Students' understanding of chemical bonding material through the rasch modelling data symptoms analysis

Almubarak and R Iriani
Chemistry Education, Faculty of Teachers Training and Education
University of Lambung Mangkurat

almubarak_kimia@ulm.ac.id

Abstract. Barke et al. (2009) said that chemistry education was a bridge in constructing students' knowledge, where everyone had preconception, which was then built into scientific concepts. The ability to interpret the students about chemical material is essential, so it needs more intervention, such as the process of analyzing the students' learning needs. The Rasch model is an alternative way to find out how the learners understand through the response patterns of Rasch data symptoms and assess how various designs arise from given responses. This study aimed to determine the average logit value and person reliability of the students based on the Rasch model analysis. The research method used was a descriptive qualitative approach. The Rasch model analysis data was interpreted scientifically to describe the students' understanding of chemical bonding material. The research result showed that the students' logit average value was 0.65 which was above the logit average value of the item; it means that the participants' ability was more significant than the difficulty level of the questions and the person reliability was 0.79 (suitable). The conclusion is that the students' understanding of chemical bonding material is quite good by looking at the distribution of Rasch model analysis data. This analysis can be a reflection and evaluation material for teachers to improve the quality of chemistry learning.

1. Introduction

Every individual has general knowledge about what they encounter in their daily lives and how they understand things or how their thinking processes examine their surroundings [1–3]. According to (H. D. Barke et al., 2009) who explained that their initial knowledge (termed as prior knowledge/pre-concept) about their attitudes and interpretations defined what was happening around them. Furthermore, [4] also added that the mentioned pre-concept needed to renew their thinking process (students). The students need to construct their knowledge into concrete and scientific understanding; this is termed as scientific concepts. The students' cognitive construction is the most crucial thing because considering that chemical material includes science that consists of many life aspects, including human life, the universe, and natural phenomena. Thus, the ability to interpret is vital in understanding chemistry, especially for them (students) as prospective teachers in the future. They are not only knowledgeable enough, but they also have interpretation in learning [5–9].

"…from [4]: Composition of Salts. A famous example of school-made misconceptions of our students arises from the Dissociation Theory of Arrhenius. In 1884, he postulated that "salt molecules are found in solid salts as the smallest particles and decompose into ions by dissolving in the water." Later, with the concept of electrons, the misconception that
"atoms of salt molecules from ions through electron exchange" was born. Today, experts recognize that there are no salt molecules, that ions exist all the time – even in solid salt. By dissolving the solid salt, water molecules surround the ions, and hydrated ions are not connected, they move freely in the salt solution…”

The ability to interpret is relevant to the study of (Gilbert & Treagust, 2009) which showed that chemistry had a relationship with the universe's context, including human life and social interactions. Gilber & Treagust (2009) [2] also added that the concept of chemical representation was a very scientific foundation for how the students understood more about chemistry and the universe. The idea of integrated representation concept in chemistry learning indirectly helps the students to explore and habituate themselves in assessing properly and concretely [10–13]. Besides, the students need to realize that chemistry is not just a part of the natural sciences or sciences. Yet, chemistry is also a very essential and sensitive part of influencing the human mindset, including representation. Chemical representation (macroscopic, particulate, symbolic) in chemistry teaching needs to be used as a fundamental concept so that the students gradually construct their knowledge scientifically [10,14–18].

The teachers' emotional involvement and the process of knowledge transformation in chemistry learning certainly require many strategies such as the use of learning media, learning resources, appropriate approach, learning styles analysis, and psychological factors, so that chemistry learning has an impact and changes on the students [1,19–26]. Learning style analysis is one of the main components that affects the students' knowledge; it means that the teachers need to assess learning and analyze the needs and learning styles of the students so that the teachers know the abilities of each participant [27–30].

"….research from [31] that, 33.50% of students held misconceptions of acid-base titrations in the curriculum. The highest percentage of misconceptions were on acid-base titration indicators with 40,42%. Students being more familiar with phenolphthalein for NaOH and HCl titrations than with bromothymol blue. This misconception is sourced from chemistry teaching due to limited understanding of acid-base concepts and the lack of titration practicum in the laboratory with various indicators and types of titration…”

The above quotation shows that the students still experience various misconceptions in learning chemistry so that the need to make a renewal in learning chemistry and conducting an assessment as a learning needs analysis must be done by the teachers [31]. According to [32], they assessed that the initialization of the assessment process in the field occurred because the assessment was still analyzing the realm of memorization and critical thinking skill had not been strengthened, so it affected the creativity and production of Higher Education (PT) graduates. Also, the students had difficulty in understanding material at the particulate level so that this condition was very different from misconceptions [12,15,33].

Rasch modeling is a data analysis technique appropriate for implementing a learning assessment [34–37]. Mapping on how to improve and detect the students' understanding through Rasch modeling is a strategy undertaken by [35]. The scenario where he developed an assessment called Connected Chemistry as Formative Assessment (CCFA) using Rasch modeling whose one of its goals was how to increase the progress of the students' understanding through the concept of representation. Then, [38] found that the Rasch model had great potential in developing a computer modeling-based measurement instrument. The main objective was to know deeply about the students' understanding of a problem in learning. Rasch modeling can comprehensively show the distribution of statistical data in various data output types, making it easier for researchers or teachers to interpret the analyzed data [34,35,39].

Rasch modeling is a powerful and creative solution in the assessment context. It shows not only the data-ability learners but also the ability of an item used. So, that the modeling Rasch could be a
renewal and alternative way in the process of assessment and analysis of the students' understanding [27,35,40–44].

2. Method
The research method used was descriptive with a quantitative approach. The Rasch model analysis data was interpreted scientifically to obtain an overview of the students' understanding of chemical bonding material [42,45]. This stage was the initial stage of the development stage of this research product. This empirical study stage was due to the assumption that the appropriate chemistry learning media is a suitable medium that can influence the students' mindset so that they gain a concrete and scientific understanding [4]. This quantitative approach also included how to read the data and interviewing techniques for the students (college students) with stated issues about their material perspectives, especially a study of material based on chemical representations. Data analysis used Rasch modeling, where the Rasch model analysis results were interpreted narratively to obtain a concrete description of how the students' understanding related to chemical bonds.

The essence of this study was every teacher needs motivation to their assumption about students’ thinking symptoms. Every teacher is directed to eliminate the paradigm which states that students have ‘zero knowledge’ before the learning activity begins, whereas every student has each one’s initial knowledge which is called pre-concepts [1]. The chemistry learning needs to bridge the pre-concepts and scientific concepts, so that students can construct their knowledge correctly and scientifically. It means that the interpretation result of Rasch model indirectly confirms on how far students’ understanding about chemistry bonding topic, in which this result can be used by teacher to prepare for the class based on the analysis result. Analysis of students’ understanding progress is a fundamental factor for teachers to acknowledge students’ potential to reach the higher level.

In the Rasch Model, multiple-choice questions are called "dichotomy", where the Rasch model combines an algorithm that includes the result of the probabilistic expectation of the "i" item and the "n" respondent, which is mathematically expressed as [42]:

$$P_{ni} (X_{ni} = 1 | b_n, d_i) = \frac{e^{(b_n-d_i)}}{1 + e^{(b_n-d_i)}}$$  \hspace{1cm} (1)

In which $P_{ni} (X_{ni} = 1 | b_n, d_i)$ is the probability of the n respondent in i item to produce the correct answer ($x = 1$); with the respondent's ability, $b_n$ and the difficulty level of $d_i$ item.

Above equation by Rasch can be further simplified by adding a logarithmic function and making it into:

$$\log P_{ni} (X_{ni} = 1 | b_n, d_i) = b_n - d_i$$  \hspace{1cm} (2)

3. Discussion
The result presented below is an empirical study related to the research "Chemistry Module based on Wetland Context to Analyze Mental Model and Visual Representation: Augmented Reality Integration", where the initial stage was to analyze the students' understanding through the Rasch model analysis technique. The Rasch model or Rasch modeling is a data analysis technique that is appropriate for carrying out a learning assessment [34–37]. Then, [38] found that the Rasch model had great potential in developing a computer modeling-based measurement instrument. The main objective was to know deeply about the students' understanding of a problem in learning. Rasch modeling can comprehensively show the distribution of statistical data in various data output types, making it easier for researchers or teachers to interpret the analyzed data [34,35,39].

Related to the above explanation, Rasch modeling is a powerful and effective way if it was being used in the assessment. This because Rasch modeling does not only show data of the students' abilities, but also shows the power of an item used, so that Rasch modeling can be a renewal and alternative way in assessment and analysis process of the students' understanding [27,35,40–44].
The development of the chemical module, which is then developed rapidly, depends on the Rasch model's analysis results implemented. That is because the Rasch modeling provides comprehensive and complete data distribution. The symptoms described in a structured manner offer a full description of how they understand the response patterns. The result of the interpretation with Rasch modeling data became the foundation in the development process in learning where the students' abilities were in the "weak" criteria. Hence, the chemical module which was developed needs to balance the weight of the content presentation and the case analysis provided in the chemistry module. Therefore, the students' ability to interpret the symptoms of the Rasch model data is a weight measurement of the developed chemical module content. So, when the chemistry learning process is created, the chemistry module has a positive influence and impact on the students. The following is the distribution of the Rasch model data symptoms from various types of data.

3.1. Wright Maps/Variable Maps

![Wright Maps/Variable Maps](image-url)

**Figure 1.** Variable Maps or Wright Maps of Rasch Modeling

Figure 4.1 is the distribution of data from maps variable data known as *wright maps*, in which *wright maps* are one of the Rasch model features. Wright maps describe the distribution of the subjects' abilities and the distribution of the difficulty levels of items with the same scale. The data on the right side is items (the questions that are distributed) and the left side is the students' ability level. Based on *Wright maps* data, it shows that the item with Q15 code is the item with the highest difficulty level.
Besides, Q16, Q19, and Q14 are the person maps with high difficulty items. Then, on the left side with the principle of ",#" is a code for students, where it seems that the code ",#" is below the code of Q1. Thus, the initial conclusion based on the right maps is the students’ ability under the power of item. The Rasch model also has its code for students where that code is the one that will show symptoms related to the analysis being carried out. This code can be accessed through Rasch model data such as “person maps, person fit, person measure, scalogram, and summary statistics” from the Rasch model data described later.

Table 4.1 is the distribution of data for the type of Rasch model data, "Person Measure." Person Measure shows the students’ tendency and ability level by displaying the data based on the logit value, which was analyzed by the Rasch model. Besides, table 4.1 also shows how each student can be reviewed through their logit value. The logit value is the value of the Rasch model data analysis result, which directly indicates their ability by paying attention to their data codes. The display of the logit value in table 4.1 is the ability level of the students for the chemical bonding material. Although there is an overall data conclusion, the table above can show the students’ values in detail and specific.

The Person box is the code for the students (college students) who took the test, Entry Number:
The serial number of the participants who took the test, the Total Score is the number of questions answered by the participant from the total items, and the measure is the logit value that shows the ability of the students in cognitive aspect based on the distributed questions. The students with 047PB, 061PB, 088LB, and 102PB have the highest logit value compared to other students with the same logit value of +3.24. This is reinforced by the "total score" data of 18. This means that the students with codes of 047PB, 061PB, 088LB, and 102PB have correctly answered 18 items distributed out of 20 total items so that indirectly they are judged as the most understanding students related to the chemical bonding material.

Table 1 Person measure

| ENTRY NUMBER | TOTAL SCORE | TOTAL COUNT | MEASURE | MODEL | INFIT | OUTFIT | FT-MEASURE | EXACT MATCH |
|--------------|-------------|-------------|---------|-------|-------|--------|-------------|-------------|
| 47           | 18          | 20          | 3.24    | .93   | .52   | -.71   | .17         | - .51       | .66         | .49         | 95.0       | 93.0       | 047PB      |
| 61           | 18          | 20          | 3.24    | .93   | .52   | -.71   | .17         | - .51       | .66         | .49         | 95.0       | 93.0       | 061PB      |
| 88           | 18          | 20          | 3.24    | .93   | .52   | -.71   | .17         | - .51       | .66         | .49         | 95.0       | 93.0       | 088LB      |
| 102          | 18          | 20          | 3.24    | .93   | .52   | -.71   | .17         | - .51       | .66         | .49         | 95.0       | 93.0       | 102PB      |
| 11           | 17          | 20          | 2.53    | .77   | .85   | -.31   | .70         | -.21        | .56         | .52         | 90.0       | 88.9       | 011PB      |
| 12           | 17          | 20          | 2.53    | .77   | .85   | -.31   | .70         | -.21        | .56         | .52         | 90.0       | 88.9       | 012PB      |
| 36           | 17          | 20          | 2.53    | .77   | .75   | -.44   | .32         | -.22        | .64         | .52         | 90.0       | 88.9       | 036LB      |
| 43           | 17          | 20          | 2.53    | .77   | .59   | -.81   | .26         | -.31        | .68         | .52         | 90.0       | 88.9       | 043PB      |
| 44           | 17          | 20          | 2.53    | .77   | .59   | -.81   | .26         | -.31        | .68         | .52         | 90.0       | 88.9       | 044LB      |
| 45           | 17          | 20          | 2.53    | .77   | .59   | -.81   | .26         | -.31        | .68         | .52         | 90.0       | 88.9       | 045PB      |
| 46           | 17          | 20          | 2.53    | .77   | .52   | -.10   | .23         | -.41        | .70         | .52         | 90.0       | 88.9       | 046PB      |
| 52           | 17          | 20          | 2.53    | .77   | .52   | -.10   | .23         | -.41        | .70         | .52         | 90.0       | 88.9       | 052PB      |
| 57           | 17          | 20          | 2.53    | .77   | .77   | -.34   | .44         | .01         | .61         | .52         | 90.0       | 88.9       | 057PB      |
| 60           | 17          | 20          | 2.53    | .77   | .77   | -.34   | .44         | .01         | .61         | .52         | 90.0       | 88.9       | 060PB      |
| 64           | 17          | 20          | 2.53    | .77   | .61   | -.21   | .52         | .01         | .59         | .52         | 90.0       | 88.9       | 064PB      |
| 67           | 17          | 20          | 2.53    | .77   | .61   | -.21   | .52         | .01         | .59         | .52         | 90.0       | 88.9       | 067PB      |
| 68           | 17          | 20          | 2.53    | .77   | .61   | -.21   | .52         | .01         | .59         | .52         | 90.0       | 88.9       | 068PB      |
| 69           | 17          | 20          | 2.53    | .77   | .61   | -.21   | .52         | .01         | .59         | .52         | 90.0       | 88.9       | 069PB      |
| 57           | 17          | 20          | 2.53    | .77   | .50   | -.01   | .36         | .71         | .50         | .52         | 90.0       | 88.9       | 057LB      |
| 141          | 17          | 20          | 2.53    | .77   | 1.31  | .71    | 1.30        | .71         | .39         | .52         | 90.0       | 88.9       | 141PB      |
| 142          | 17          | 20          | 2.53    | .77   | 1.31  | .71    | 1.30        | .71         | .39         | .52         | 90.0       | 88.9       | 142PB      |
| 161          | 17          | 20          | 2.53    | .77   | 1.31  | .71    | 1.30        | .71         | .39         | .52         | 90.0       | 88.9       | 161PB      |
| 8            | 16          | 20          | 2.00    | .69   | .73   | -.61   | .53         | -.11        | .64         | .53         | 90.0       | 85.4       | 008PB      |
| 10           | 16          | 20          | 2.00    | .69   | .80   | -.46   | .92         | .31         | .58         | .53         | 90.0       | 85.4       | 010PB      |
| 13           | 16          | 20          | 2.00    | .69   | .80   | -.46   | .92         | .31         | .58         | .53         | 90.0       | 85.4       | 013PB      |
| 13           | 16          | 20          | 2.00    | .69   | .73   | -.53   | .01         | .64         | .52         | 90.0       | 88.9       | 013PB      |
| 21           | 16          | 20          | 2.00    | .69   | .60   | -.41   | .92         | .31         | .58         | .53         | 90.0       | 85.4       | 021PB      |
| 22           | 16          | 20          | 2.00    | .69   | .73   | -.61   | .53         | -.11        | .64         | .53         | 90.0       | 85.4       | 022PB      |

In connection with the above explanation, previously there were students who had the highest logit value or who responded most correctly, then the students with codes of 144LB, 146PB, 154LB,
155LB, 170LB, 171LB, and 189PB were the participants who were rated to have the lowest ability. This was supported by a logit value of -2.56, and they only answered 3 (three) items correctly, meaning that they had already answered 17 items incorrectly. However, the student who had the 140LB code was the only participant at the lowest level with a logit value of -3.17, where 140LB only correctly answered 2 (two) items or 140LB incorrectly answered 18 questions. This means that the students with codes of 144LB, 146PB, 154LB, 155LB, 170LB, 171LB, and 189PB were far below the ability of the students with codes of 047PB, 061PB, 088LB, and 102PB, where they (the mentioned code) had the highest logit value than other students.

Table 1 provides a concrete description, especially how the students (college students) in chemical bonding material. The average logit value was 0.00. With a deviation standard of 1.0., this statistical data's presentation provides an initial picture in examining how far the students' cognitive understanding of chemical bonding material. Thus, the "person measure" value can be compared with other Rasch model data recapitulation to obtain a complete description and judgmental on the students' understanding of the distributed items. The same logit value means that they knew, understood, and interpreted the answers to the questions given so that their knowledge or cognitive level was assessed to be identical. Logit value can be advanced study materials for lecturers to assess students' cognitive ability; However, there are other forms of Rasch analysis to convince the teachers/lecturers further about how far the knowledge of chemistry college students is.

### Table 2 Person fit

| ENTRY | TOTAL SCORE | TOTAL COUNT | MEASURE S.E. | MODEL | INFIT | OUTFIT | PT-MEASURE | EXACT MATCH | Person |
|-------|-------------|-------------|--------------|-------|-------|--------|-------------|-------------|--------|
| 105   | 6           | 20          | -0.65        | 0.65  | 0.65  | 0.65   | 0.65        | 0.65        | 105PB  |
| 106   | 9           | 20          | -0.35        | 0.35  | 0.35  | 0.35   | 0.35        | 0.35        | 106PB  |
| 96    | 10          | 20          | -0.05        | 0.05  | 0.05  | 0.05   | 0.05        | 0.05        | 96PB   |
| 93    | 11          | 20          | -0.35        | 0.35  | 0.35  | 0.35   | 0.35        | 0.35        | 93PB   |
| 190   | 11          | 20          | -0.24        | 0.24  | 0.24  | 0.24   | 0.24        | 0.24        | 190PB  |
| 73    | 12          | 20          | -0.54        | 0.54  | 0.54  | 0.54   | 0.54        | 0.54        | 73PB   |
| 173   | 5           | 20          | -1.66        | 1.66  | 1.66  | 1.66   | 1.66        | 1.66        | 173PB  |
| 14    | 15          | 20          | 1.57         | 1.57  | 1.57  | 1.57   | 1.57        | 1.57        | 14PB   |
| 158   | 9           | 20          | -0.35        | 0.35  | 0.35  | 0.35   | 0.35        | 0.35        | 158LB  |
| 98    | 8           | 20          | -0.65        | 0.65  | 0.65  | 0.65   | 0.65        | 0.65        | 98LB   |
| 167   | 11          | 20          | -0.24        | 0.24  | 0.24  | 0.24   | 0.24        | 0.24        | 167PB  |
| 65    | 14          | 20          | 1.20         | 1.20  | 1.20  | 1.20   | 1.20        | 1.20        | 65PB   |
| 74    | 14          | 20          | 1.20         | 1.20  | 1.20  | 1.20   | 1.20        | 1.20        | 74PB   |
| 186   | 10          | 20          | -0.05        | 0.05  | 0.05  | 0.05   | 0.05        | 0.05        | 186PB  |
| 95    | 12          | 20          | -0.24        | 0.24  | 0.24  | 0.24   | 0.24        | 0.24        | 95PB   |
| 90    | 9           | 20          | -0.35        | 0.35  | 0.35  | 0.35   | 0.35        | 0.35        | 90PB   |
| 110   | 6           | 20          | -1.30        | 1.30  | 1.30  | 1.30   | 1.30        | 1.30        | 110PB  |
| 196   | 7           | 20          | -0.56        | 0.56  | 0.56  | 0.56   | 0.56        | 0.56        | 196PB  |
| 94    | 11          | 20          | 0.24         | 0.24  | 0.24  | 0.24   | 0.24        | 0.24        | 94PB   |
| 109   | 13          | 20          | 0.86         | 0.86  | 0.86  | 0.86   | 0.86        | 0.86        | 109PB  |
| 148   | 7           | 20          | -0.96        | 0.96  | 0.96  | 0.96   | 0.96        | 0.96        | 148PB  |
| 149   | 7           | 20          | -0.96        | 0.96  | 0.96  | 0.96   | 0.96        | 0.96        | 149PB  |
| 99    | 15          | 20          | 1.57         | 1.57  | 1.57  | 1.57   | 1.57        | 1.57        | 99PB   |
| 104   | 6           | 20          | -0.65        | 0.65  | 0.65  | 0.65   | 0.65        | 0.65        | 104PB  |
| 104   | 7           | 20          | -0.56        | 0.56  | 0.56  | 0.56   | 0.56        | 0.56        | 104PB  |

Table 4.2 is a "person fit" table where the goal of data was to map the participants' abilities according to achievement classification; Rasch modeling can also detect if it is found that participants' or samples' response patterns are wrong. The response pattern is considered to be different if there is a discrepancy in the given answer based on its ability compared to the Rasch model. It means that the teacher can detect the students' response patterns' consistency or identify in detail if there is fraud committed by the samples [42].
Boone et al. (2014) described the criteria used to check the suitability of samples that did not fit the model \textit{(outlier or misfit)}. The selection was said to had experienced conformity according to the standard of analysis if the criteria value showed in the agreed range. Otherwise, the participants were judged to experience differences between the answer pattern and their ability. The following criteria are:

- Value of \textit{Outfit Mean Square} (MNSQ) which was received: \(0.5 < \text{MNSQ} < 1.5\)
- Value of \textit{Outfit Z-Standard} (ZSTD) which was received: \(-2.0 < \text{ZSTD} < +2.0\)
- Value of \textit{Point Measure Correlation} (Pt Mean Corr): \(0.4 < \text{Pt Mean Corr} < 0.85\)

The person fit table shows that there were criteria that met the standards and those that were in the contrary. For example, participants with code of 105PB and 106PB with participants who had values outside the standard criteria with MNSQ value of \((+9.90 \& +9.15)\), ZSTD value of \((+4.9 \& +4.7)\), and Pt Mean Corr value of \((0.08 \& 0.13)\), those two kinds of participants had a response pattern that was misfit, so it was indicated that they had an unusual response pattern reviewed from the criteria for the Rasch model above.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{guttman-scalogram.png}
\caption{Scalogram 1: 105PB & 106PB}
\end{figure}

It was strengthened on the GUTTMAN Scalogram; participants of 105PB and 106PB had a response pattern out of the ordinary. For example, for 106PB participants, he/she answered correctly for item 15 even though items 15 was the item with the highest difficulty level. On the other hand, 106PB answered incorrectly for item 14, where items 14 had a lower difficulty level than items 15 (note: \textit{output Rasch-item measure}). The participant with the code of 105PB also had the same pattern in a certain number where 105PB was able to answer the most challenging item but answered incorrectly on the item that had a lower difficulty level. This was an assessment which should be brought to further analysis of participants with the same symptoms, including analysis of misconceptions and mental models. It means that the response of 105PB and 106PB participants was an example of how they understood chemical bonding materials. Rasch model data, especially on person measure and person fit data, were data components that were crucial in showing their understanding of chemical bonding material through the distribution of chemical problems.

A person or participant who was previously assessed as a \textit{misfit} concluded that they had a response pattern that was out of the ordinary. Therefore, this was related to their knowledge of chemical materials (chemical bonds). Even though there were misfit participants, but based on the \textit{misfit person} data, it also showed that many participants were considered as \textit{fit} or had given an appropriate response pattern and according to the model. This statement was demonstrated by the participants with the
codes of 047PB, 061PB, and 088LB. They were considered fit or had proper knowledge of chemical materials (atomic structure) or were classified as *fit*.

**Figure 3.** Scalogram 2: 047PB, 061PB, & 088LB

Participants of 047PB, 061PB, & 088LB codes had the same *Outfit Mean Square* value which was +0.52, same *Z-Standard* value which was -0.7, and same *Pt Mean Corr* value which was +0.17. They stated that they could solve questions with appropriate responses, or they had good knowledge of chemical bonding. Also, the *person measure* table shows that students with the codes of 047PB, 061PB, & 088LB had the highest ability among all research samples so that it can be stated that they understand chemical bonding material or they are consistently based on their response patterns.

**Table 3.** Summary of the Rasch Model Statistic

| TOTAL SCORE | COUNT | MEASURE | MODEL ERROR | MNSQ | ZSTD | INFIT | OUTFIT | ZSTD |
|-------------|-------|---------|-------------|------|------|-------|--------|------|
| MEAN        | 12.1  | 20.0    | .05         | .95  | .0   | 1.11  | .3     |
| S.D.        | 4.0   | .0     | 1.38        | .09  | .32  | 1.0   | 1.0    |
| MAX.        | 18.0  | 20.0   | 3.24        | .93  | 1.96 | 3.1   | 4.0    |
| MIN.        | 2.0   | 40.0   | 3.17        | .54  | .47  | .9    | .9     |

**REAL RMSE** .66 TRUE SD 1.21 SEPARATION 1.84 Person RELIABILITY .77  
**MODEL RMSE** .63 TRUE SD 1.22 SEPARATION 1.95 Person RELIABILITY .79

Person RAW SCORE-TO-MEASURE CORRELATION = 1.00  
CRONBACH ALPHA (KR-20) Person RAW SCORE "TEST" RELIABILITY = .01

**SUMMARY OF 20 MEASURED Item**

| TOTAL SCORE | COUNT | MEASURE | MODEL ERROR | MNSQ | ZSTD | INFIT | OUTFIT | ZSTD |
|-------------|-------|---------|-------------|------|------|-------|--------|------|
| MEAN        | 120.8 | 200.0   | .00         | .21  | 1.00 | .3    | 1.12   | .3   |
| S.D.        | 48.0  | .0     | 1.80        | .07  | .22  | 2.2   | 2.0    |
| MAX.        | 192.0 | 200.0  | 4.64        | .39  | 1.59 | 5.1   | 3.73   | 4.6  |
| MIN.        | 7.0   | 200.0  | 3.45        | .16  | .64  | 3.8   | .41    | 3.7  |

**REAL RMSE** .23 TRUE SD 1.78 SEPARATION 7.67 Item RELIABILITY .90  
**MODEL RMSE** .22 TRUE SD 1.70 SEPARATION 8.05 Item RELIABILITY .90

S.E. OF Item MEAN = .41

**UPWEAN = .0000 USCALE=1.0000**  
4000 DATA POINTS. LOG-LIKELIHOOD CHI-SQUARE: 3345.22 with 3781 d.f. p=.0000  
Global Root-Mean-Square Residual (excluding extreme scores): .3648  
Capped Binomial Deviance = .1816 for 4000.0 dichotomous observations
The above table (table 4.3) is the *Summary statistic* where that table provides comprehensive information about the quality of the participants' response patterns, including the quality of the instrument and the interaction between person and item. The statistical data below shows that the *mean person measure* was +0.65, which means that this value was the average value of all participants when working on the given item. This value was above 0.0, which indicated that the participants' tendency was greater than the difficulty level of the questions. Then, the *alpha Cronbach* value aimed to determine the interaction between people and the items with a value of +0.81. If we look at the alpha Cronbach's criteria, this value was in the *"Very Good"* standards. Following are the requirements of *alpha Cronbach* [42]:

- < 0.5: Worst
- 0.5 - 0.6: Bad
- 0.6 -0.7: Enough
- 0.7 - 0.8: Good
- > 0.8: Very Good

Furthermore, the obtained *person reliability* value was +0.77, and the *item reliability* was +0.98. This value shows that the participants' response pattern's consistency was *"good,"* while the quality of the items in its reliability aspect instrument is was *"special."* So, it can be concluded that understanding the participants' cognitive context was considered useful in answering questions about chemical bonding material. Although, based on the Rasch model's specific data, students still had a poor understanding and response pattern to the chemical bonding material. However, based on average, students still need to be trained in content and problem analysis practice.

Overall, it is related to the data above that the Rasch modeling data interpretation was a fundamental foundation for every teacher to identify the participants and problems they faced, which could then improve the quality of learning in the classroom. Students who had inappropriate response patterns would likely experience misconceptions about the material. Thus, this data can be used as a reflective material on how far the teachers can accommodate the participants' abilities and needs in learning chemistry. It means that the assessment of learning needs and students' initial ability analysis is needed considering that learning chemistry requires reasoning power and appropriate mental model in examining chemical materials; especially, for those who are prospective teachers in the future.

### 4. Conclusion

Chemistry learning assessment is part of a vital component in constructing students' understanding. An empirical study is necessary to assess how far the students' perspective progress in understanding and interpreting the problems given. The results showed that the students' average logit value was 0.65, which was above the average logit value of the items, which means that the participants' ability tended to be greater than the difficulty level of the questions. Person reliability was 0.79 (good). The conclusion is the students' understanding of chemical bonding material was good by looking at the distribution of Rasch model analysis data and their response patterns. Besides, this research can also be material for reflection and evaluation for teachers to improve the quality of chemistry learning.

### 5. Acknowledge

The research was supported by the Institute for Research and Community Service, Lambung Mangkurat University. We, the whole research team, would like to thank you for the Research Grant with the PNBP funding scheme for the University of Lambung Mangkurat. The research team would also like to thank the parties within the University of Lambung Mangkurat that have contributed a lot to this research's implementation.

### References

[1] Barke H, Harsch G and Schmid S 2012 *Essentials of Chemical Education* (Verlag Berlin Heidelberg: Springer)

[2] Gilbert J K and Treagust D F 2009 Introduction: Macro, Submicro and Symbolic
Representations and the Relationship Between Them: Key Models in Chemical Education

Multiple Representations in Chemical Education, MOdels and Modeling in Science Education (Berlin, Heidelberg: Springer Science + Business) pp 1–8

[3] Padilla K and Van Driel J H 2018 Educ. Química 23 311
[4] Barke H D, Hazari A and Yitbarek S 2009 Misconceptions in Chemistry (Addressing Perceptions in Chemical Education) (Berlin, Heidelberg: Sense Publisher)

[5] Boz N and Boz Y 2008 J. Sci. Teacher Educ. 19 135
[6] Dincol, Ozgur S 2018 Cypriot J. Educ. Sci. 13 521
[7] Savec V F, Urankar B, Aksela M and Devetak I 2017 J. Serbian Chem. Soc. 82 1193

[8] Durmaz M 2018 J. Educ. Train. Stud. 6 13
[9] Nilsson P and Karlsson G 2019 Int. J. Sci. Educ. 41 419
[10] Figueiredo M, Neves J and Gomes G 2016 2nd Inter. Conf. on Higher Educ. Advances, HEAd’16, 21-23 June 2016, València, vol 228 pp 161

[11] Berkel, Berry V, Pilot A and Bulte, Astrid, M W 2009 Micro-Macro Thinking in Chemical Education: Why and How to Escape Multiple Representations in Chemical Education, MOdels and Modeling in Science Education ed J K Gilbert and D F Treagust (Berlin, Heidelberg: Springer Science + Business) pp 31–54
[12] Santos V C and Arroio A 2016 J. Turkish Sci. Educ. 13 3
[13] Ryan S and Herrington D G 2014 J. Chem. Educ. 91 860
[14] Kozma R, Chin E, Russell J and Marx N 2000 J. Chem. Educ. 9 105

[15] Ekiz B, Tarkin A, Bektas O, Tuysuz M, Kutucu E S and Uzuntiryaki E 2011 Procedia - Soc. Behav. Sci. 15 452
[16] Yakmaci-Guzel B and Adadan E 2013 Int. J. Environ. Sci. Educ. 8 109
[17] Alves C A, Vicente E D, Evtyugina M, Vicente A M, Nunes T, Lucarelli F, Calzolai G, Nava S, Calvo A I, Alegre C del B, Oduber F, Castro A and Fraile R 2020 Atmos. Pollut. Res. 11 531
[18] Pande P and Chandrasekharan S 2017 Stud. Sci. Educ. 53 1
[19] Shen B, McCaughter N, Martin J, Garn A, Kulik N and Fahlan M 2015 Br. J. Educ. Psychol. 85 519
[20] Aritzeta A, Balluerka N, Gorostiaga A, Alonso-Arbiol I, Haranburu M and Gartzia L 2016 Eur. J. Educ. Psychol. 9 1
[21] Üce M and Ceyhan İ 2019 J. Educ. Train. Stud. 7 202
[22] Taber K S 2017 Educ. Química 28 66
[23] Yuanita L and Ibrahim M 2015 Online J. New Horiz. Educ. 5 30
[24] Cooper M M and Sandi-Urena S 2009 J. Chem. Educ. 86 240
[25] Yazıcılar Ö and Güven B 2009 Procedia - Soc. Behav. Sci. 1 2578
[26] Taber K S 2013 Chem. Educ. Res. Pract. 14 156
[27] Cloonan, Carrie A and Hutchinson, John S 2011 Chem. Educ. Res. Pract. 12 205
[28] Potgieter M and Davidowitz B 2011 Chem. Educ. Res. Pract. 12 193
[29] Shernoff D J, Sinha S, Bressler D M and Ginsburg L 2017 Int. J. STEM Educ. 4 1
[30] Harsh J, Esteb J J and Maltese A V. 2017 Chem. Educ. Res. Pract. 18 472
[31] Supatmi S, Setiawan A, Rahmawati Y, Education C, Program S and Jakarta U N 2019 African J. Chem. Educ. 9 18
[32] Amalia F N and Susilaniingsih E 2014 J. Inov. Pendidik. Kim. 8 1380
[33] Darmiyanti W, Rahmawati Y, Kurniadewi F and Ridwan A 2017 JRPK J. Ris. Pendidik. Kim. 7 38
[34] Runnels J 2012 Int. J. Lang. Stud. 6 141
[35] Park M, Liu X and Waight N 2017 J. Chem. Educ. 94 273
[36] Chiang W-W 2015 IETC 2014 vol 176 (Elsevier B.V.) pp 200
[37] Andrich D and Pedler P 2019 Meas. J. Int. Meas. Confed. 131 771
[38] Wei S, Liu X, Wang Z and Wang X 2012 J. Chem. Educ. 89 335
[39] Yamato T P, Maher C G, Saragiotto B T, Catley M J and Moseley A M 2018 J. Clin. Epidemiol.
101 28

[40] Zamri bin Khairani A and Bin Abd. Razak N 2015 Modeling a Multiple Choice Mathematics Test with the Rasch Model *Indian J. Sci. Technol.* **8**

[41] Maier K S 2007 *J. Educ. Behav. Stat.* **26** 307

[42] Sumintono B and Widhiarso W 2015 *Aplikasi Pemodelan Rasch Pada Assessment Pendidikan* (Cimahi: Penerbit Trim Komunikata)

[43] Sprague E, Siegert R J, Medvedev O and Roberts M H 2018 *J. Pain Symptom Manage.* **55** 1356

[44] Wan Y and Bi H 2016 *J. Chem. Educ.* **93** 70

[45] Charmaz K 2006 *Constructing Grounded Theory: A Practical Guide Through Qualitative Analysis* (London: SAGE Publication)