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Student's Chemical Bonds Concept: Rasch Model Analysis

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ABSTRACT: This study was conducted to measure students' conceptual understanding of chemical bonds. The test through an online form, include two-level test—a total of 50 students who have studied chemical bonds as research subjects. The method used is quantitative through analysis with the dichotomous Rasch model. A total of seven sub-concepts of chemical bonds have been tested on students through a two-level test, namely questions and reasons. The questions given were declared valid and reliable according to the Rasch model. The concept that is considered the most difficult for students is the description of orbitals and molecular hybridization

Keywords: chemical bonding; organic chemistry; Rasch model

INTRODUCTION

Chemical bonding on the subject of organic chemistry is one of the basic concept that must be understood by students [1]. Chemical bonds allow for a compound to be formed a compound can be formed, including the characteristics of every compound's molecules [2]. This basic knowledge is a determinant in mastering higher concepts of organic chemistry, so students must be able to understand the concept of chemical bonds very well. So far, the study of organic chemistry has been dominated by rote, so students cannot fully understand the linkages between the basic concepts of each subject in organic chemistry [3].

Mastery of the concept of chemical bonds includes various sub-concepts that students must master, such as determining valence electrons and types of chemical bonds [4]. These sub-concepts will be well understood if students can know each process of bond formation and the reasons for the formation of these bonds. Both of this knowledge can be an indicator of whether students know well or experience misconceptions due to a lack of knowledge of the reasons for the formation of bonds from a compound [5]. In line with Handsons's research which explained that to be able to teach the concept of chemical bonds. Then it takes an analysis of how the understanding of concepts from students who have studied organic chemistry before [6].

Analysis of students' concepts can be done with various statistical designs [7], [8]. However, the analysis with various techniques is a group-centered statistical analysis and cannot describe the specifics of each individual. The analysis technique that explicitly addresses each subject and includes its ability to level the difficulty of the questions is the Rasch model [9], [10]. Analysis with the Rasch model can specifically find out how students are able to answer questions, both on the questions and the reasons underlying the answers [11]. Through the analysis of the level of student ability, it becomes a reference for students to understand well or even misconceptions with reasons and answers that are out of sync. There has been no analysis with two levels on the questions that explore students' abilities on the subject of chemical bonds and analyzed from the probability of answering the questions analyzed using the Rasch model [12]. Thus, an analysis of students' abilities in the concept of chemical bonds is needed, which accurately describes students' abilities with an accurate analysis

METHOD

Research Method

The research applies quantitative methods [13] with analysis using the Rasch model [14]. Data obtained from 50 students test results after learning includes mastery of concepts in the discussion of chemical bonds in basic organic chemistry courses.

Item Test

7-item tests, including multiple-choice questions and the reasons, to determine the level of student understanding, including misconceptions from the discussion that has been studied. The concepts are: sigma bond, molecular orbitals, bond energy, phi bond, sigma bond hybridization, double bond hybridization, bond angle.

Analysis Method

Analysis of the results of student answers using the Rasch model, including the level of difficulty of the questions, statistical fit, and the reliability of the questions both on the test and the reasons. The analysis was also carried out on the students' ability to answer questions and compared with the ability to answer the reasons for each question. Content validity, including the Rasch model criteria on three criteria, are:

- Outfit MNSQ (Mean Square) (< 1,5)
- Outfit ZSTD (Z Standard) (between -1,9 and +1,9), and
- PT Mean Corr (PT Mean Correlation) (positive value)

RESULT AND DISCUSSION

Fifty students who have attended organic chemistry lessons on the subject of chemical bonds, became the subject of this research. Students are given two-level practice questions (test and reasons) online, namely multiple-choice questions including the reasons [15]. The results of student answers were then analyzed using the Rasch model in the Winsteps program, including the feasibility of the test instruments being tested and students' mastery of concepts on the subject of chemical bonds [16, 17]. The results of the analysis with Rasch include the level of difficulty of the questions in the form of measure (logit), fit statistics, eigenvalues, and reliability of the question and the reasons. The analysis was carried out in a dichotomy, because the questions were in the form of multiple choice [18, 19].

Results and Analysis of questions and reasons

Question code A shows the test and code B shows the reason, Table 1 shows the level of difficulty of the test and the reasons, as well as conformity with the Rasch model in terms of content validity (three statistical criteria). The question that is considered the most difficult for students is about molecular orbitals in sigma bonds (A2), and this can be seen from the logit value, which is the largest among all questions, which is 2.27. The problem that is considered the easiest is the energy possessed by the pi bond, with the lowest logit value of -1.03 (A3).

TABLE 1. Difficulty level and fit statistic with Rasch model

Test and Reason	Logit	Outfit MNSQ	Outfit ZSTD	PT Mean Corr
A2	2.27	1.28	0.7	0.31
A5	0.2	0.72	-1.4	0.61
A6	-0.02	0.65	-1.7	0.65
A7	-0.02	1.06	0.3	0.43
A4	-0.49	1.78	2.4	0.18
A1	-0.89	0.7	-0.8	0.55
A3	-1.03	0.8	-0.4	0.51
B5	2.23	3.17	2.4	-0.5
B2	0.44	1.08	0.5	0.33
B1	0.22	0.93	-0.3	0.42
B4	0.11	0.86	-0.8	0.55
B6	-0.4	0.87	-0.9	0.52
B3	-0.9	1.21	1.2	0.35
B7	-1.7	0.84	-0.5	0.58

Problems about molecular orbitals are considered the most difficult because the concept of orbitals is always the most abstract concept and requires a high spatial ability for students to understand it [20]–[22]. This finding is a consideration for lecturers to teach the concept of molecular orbitals to be easier to understand, even though the level of difficulty is not low. The concept of molecular orbitals is always visualized with balloons or orbital bubbles, several attempts by teachers to teach orbital theory by bringing balloons as learning media [23]. However, when the molecular hybridization process returns, students are required to think at a higher level in an effort to understand the concept of molecular hybridization, which involves various abstractions of the merging process between atoms, including the electrons in it [24], [25]. This is in line with the reasoning in B5 which is considered the most difficult for students with a logit value of 2.23.

Based on the distribution of the logit values of the seven tests and the reasons, it shows that the level of difficulty of the questions and reasons is evenly distributed, which means that the validity of the content of the questions is declared valid and suitable to be used to measure students' abilities in the concept of chemical bonds. for the highest logit value is 2.27 logit, and the lowest value is -1.7 [14]. Based on construct validity, namely from three statistical criteria starting from the MNSQ outfit with the accepted criteria being < 1.5, table 1 shows the questions on A2 exceed 1.5, but the questions are still considered valid because the two criteria from the Rasch model are still in the accepted range, namely on outfit ZSTD 0.7 (accepted range -1.9 < outfit ZSTD < 1.9) and PT Mean Corr 0.31 (with accepted value is > 0.00) [26].

The validity criterion in the other Rasch models is that the test instrument must be able to comprehensively measure the expected variables, which is proven by eigenvalues including Raw variance explained by measures higher than 20% [27]. The result of Raw variance value is explained by measures test 32.5% and on reason 29.5%. The data shows that the test in this study measures the students' conceptual mastery ability completely on the subject of chemical bonds. The final criteria for the feasibility of the test instrument used in this study are separation and reliability, the test obtained reliability of test 0.87 and separation 2.55, for reasons reliability 0.89 and separation 2.83. The reliability score shows very good consistency on the test and the reasons given to students. Whereas in separation, it means that the tests and reasons that are done by students can distinguish very well from each student's ability level [28].

Results and analysis of students' abilities on the concept of bonding

The results of the Rasch model analysis on student answers, based on the logit value, are divided into two, both tests and reasons. The two criteria of student answers are high and low [29]:

- Test : > 1.00 logit = high
  : < 1.00 logit = low
- Reason : > 0,00 logit = high
  : < 0,00 logit = low

These two criteria are further divided into three categories, including:

- Both of test and reason are **high** → Scientific knowledge
- One of test or reason is **low** → Misconception
- Both of test and reason are **low** → Low knowledge

TABLE 2. Category of student'e concept from Rasch analysis

No	Students	Logit Test	Criteria	Logit Reason	Criteria	Category
1	M54	3.70	High	-0.40	Low	Misconception
2	M22	2.16	High	-0.40	Low	Misconception
3	M14	2.16	High	-0.40	Low	Misconception
4	M21	2.16	High	0.32	High	Scientific knowledge
5	M36	2.16	High	-0.40	Low	Misconception
6	M23	2.16	High	1.11	High	Scientific knowledge
7	M37	2.16	High	-0.40	Low	Misconception
8	M46	2.16	High	0.32	High	Scientific knowledge
9	M26	2.16	High	1.11	High	Scientific knowledge
10	M53	2.16	High	1.16	High	Scientific knowledge
11	M51	2.16	High	1.16	High	Scientific knowledge

No	Students	Logit Test	Criteria	Logit Reason	Criteria	Category
12	M20	2.16	High	0.32	High	Scientific knowledge
13	M04	1.04	High	1.11	High	Scientific knowledge
14	M15	1.04	High	-1.16	Low	Misconception
15	M12	1.04	High	1.11	High	Scientific knowledge
16	M16	1.04	High	-0.40	Low	Misconception
17	M34	1.04	High	0.32	High	Scientific knowledge
18	M32	1.04	High	-0.40	Low	Misconception
19	M28	1.04	High	0.32	High	Scientific knowledge
20	M45	1.04	High	1.16	High	Scientific knowledge
21	M49	1.04	High	-0.40	Low	Misconception
22	M44	1.04	High	-0.40	Low	Misconception
23	M17	1.04	High	0.32	High	Scientific knowledge
24	M42	1.04	High	1.11	High	Scientific knowledge
25	M48	1.04	High	1.16	High	Scientific knowledge
26	M10	0,26	Low	-1.16	Low	Low knowledge
27	M09	0,26	Low	-0.40	Low	Low knowledge
28	M52	0,26	Low	-0.40	Low	Low knowledge
29	M08	0,26	Low	-1.16	Low	Low knowledge
30	M30	0,26	Low	0.32	High	Misconception
31	M24	0,26	Low	0.32	High	Misconception
32	M29	0,26	Low	0.32	High	Misconception
33	M47	0,26	Low	1.16	High	Misconception
34	M31	0,26	Low	0.32	High	Misconception
35	M25	0,26	Low	1.16	High	Misconception
36	M39	0,26	Low	0.32	High	Misconception
37	M27	-0.42	Low	-2.17	Low	Low knowledge
38	M13	-0.42	Low	-1.16	Low	Low knowledge
39	M43	-0.42	Low	-2.17	Low	Low knowledge
40	M50	-0.42	Low	-1.16	Low	Low knowledge
41	M33	-0.42	Low	1.16	High	Misconception
42	M40	-0.42	Low	-0.40	Low	Low knowledge
43	M35	-0.42	Low	-2.17	Low	Low knowledge
44	M03	-1.13	Low	-3.58	Low	Low knowledge
45	M11	-1.13	Low	-3.58	Low	Low knowledge
46	M19	-1.13	Low	1.16	High	Misconception
47	M41	-1.13	Low	-2.17	Low	Low knowledge
48	M02	-2.07	Low	-3.58	Low	Low knowledge
49	M07	-2.07	Low	-1.16	Low	Low knowledge
50	M55	-2.07	Low	-1.16	Low	Low knowledge

Based on Table 2, student information is obtained with three categories, including:
Scientific knowledge = 15 person = 30%
Misconception = 18 person = 36%
Low knowledge = 17 person = 34%

As many as 30% of students can answer the questions and their reasons very precisely. This is information that only one-third of students can master the concept of chemical bonds well because the concept of chemical bonds requires a high understanding of molecular visualization reasoning [30]. There are 36% of students who only got one right, between the questions and the reasons, as proof that there are still many students who answer questions by guessing, so the reason is right, but the question is wrong. In line with this, the right answer but the wrong reason is still considered a misconception because students may not fully understand the concept being asked, understand the answer but do not understand the reason behind the answer [5].

The final part is the student who cannot answer the question properly and the reason, so it is concluded that the student still does not understand the concepts asked regarding chemical bonds. All of this information becomes important information for teachers in the field of organic chemistry that the basic concept of organic chemistry, namely chemical bonds, is still a difficult concept to understand, and ironically this concept determines students' understanding of other subjects in organic chemistry [31]. The results of this study serve as a reference that the test instruments used to measure the concept of chemical bonds are valid and reliable questions based on the Rasch model [32]. The results of students' abilities in the concept of chemical bonds as consideration for organic chemistry lecturers, to be more innovative in teaching chemical bonds to students so that the concept can be well understood by students as a provision for understanding other concepts in organic chemistry courses [33].

CONCLUSION

A total of seven sub-concepts of chemical bonds have been tested on students through a two-level test, namely questions and reasons. The questions given were declared valid and reliable according to the Rasch model. The concept that is considered the most difficult for students is the description of orbitals and molecular hybridization. This is because it requires an understanding of molecular visualization and sufficient spatial ability. These two concepts are misconceptions for students because understanding them requires in-depth analysis skills, especially abstract concepts. This finding provides information for teachers and researchers to teach that both needed a concrete visualization or an analogy that can represent the two concepts. The analysis of student abilities shows that there are still many who are still low in mastering the concept of chemical bonds. This is a discourse for teachers to continue to innovate in teaching the concept of chemical bonds. Learning should also be linked to real examples of the existence of these two concepts.

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