

Analysis of Conceptual Understanding of Reaction Rate Material Using Four-Tier Multiple Choice Diagnostic Test

Submitted 19 November 2025, Revised 24 November 2025, Accepted 24 November 2026

Sandi Dinar Cynthia Sari^{1*}, Devi Ayu Nur'aini², Dwi Apriliyani¹, Laelatul Fajriyah¹, Siti Sa'diah¹,
Lerisma Lehon Sinurat¹, Nani Resminingsih Sutisna³, Triyanto Ardi⁴

¹Chemistry Education Department, Faculty Teacher Training and Education,
Universitas Sultan Ageng Tirtayasa, Serang, Indonesia

²Physics Education Department, Faculty Teacher Training and Education,
Universitas Sultan Ageng Tirtayasa, Serang, Indonesia

³SMAN 1 Petir, Serang, Indonesia

⁴MAN 3 Serang, Serang, Indonesia
Corresponding Email: *sandidanarcs@untirta.ac.id

Abstract

Due to the abstract nature of the concept of reaction rates, it is one of the chemistry concepts commonly misinterpreted by students. A qualitative descriptive research method was used in this study to measure students' understanding of the concept of reaction rates and the variables involved. The population of this research consisted of 38 students from the eleventh-grade students at a Senior High School in Serang, Indonesia. A four-tier multiple-choice diagnostic test was used as the research instrument. The results showed that 13.03% understood the concept, 61.84% did not understand the concept, and 25.13% had misconceptions. The results showed that the Four-Level Multiple Choice Test is a valid instrument in uncovering misconceptions in conceptual understanding by distinguishing students who correctly answered through reasoning from students who correctly answered through guessing alone. The catalyst factor showed the highest misconceptions at 73.16%, followed by surface area at 68.95%, temperature at 53.16%, and concentration at 52.11%.

Keywords: Conceptual Understanding, Reaction Rate, Four-Tier Multiple Choice, Misconceptions

INTRODUCTION

The pace at which a substance changes, the variables that influence the change, and the quantitative relationships between the variables and the reaction rate are all included in the chemical kinetics notion of reaction rate. However, because the concept of reaction rates is connected to both the macroscopic and microscopic worlds, as in the case of molecular collisions and the idea of activation energy, as well as the influence of temperature or concentration on the reaction rate, it is challenging for students to understand. According to research by Djafar et al. (2024), one of the abstract chemistry topics that students struggle to grasp is the reaction rate.

The complexity of the concept of reaction rate results in a variety of misconceptions, such as misconceptions of the mechanism of catalysts, misconceptions of the rate equation, and ignorance of the variables affecting reaction rate. The misconceptions of students, as studied by Harahap & Novita, included the subtopics of concentration, which comprised 16%; temperature, which comprised 19%; surface area, which comprised 41%; and catalysts, which comprised 24%. Lestari et al. (2021) study revealed misconceptions of students regarding the

fundamental concept of reaction rate, which comprised 22.58%; the relationship between reaction order and reaction coefficient, which comprised 41.93%; and the variables affecting reaction rate. In addition, as 41.93% of the students showed misconceptions of the reaction rate equation, it was demonstrated that the quantifications of chemical kinetics are not easy. Past studies have shown that students still have misconceptions about the rate of reaction. It is essential for the teacher to identify students with misconceptions and provide solutions to these misconceptions. If students still have misconceptions about the rate of reaction, it will affect their understanding of the next topic.

Unlike multiple-choice tests, which require pupils to make guesses, essay tests are lengthy and cover a broad range of issues. In order to eliminate the weaknesses of the traditional multiple-choice test, as well as reduce the potential for bias, multiple-choice tests were created (Sakahuni & Ramadhanti, 2021). Since pupils are only required to make guesses based on memorization in multiple-choice tests, it is hard to determine which pupils understand a topic and which do not.

The identification of misconceptions is an important part of understanding the difficulties students face in their learning and improving the strategies for teaching. It can be done through multiple-choice tests, concept mapping, open-ended tests, in-depth interviews, and other tools. Among all the tools, the multiple-choice test is the most commonly used because it is the easiest method in terms of administration, processing, and analysis (Tan et al., 2019). Tests used to diagnose misconceptions are classified into five types: one-tier, two-tier, three-tier, four-tier, and five-tier tests. A one-tier diagnostic test has been found to be less effective as a diagnostic tool because it cannot clearly distinguish between students who are correct or incorrect in their response, particularly in understanding the reason behind the response. On the other hand, a three-tier diagnostic test includes a measure of students' level of confidence in the response as well as the reason given. A four-tier diagnostic test allows the level of confidence in both the chosen response and the reason to be evaluated separately. A four-level diagnostic test can be conducted to determine the students who are right in giving answers but wrong in the reasoning part (Mualifah & Rahayu, 2023). All the four levels together can be used to distinguish the understanding and misunderstanding of students in terms of high confidence.

Misunderstandings in learning are extremely adverse for students since they can impede their learning process. Misunderstanding or misunderstanding learning concepts, especially in reaction rates, makes it hard for students to fully comprehend advanced learning concepts associated with reaction rates, which hinders their progressive development of correct

knowledge (Maghfira et al., 2022). The students' level of misconceptions is extremely high, which shows poor conceptual analysis skills on their part, making them rely on memorization instead of grasping the basics of the concept. This will only impede their learning process since initial conceptual understanding plays a crucial role in grasping complex ideas in subsequent learning materials. Therefore, misconceptions need to be addressed in order to ensure a smooth flow in the learning process for students so that misconceptions do not impede them in their learning process.

Students have the opportunity to learn independently during the learning process. When teachers provide instructions, each student's cognitive abilities influence the process of receiving and understanding the material. Different types of knowledge construction can result from variations in students' capacity to receive and process learning materials. Students are more likely to associate new knowledge with their pre-existing cognitive schemas. In this regard, the students may develop misunderstandings because their gained knowledge may not be in accordance with the proper scientific concepts (Hidayat et al., 2020). To identify the conceptual errors and misconceptions in the minds of the students, the diagnostic tests can be used. The questions given in the tests not only indicate the level of understanding of the students regarding a particular topic, but the way in which the students solve the problems, even if their answers are wrong, can also be seen (Yasthophi & Ritongga, 2019).

METHOD

The participants in this research were students in the eleventh-grade class at a Senior High School in Serang, Indonesia who had previously learned the concept of reaction rates. A total of 38 students was involved as the research sample. The research method in this study was qualitative descriptive research. Descriptive research is a method of collecting data intended as a test of the hypotheses and questions posed in relation to the end condition of the research subjects, as explained by Purba et al. (2021).

This study used a four-level multiple-choice test with twenty validated multiple-choice questions as its data gathering method. The purpose of this test is to gauge students' conceptual grasp of the idea of reaction rates, specifically the subconcept that addresses the variables that influence reaction rates. There are four tiers in the four-level multiple-choice exam. The first tier consists of the typical multiple-choice questions; the second tier is the students' degree of confidence in the answer they have selected; the third tier is the multiple-choice questions that the students have selected as the explanation for the answer they have selected; and the final tier is the students' degree of confidence in the explanation they have selected. After the test was finished, the 4TMC diagnostic test results were examined and

categorized into three groups: Understanding the Concept (UC), Misunderstanding (M), and Not Understanding the Concept (NUC), as shown in Table 1.

Table 1. Categories of Student Understanding Levels with the *Four Tier Multiple Choice Test*

Tier I	Tier II	Tier III	Tier IV	Criteria
Correct	Confident	Correct	Confident	Understand the Concept (UC)
Correct	Not Confident	Incorrect	Confident	
Correct	Confident	Incorrect	Confident	Misconception (M)
Incorrect	Confident	Correct	Not Confident	
Incorrect	Confident	Correct	Confident	
Incorrect	Confident	Incorrect	Not Confident	
Incorrect	Not Confident	Incorrect	Confident	
Incorrect	Confident	Incorrect	Confident	
Correct	Not Confident	Correct	Not Confident	Not Understand the Concept (NUC)
Correct	Confident	Correct	Not Confident	
Correct	Not Confident	Correct	Confident	
Correct	Not Confident	Incorrect	Not Confident	
Incorrect	Not Confident	Correct	Not Confident	
Incorrect	Not Confident	Incorrect	Not Confident	
Correct	Confident	Incorrect	Not Confident	
Correct	Not Confident	Correct	Confident	

(Fariyani et al., 2015)

RESULTS AND DISCUSSION

This study was designed to examine the students' understanding of the concepts related to reaction rates, specifically the subtopics dealing with the factors that affect reaction rates. In the analysis of the students' understanding of the concepts, the students' understanding was divided into three categories: Understanding the Concept (UC), Misunderstanding (M), and Not Understanding the Concept (NUC). In order to conduct the study, the instrument used was the Four-Level Multiple Choice Test. Students' conceptual understanding percentage can be seen in Figure 1.

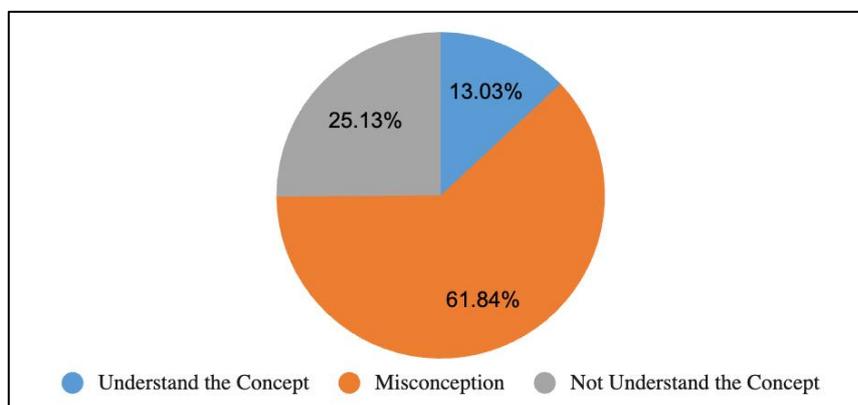


Figure 1. Students' Conceptual Understanding Percentage

The results of this study show that students in class XI have a conceptual knowledge of 13.03%, misconceptions of 61.84%, and a lack of comprehension of 25.13%, as shown in Figure 1.

Table 2. Percentage Categories of Misconception Levels

Percentage	Category
0 – 30 %	Low
31 – 60 %	Medium
61 – 100%	High

(Febrianti et al., 2024)

Table 2 shows that the majority of students had misconceptions and just a tiny portion demonstrated a solid grasp of the idea. The outcomes demonstrate how well the four-tier multiple-choice exam assesses students' conceptual comprehension. This approach offers a more thorough analysis since it looks at the students' rationale and degree of confidence in their answers in addition to determining whether or not the students' answers are correct. The efficacy of the multi-tier diagnostic test in reducing the likelihood of classification errors was validated by earlier research (Kaltakci-Gurel et al., 2015).

Twenty questions on the idea of reaction rates, namely the variables that influence reaction rates, made up the four-tier multiple-choice test used in this study. Five questions about concentration, five about temperature, five about surface area, and five about catalysts made up the test. As indicated by the classification findings in Table 3, the gathered data was further categorized based on the percentage distribution of the variables influencing reaction rates.

Table 3. Percentage of Each Category of Students' Understanding Level of Factors Affecting the Reaction Rate

Item Numbers	Factors Affecting the Reaction Rate	UC	M	NUC
1–5	Concentration	22.63%	52.11%	25.26%
6–10	Temperature	23.68%	53.16%	23.16%
11–15	Surface Area	3.16%	68.95%	27.89%
16–20	Catalyst	2.63%	73.16%	24.21%

Notes: **UC** = Understand the Concept, **M** = Misconception, **NUC** = Not Understand the Concept

The results of the research showed that the conceptual understanding of the students regarding the subtopics of the factors related to the rate of reaction is diverse. Among the factors, the temperature factor had the highest percentage of students' conceptual understanding, amounting to 23.68%. This shows that the temperature factor is easier for the students to understand than the other factors that influence the rate of reaction. These findings

are in accordance with the results of the studies previously conducted by Harahap et al. (2021) and Samay et al. (2025), which showed that students mostly correctly understand the concept of increasing temperature. The direct relationship between the concept of temperature and the phenomena of everyday life and the demonstration of temperature in the learning process could be the main reason for this phenomenon.

The catalyst factor showed the highest percentage of misconceptions, amounting to 73.16%. This reveals that the concept of the way catalysts function in chemical reactions is still one of the most difficult concepts for students to understand correctly. Previous studies by Jusniar et al. (2020) and Wiji et al. (2022) also found that students often develop misconceptions in the concept of catalysts. Most students believe that the inclusion of a catalyst in a chemical reaction increases both activation energy and kinetic energy. According to Rahayu et al. (2024), this misconception might occur because students are still unable to understand the energy profile diagram and make a proper distinction between activation energy and kinetic energy.

In the study by Fantiani et al. (2023), it was found that a misconception exists in the minds of the students, where they think that a substance with smaller particle size will have surface area, and this study also found that the students were not yet able to develop a conceptual relationship between the surface area of a substance and the frequency of collisions between the particles of that substance. Percentage of misconceptions for each factor affecting the reaction rate can be seen in Figure 2. The highest percentage of students who did not understand this concept was 27.89 percent. During the learning process, the lack of ability in visualizing and concretely representing the concept also led to the lack of understanding by the students regarding the effect of surface area on the rate of reactions.

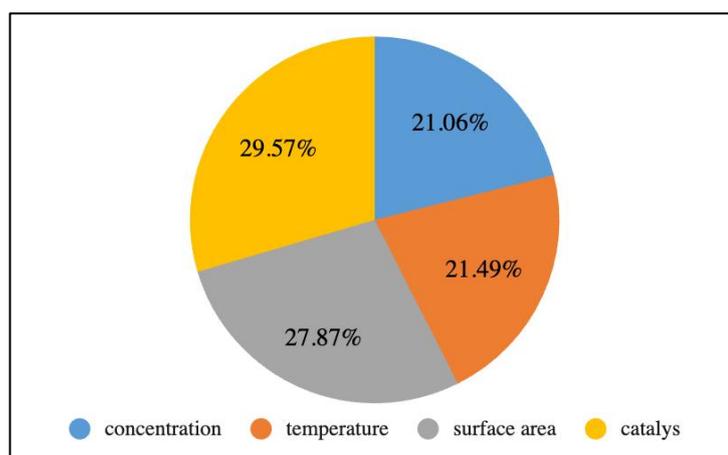


Figure 2. Percentage of Misconceptions for Each Factor Affecting the Reaction Rate

The catalyst factor was represented by five questions, i.e., questions 16 to 20, with different indicators. This factor recorded the highest level of misconception with a prevalence

of 29.57%, as depicted in Figure 2. Question number 16 focused on the students' ability to justify the relationship between the addition of the catalyst and the activation energy of the reaction, as well as the appropriate reasoning. Misconceptions related to this question may stem from the fact that students lack the ability to differentiate between the two types of energy—activation and kinetic—leading to the assumption that the addition of the catalyst affects the two types of energy at the same time. On the other hand, question number 17 focused on the students' ability to justify the influence of the changes in the activation energy caused by the addition of the catalyst on the reaction rate, as well as the appropriate justification. This question may be based on the fact that students lack the knowledge that catalysts have the ability to decrease the activation energy in order to increase the number of reacting particles with the minimum energy required for the reaction to take place. Consequently, they may link low activation energy with slow reactions. The students' capacity to explain the catalyst classification and give a valid rationale is being tested in question 18. The students may misunderstand this section because they may confuse the functional activator-inhibitor catalyst classification system with the phase catalyst classification system, which is homogeneous-heterogeneous. The students may assume that the two systems have the same purpose and can be used interchangeably. The students' capacity to give examples of the addition of the catalyst to the reaction and give a valid rationale is being tested in question 19. The students may misunderstand this section because they may not comprehend that the catalyst must be something that speeds up the reaction and is not permanently used up. Therefore, they may assume that the reactant is glucose. For instance, in Question 20, students are asked to understand a graph showing the relationship between the different stages of a reaction and the required energy, then explain the effect of a catalyst on the rate of a reaction. However, some students are not clear about the graph showing the relationship between the different stages of a reaction and the required energy, as they think the reaction path showing the higher activation energy indicates the addition of a catalyst to the reaction. This shows that students might not understand the reaction mechanism as presented in the graph. According to the analysis, the misconceptions of students might come from students' personal understanding or intuition. Sometimes, students might associate some aspects of what they know with the concepts they are required to learn, but this might not be accurate at all times. Students might also create new knowledge based on incorrect information, relying on personal understanding, which might not be accurate at all times, leading to a difference in the created concepts and the accurate information (Rohmah et al., 2023).

CONCLUSION

The results and discussion lead to the conclusion that students in the eleventh grade have a poor level of conceptual knowledge and a high percentage of misunderstandings (61.84%). Additionally, this study demonstrated that the Four Level Multiple Choice Test is a useful instrument for evaluating students' comprehension in a number of areas, particularly in differentiating between students who only know the answer and those who truly grasp the concepts. The usage of catalysts had the highest number of misconceptions (73.16%) among the factors. This could be because the catalyst's action is a complicated process that calls for unique teaching methods to guarantee greater comprehension.

The results of this study show that more effective teaching methods are needed to raise students' comprehension levels, particularly when it comes to dispelling their preconceptions. This is especially crucial when explaining complex ideas like activation energy, catalytic mechanisms, and the connection between particle impact frequency and surface area. In order to prevent any detrimental effects on the students' comprehension of chemical ideas, it is crucial for the teacher to detect the misconceptions that the pupils hold.

REFERENCES

- Djafar, Y., Ishak, I., & Tangio, J. S. (2024). Analisis kemampuan berpikir kritis siswa dalam menyelesaikan instrumen tes two-tier multiple choice pada materi laju reaksi. *Jurnal Inovasi Pendidikan Kimia*, 18(2), 112–117. <https://doi.org/10.15294/f677x032>
- Fantiani, C., Afgani, M. W., & Astuti, R. T. (2023). Analisis miskonsepsi siswa berbantuan Certainty of Response Index (CRI) pada materi pembelajaran laju dan orde reaksi. *Jurnal Inovasi Pendidikan Kimia*, 17(1), 49–53.
- Fariyani, Q., Rusilowati, A., & Sugianto. (2015). Pengembangan four-tier diagnostic test untuk mengungkap miskonsepsi fisika peserta didik SMA kelas X. *Journal of Innovative Science Education*, 4(2), 41–49.
- Harahap, I. P. P., Novita, D., Fauziah, R. U., & Sriwarom, C. (2021). Exploring cause of misconception on reaction rate using 4TMC diagnostic test instrument. *JPPS (Jurnal Penelitian Pendidikan Sains)*, 11(1), 1–11.
- Harahap, I. P. P., & Novita, D. (2021). Identify misconception on reaction rate concept using four-tier multiple choice test diagnostic test instrument. *Journal of Chemistry Education Research*, 5(1), 6–11. <https://doi.org/10.26740/jcer.v5n1.p6-11>
- Hidayat, F. A., Irianti, M., & Fathurrahman, F. (2020). Analisis miskonsepsi siswa dan faktor penyebabnya pada pembelajaran kimia di Kabupaten Sorong. *BASA (Barometer Sains) Jurnal Inovasi Pembelajaran IPA*, 1(1). <https://doi.org/10.36232/basa.v1i1.456>
- Jusniar, J., Effendy, E., Budiasih, E., & Sutrisno, S. (2020). Misconceptions in rate of reaction and their impact on misconceptions in chemical equilibrium. *European Journal of Educational Research*, 9(4), 1405–1423. <https://doi.org/10.12973/eujer.9.4.1405>
- Kaltakci-Gurel, D., Eryilmaz, A., & McDermott, L. C. (2015). A Review and Comparison of Diagnostic Instruments to Identify Students' Misconceptions in Science. *Eurasia*

Journal of Mathematics, Science and Technology Education, 11(5), 989-1008.
<https://doi.org/10.12973/eurasia.2015.1369a>

- Lestari, L. A., Subandi, & Habiddin. (2021). Identifikasi miskonsepsi siswa pada materi laju reaksi dan perbaikannya menggunakan model pembelajaran Learning Cycle 5E dengan strategi konflik kognitif. *Jurnal Pendidikan: Teori, Penelitian, dan Pengembangan*, 6(6), 888–894. <https://doi.org/10.17977/jptpp.v6i6.14876>
- Maghfira, A., Jusniar, J., & Muhammad, A. (2022). Pengembangan instrumen tes diagnostik tiga tingkat untuk mengidentifikasi miskonsepsi peserta didik pada materi pokok laju reaksi. *Chemistry Education Review*, 6(1), 96–109.
- Mualifah, S. R. L., & Rahayu, M. (2023). Identifikasi Miskonsepsi Siswa Kelas XI IPA MAN 2 Lamongan Menggunakan Instrumen Tes Diagnostik Five Tier pada Konsep Laju Reaksi. *Berajah Journal*, 3(3), 513-526. <https://doi.org/10.47353/bj.v3i3.260>
- Purba, R. A., Mawati, A. T., Ardiana, D. P. Y., Pramusita, S. M., Bermuli, J. E., Purba, S. R. F., Sinaga, K., Mardiana, N., Rofiki, I., & Recard, M. (2021). *Media dan teknologi pembelajaran*. Yayasan Kita Menulis.
- Rahayu, I., Wiji, W., Widhiyanti, T., & Mulyani, S. (2024). Analysis of misconceptions on the factors that affect the reaction rate. In *International Conference on Mathematics and Science Education* (pp. 140–150). KnE Social Sciences. <https://doi.org/10.18502/kss.v9i13.15914>
- Rohmah, A. N., Sari, I. J., Rohmah, N. L., Syafira, R., Fitriana, Admoko, S. (2023). Implementation of the “Merdeka Belajar” curriculum in the Industrial 4.0 era. *International Journal of Research and Community Empowerment*, 1(1), 22–28. <https://doi.org/10.58706/ijorce>
- Sakahuni, S., & Ramadhanti, A. (2021). Perbandingan hasil belajar menggunakan tes pilihan ganda ditinjau dari kemampuan berpikir kritis siswa. *Integrated Science Education Journal (ISEJ)*, 2(3), 89–93. <https://doi.org/10.37251/isej.v2i3.174>
- Samay, U. F. K., Amsad, L. N., & Suaka, I. Y. (2025). Analisis penguasaan konsep kecepatan reaksi pada peserta didik kelas XI IPA 3 SMA YPPK Teruna Bakti Jayapura. *Papua Journal of Chemical Education*, 1(1), 1–10.
- Tan, K. C. D., Taber, K. S., Liew, Y. Q., & Teo, K. L. A. (2019). A web-based ionisation energy diagnostic instrument: Exploiting the affordances of technology. *Chemistry Education Research and Practice*, 20(2), 412-427. <http://dx.doi.org/10.1039/C8RP00215K>
- Wiji, W., Rahayu, I., Widhiyanti, T., & Mulyani, S. (2022). Students’ conception, troublesome knowledge, and threshold concept of catalyst effect on reaction rate. *Jurnal Pengajaran MIPA*, 27(1), 1–8. <https://doi.org/10.18269/jpmipa.v27i1.49957>
- Yasthophi, A., & Ritonga, P. S. (2019). Pengembangan instrumen tes diagnostik multiple choice four tier pada materi ikatan kimia. *Konfigurasi*, 3(1), 23-31. <https://doi.org/10.24014/konfigurasi.v3i1.6797>