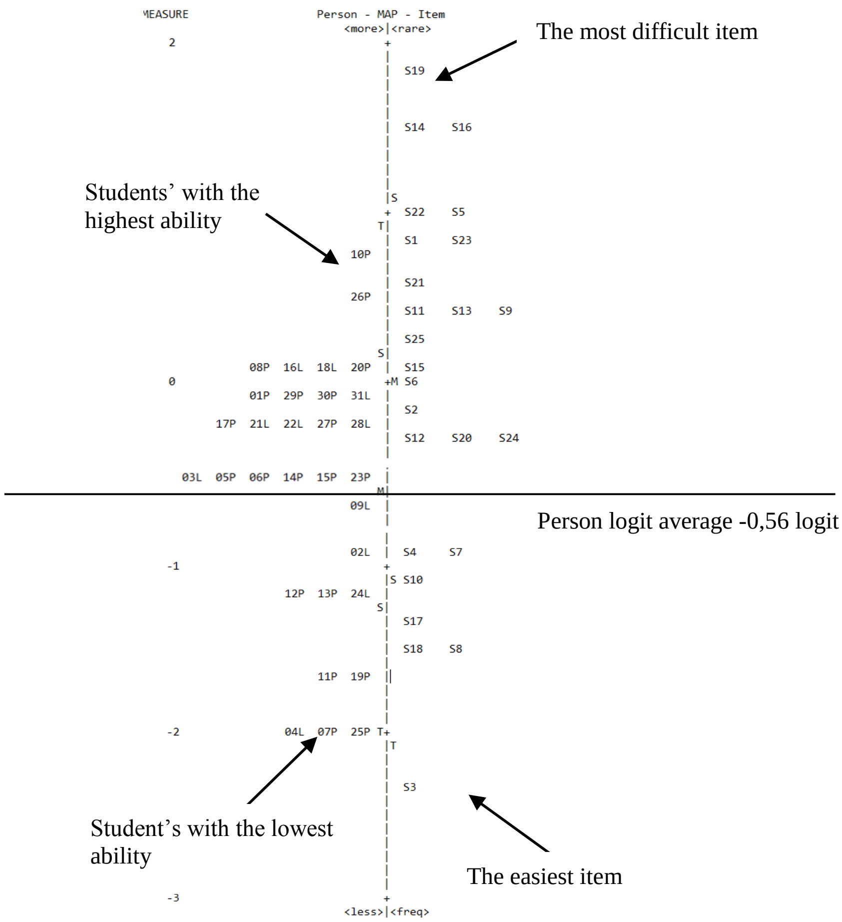
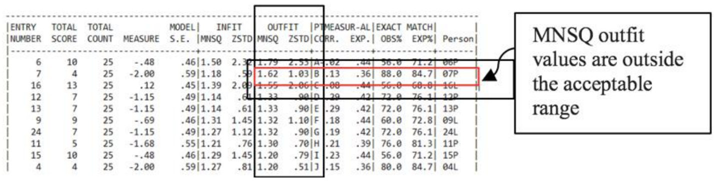


Fig. 4. Wright map analysis.

10P students who have the highest ability can only do 16 questions and 9 questions cannot be answered correctly. This is because the 10P (+0.73 logit) ability is still lower than the logit at the difficulty level of S23, S1, S22, S5, S16, S14, and S19. The student's logit score of his ability lower than the item's logit means that the probability of being able to work on the problem with a larger logit correctly is less than 50% e.g. [16-17]. Students 04L, 07P, and 25P can be said to have the ability to answer correctly which is very low with the same logit value of -2.00 logit. The problem with the easiest level of S3 (-2.37 logit) can be answered correctly by all students. The same logit value is +0.12 logit at 08P, 16L, 18L, and 20L showing the same ability, in other words, the same number of correct answers (answering 13 items correctly) are owned by these students. The level of student ability can be seen from the logit grade. High logit scores indicate a high level of ability to solve problems.

The result of the personal fit rate by using Rasch model analysis can be seen in **Figure 5**.



ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PT MEASUR-AL CORR.	PT MEASUR-AL EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Person
6	10	25	-.48	.46	1.50	2.32	1.79	2.53	A .02	.44	56.0	71.2	06P
7	4	25	-2.00	.59	1.18	.59	1.62	1.03	B .13	.36	88.0	84.7	07P
16	13	25	.12	.45	1.39	2.09	1.55	2.06	C .00	.44	56.0	68.0	16L
12	7	25	-1.15	.49	1.14	.61	1.33	.90	D .29	.42	72.0	76.1	12P
13	7	25	-1.15	.49	1.14	.61	1.33	.90	E .29	.42	72.0	76.1	13P
9	9	25	-.69	.46	1.31	1.45	1.32	1.10	F .18	.44	60.0	72.8	09L
24	7	25	-1.15	.49	1.27	1.12	1.32	.90	G .19	.42	72.0	76.1	24L
11	5	25	-1.68	.55	1.21	.76	1.30	.70	H .21	.39	76.0	81.3	11P
15	10	25	-.48	.46	1.29	1.45	1.20	.79	I .23	.44	56.0	71.2	15P
4	4	25	-2.00	.59	1.27	.81	1.20	.51	J .15	.36	80.0	84.7	04L

Fig. 5. Person fit level.

The person fit of students can be seen in the MNSQ outfit. Students 06P, 07P, and 16L have MNSQ outfit values beyond the acceptable limits based on the categories in Table 3. The only aspect of the ZSTD outfit is 07P (+1.03) that meets the requirements, while none of the Pt Mean Corr values are eligible. If the value of infit and outfit on MNSQ and ZSTD is outside the requirements, then there are indications that students do not respond according to their abilities, meaning that students have unusual response patterns [18]. Students with lower ability can answer questions with a higher level of difficulty, this is likely due to students answering by guessing. The examination of response patterns can further follow the scalogram pattern in **Figure 6**.

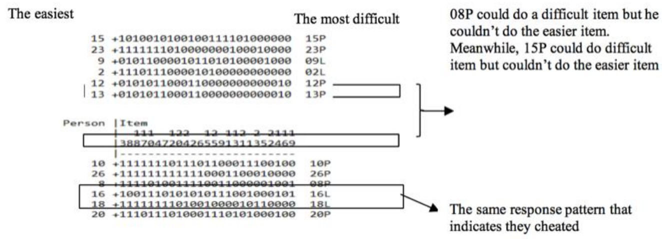


Fig. 6. Scalogram Guttman.

From left to right the Guttman scalogram shows the difficulty level of the questions. The advantage of a scalogram is that it can detect cheating on answers, for example in students 12P and 13P have the same person logit that is -0.15 logit and scalogram analysis shows the same answer pattern in both students. 15P students are able to work on problems with a higher level of difficulty, but cannot answer correctly on questions with low difficulty levels namely items 8, 17 and 10. 08P students are students with high ability who have many correct answers, but unable to answer questions with a low level of difficulty while 08P students are able to answer difficult questions. If students can answer difficult questions, they should be able to answer questions with easy to difficult levels. If students are not able to answer easy questions, they should not be able to answer difficult questions and are only able to answer easy questions [19].

Generally, the percentage of students' scientific literacy ability can be seen in **Figure 7**.

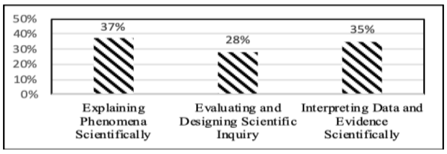


Fig. 7. Percentage of student's right answer for scientific literacy.

Based on **Figure 7**, the first indicator of the scientific literacy competency describing the scientific phenomena having the highest percentage compared to the others. This ability needs knowledge about basic ideas of science and the problems appearing in the training and objective of science itself. The competence to explain the scientific phenomena and technology depends on the knowledge about the main explanatory ideas of science. Based on the research conducted by Fakriyah [5], students have sufficient theoretical ability and the scientific concept. They can identify or determine the problems but they feel difficult to explain the phenomena properly. There are many factors found, such as; the lack of interest owned by the students to learn heat and temperature. They are usually taught by using the monotone learning method. Students do not have a chance to practice to explain the phenomena. The teacher must rethink and plan holistically to be involved in the development of scientific literacy in the learning process [20].

The second indicator, this indicator gained the lowest percentage of 28%. This research might have a problem in the process of not practicing students to ask the question, for example, the teacher proposed too many questions that cannot raise new questions from the students. Every conceptual activity should be contextualized and students should be directed to practical thinking and problems. Students are encouraged to make experiment analysis done by comparing the experiment result gained through the publication or online media in a hypothesis conclusion so that can promote the ability to design and evaluate scientific experiment [21].

The third indicator, interpreting data, and scientific facts had a percentage of 35 % for the correct answer. Data of research will be meaningful if there is proper interpretation accompanied by the supporting facts and evidence. Data interpreted will describe the information which is helpful to prove the research hypothesis. Students who able to interpret scientific data and the facts must be able to deliver the meaning of a piece of scientific evidence and to imply them to the public by using their own words, diagram or another representation that is suitable and acceptable. This can help the students to explain the problems critically and by using the logical procedure to solve the problems on time and supported by evidence from various perspectives [22]. Concepts, information, and interpretations obtained by students from personal experiences in the home and community environment and cultural knowledge can be used to view and interpret knowledge and experience in school.

4 Conclusion

Based on the result of this research, the scientific literacy competence of the eleventh-year students at high school in heat and temperature topic for the three domains of literacy were categorized low. This implies that the learning process could not develop the students' scientific literacy. There should be improvement efforts in the learning process so that the students can be trained in scientific literacy, for example by implementing variously suitable and acceptable learning models, methods, and media.

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