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Analyzing Pre-Service Chemistry Teachers' Understanding and Misconceptions of Reaction Rates Using a Four-Tier Diagnostic Instrument

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ABSTRACT

This study aims to analyze the understanding and misconceptions of prospective chemistry teacher students regarding the concept of reaction rate using the four-tier diagnostic instrument FTDICK (Four-Tier Diagnostic Instrument for Chemical Kinetics). The study was conducted descriptively quantitatively involving 115 students from four academic levels at a university in Palembang. Data were obtained through the FTDICK diagnostic test which has been validated and translated into Indonesian. This instrument measures conceptual understanding, reasons for answers, and the level of confidence in the answers and reasons. The results of the analysis showed that only 6–7% of respondents answered correctly consistently in three main conceptual categories: reaction order, rate law, and factors that affect reaction rate. The level of understanding of Tier 1 (conceptual answers) was high, but the reasons (Tier 3) tended to be low, indicating deep-rooted misconceptions. Common misconceptions include the assumption that reaction order is determined by stoichiometric coefficients, that increasing temperature increases activation energy, and ignorance of catalyst mechanisms. Although final year students showed increased understanding, misconceptions were still found at all levels. These findings indicate the need for cognitive conflict-based learning strategies, the use of simulations, and contextual approaches in chemistry teacher education. This study recommends strengthening diagnostic instruments and learning interventions to prevent the spread of scientific misconceptions to school students by future chemistry teachers.

INTRODUCTION

Misconceptions about reaction rates are a common problem in chemistry learning, especially among student chemistry teachers. These misconceptions can hinder the understanding of more complex chemistry concepts and impact the quality of their teaching in the future. Study by Çalik & Ayas (2005) shows that students often misunderstand basic concepts such as the effect of concentration and temperature on reaction rates. Students also find it difficult to solve problems on the concept of heating and temperature. (Inaltekin & Akcay, 2021). This is reinforced by research in Indonesia which found that 60% of pre-service chemistry teacher students had an inaccurate understanding of the factors that influence reaction rates (Rahmawati et al., 2019). Therefore, identifying and correcting these misconceptions is important to improve the quality of chemistry education. If left unaddressed, persistent misconceptions may become deeply rooted and difficult to change, ultimately affecting students' ability to teach chemistry accurately and effectively.

A proper understanding of reaction rates is essential for aspiring chemistry teachers as they will be at the forefront of transferring knowledge to the next generation. Teachers who have a strong understanding of chemical concepts will be more effective in teaching and inspiring students.(Nieswandt, 2007; Wu et al., 2001). Research by Kind (2004) shows that teachers who have a good understanding of concepts tend to be able to create a more interactive and in-depth learning environment. In addition, teachers' misconceptions can be passed on to students, thus worsening the quality of learning. (Leonard et al., 2014; Maskiewicz & Lineback, 2013). Thus, ensuring that pre-service teachers have an accurate understanding of reaction rates is a critical step in improving the quality of chemistry education.

Previous studies have identified common misconceptions in learning reaction rates. These studies provide a basis for understanding the patterns of errors that are often made. Many research reports indicate that many students have difficulty in understanding reaction rates even though this topic has been studied in high school. (Cakmakci & Aydogdu, 2011). Reaction rates require good conceptual understanding and algorithmic operational skills. (Lestari et al., 2021). Voska & Heikkinen (2000) identified that students often misinterpret the effect of catalysts on activation energy. Likewise, research by Chandrasegaran et al., (2007) found that many students do not understand the relationship between surface area and reaction rate. Although much research has been done, there is still a need to explore this misconception in more depth, especially among student chemistry teachers.

Although there are many studies on reaction rate misconceptions, studies that focus on student chemistry teachers are still limited. Most previous studies focused on high school students rather than student teachers, who have a crucial role in chemistry education (Markic & Eilks, 2013). For example, research by Sanger & Greenbowe (1999) discusses many high school students' misconceptions, but does not specifically address pre-service teachers. In addition, studies in Indonesia show that pre-service chemistry teachers' misconceptions are often not detected in teacher education curricula (Jusniar et al., 2020; Wardah et al., 2020). Therefore, more specific research is needed to identify and address misconceptions in pre-service chemistry Preliminary findings from our department also reveal that more than 50% of chemistry education students across various academic levels experience misconceptions related to reaction rates, indicating a persistent and widespread issue. Therefore, more specific research is needed to identify and address misconceptions in pre-service chemistry teacher students.

This research is important to obtain effective identification in overcoming misconceptions about reaction rates. By understanding the root of misconceptions, an efficient formula can be designed in solving the problem. Identification of misconceptions can use two-tier or three-tier multiple choice test instruments. (Chandrasegaran et al., 2007; Laksono, 2018, 2019). However, this instrument still has some weaknesses so it was developed into a four-tier format to improve accuracy and breadth in measuring conceptual understanding. One of the instruments that can be used is the Four Tier Diagnostic Instrument for Chemical Kinetics developed by Habiddin & Page (2019). This instrument consists of four levels that include conceptual understanding and the level of confidence in the answers and reasons, thus providing a comprehensive picture of the location and type of misconceptions experienced by students. This study is expected to provide a significant contribution to improving the understanding of the concept of reaction rate.

This study aims to provide information on misconceptions held by pre-service chemistry teacher students related to the concept of reaction rate. Misunderstanding of this concept can have an impact on the effectiveness of chemistry learning at the school level, considering the strategic role of pre-service teachers as agents of science transformation. By identifying emerging misconceptions, educators and curriculum developers can design more targeted learning interventions. This study specifically examines three main aspects, namely the analysis of the understanding of pre-service chemistry teacher students in three categories of concepts, analysis of the consistency of answers to assess the stability of conceptual understanding, and identification of misconceptions that occur. The findings of this study are expected to provide practical recommendations in improving the quality of chemistry learning in higher education, as well as supporting the formation of more competent and reflective pre-service educators.

METHODS

Research Design

This study uses a quantitative descriptive approach to obtain an objective picture of students' misconceptions on the concept of reaction rate (Sugiyono, 2018; Yonata, 2021). This study was conducted with diagnostics to identify prospective chemistry teachers' misconceptions about the concept of reaction rate and to test the relationship between their misconceptions and self-confidence.. The main instrument used in this study was the Four-Tier Diagnostic Instrument for Chemical Kinetics (FTDICK) developed by Habiddin & Page (2019) and has been translated into Indonesian.

In addition to FTDICK, this study also used a learning style questionnaire to explore the possible relationship between learning styles and students' misconceptions. This diagnostic test was designed to measure students' conceptual understanding of three main categories in the concept of reaction rate, namely (1) factors that affect reaction rate, (2) collision theory and activation energy, and (3) reaction kinetics models and rate equations. Thus, this study not only identified the level of students' understanding but also analyzed the main sources of misconceptions. The instruments used in this study have been validated by experts to ensure the accuracy of their content and constructs. After validation, revisions were made to the instruments based on input from experts before being applied in the study.

Research Target

The study was conducted at a university located in Palembang that offers a chemistry education program. The participants consisted of 115 pre-service chemistry teacher students from four academic levels: Level I (20 students), Level II (30 students), Level III (35 students), and Level IV (40 students). In this context, Level I refers to first-year students, Level II to second-year students, Level III to third-year students, and Level IV to final-year students.

Students in Level I had only studied reaction rate material during high school, while those in Levels II to IV had studied the material both in high school and in university courses. The university-level material covered in Levels II to IV includes topics such as reaction order, rate law, and factors that affect the rate of reaction. This classification allows for the identification of conceptual understanding and potential misconceptions across different stages of academic progression.

Research Data

The data in this study were obtained through the FTDICK (Four-Tier Diagnostic Instrument for Chemical Kinetics) Instrument developed by Habiddin (2019) and has been translated into Indonesian. This instrument is based on the Four-Tier Misconception Test which is designed to identify students' conceptual understanding and misconceptions of chemical kinetics.

The Four-Tier Misconception Test consists of four levels of questions as follows:

1. Tier 1 (Conceptual Understanding): Students are asked to choose an answer to a concept-based question related to chemical kinetics.
2. Tier 2 (Answer Confidence): Students provide a level of confidence in the answer they chose in the first tier.
3. Tier 3 (Conceptual Reasoning): Students choose an appropriate reason to support their answer in the first tier.
4. Tier 4 (Reason Confidence): Students provide a level of confidence in the reason they

chose in the third tier.

The Four-Tier Misconception Test allows researchers to not only identify incorrect answers but also detect the level of students' confidence in their understanding. This helps in classifying students into categories of correct understanding, misconception, or not knowing the concept.

Research Instruments

This study uses the FTDICK (Four-Tier Diagnostic Instrument for Chemical Kinetics) instrument developed by Habiddin (2019) and has been translated into Indonesian. This instrument is used to measure the conceptual understanding of pre-service chemistry teachers regarding the concept of reaction rate and to identify misconceptions.

Data Analysis

Data analysis in this study was primarily conducted using descriptive quantitative methods. The goal was to identify the level of students' understanding of the reaction rate concept, measure the prevalence of misconceptions, and observe trends related to their self-confidence. The number of students in each category was then converted into percentages, which were used to describe the distribution of conceptual understanding and misconceptions across different academic levels. This percentage-based analysis also helped highlight patterns and the extent of misconceptions among pre-service chemistry teachers.

The study used the FTDICK (Four-Tier Diagnostic Instrument of Chemical Knowledge), an existing validated instrument designed to identify students' understanding and misconceptions. The instrument was administered online to pre-service chemistry teacher students. The responses were then analyzed quantitatively, with student answers categorized into three levels: understood, misconception, and not understood. The percentage distribution of each category was used to reveal patterns of misconceptions related to reaction rate material. In the final stage, the data were interpreted, and the findings were discussed in relation to previous research and the educational context.

The analysis was conducted to identify the level of misconceptions in each category of reaction rate concepts and the most dominant conceptual error patterns. The results of this study were then compared with previous studies to provide broader insight into the factors that influence students' understanding of the concept of reaction rates. Through this analysis, the research is expected to contribute to the development of more effective learning strategies in overcoming misconceptions and improving pre-service chemistry teachers' conceptual understanding of the material on reaction rates.

RESULTS AND DISCUSSION

The results of the study were obtained by analyzing the number of correct answers in each category with the percentage of each class on each question item. The percentage of correct answers on questions at tier 1, accompanied by a level of confidence at tier 2, reasons at tier 3, and accompanied by a level of confidence at tier 4. The main categories of misunderstanding, recorded by FTDICK, can be seen in Table 1.

Table 1. Major Misconception Categories Assessed by FTDICK

FTDICK Category	Category Description	Item
Reaction Order	Application and/or understanding of reaction orders 0, 1, 2 and half-life	1, 2, 3, 4, 5,6,9,10,35,36, 37, 38
Law of Rate	Using chemical reactions to determine the rate law of a reaction	7,8,13,14,15,16, 23,24, 33,34, 39,40
Factors that affect the rate of reaction	The effect of concentration, temperature, surface area, catalyst on reaction rate	11, 12, 17, 18, 19, 20, 21, 22, 25, 26, 27, 28, 29, 30, 31, 32

A. Analysis of Pre-Service Chemistry Teachers' Understanding in Three Concept Categories

The analysis was conducted to compare the conceptual understanding of respondents from 4 levels of education of pre-service chemistry teachers in the three conceptual categories shown in Table 2.

Table 2. Percentage of pre-service chemistry teachers' who answered correctly in three conceptual categories

No	Concept Category	Question Number	Pre-Service Teacher Student Level				Amount N=115
			I N=20	II N=20	III N=35	IV N=40	
1	Reaction Order	1 (D)	75,00 (15)	60,00 (12)	68,57(24)	87,50(35)	74,78(86)
		2 (E)	80,00(16)	50,00(10)	60,00(21)	80,00(32)	68,70(32)
		3 (C)	70,00(14)	75,00(15)	40,00(14)	62,50(25)	59,13(68)
		4 (B)	60,00(12)	70,00(14)	40,00(14)	72,50(29)	60,00(69)
		5 (C)	45,00(9)	40,00(8)	25,71(9)	70,00(28)	46,96(54)
		6 (E)	90,00(18)	40,00(8)	28,57(10)	70,00(28)	55,65(64)
		9 (C)	30,00(6)	30,00(6)	2,86(1)	62,50(25)	33,04(38)
		10 (A)	80,00(16)	75,00(15)	40,00(14)	92,50(37)	71,30(82)
		35 (D)	30,00(6)	45,00(9)	11,43(4)	50,00(20)	33,91(39)
		36 (A)	60,00(12)	70,00(14)	42,86(15)	75,00(30)	61,74(71)
		37 (A)	70,00(14)	80,00(16)	60,00(21)	67,50(37)	67,83(78)
		38 (B)	45,00(9)	40,00(8)	25,71(9)	60,00(24)	43,48(50)
		Average	61,25	56,25	37,14	70,83	56,38
2	Law of Rate	7 (B)	80,00(16)	65,00(13)	40,00(14)	92,50(37)	69,57(80)
		8 (C)	15,00(3)	30,00(6)	14,29(5)	17,50(7)	18,26(21)
		13 (A)	30,00(6)	45,00(9)	11,43(4)	50,00(20)	33,91(39)
		14 (B)	75,00(15)	70,00(14)	48,57(17)	85,00(34)	69,57(80)
		15 (E)	80,00(16)	70,00(14)	57,14(34)	85,00 (34)	85,22(98)
		16 (C)	15,00(3)	10,00(2)	5,71(2)	30,00(12)	16,52(19)
		23 (A)	15,00(3)	10,00(2)	5,71(2)	30,00(12)	16,52(19)
		24 (A)	60,00(12)	70,00(14)	40,00(14)	72,50(29)	60,00(69)
		33 (B)	75,00(15)	75,00(15)	28,57(10)	77,50(31)	61,74(71)
		34 (A)	35,00(7)	70,00(14)	14,29(5)	60,00(24)	43,48(50)
		39 (A)	90,00(18)	30,00(6)	28,57(10)	70,00(28)	53,91(62)
		40 (C)	70,00(14)	65,00(13)	40,00(14)	85,00(34)	65,22(75)
		Average	57,92	56,25	30,71	65,63	53,04
3	Reaction Rate Factors	11 (A)	80,00(16)	80,00(16)	28,57(10)	77,50(31)	63,48(73)
		12 (C)	35,00(7)	70,00(14)	17,14(6)	62,50(25)	45,22(52)
		17 (B)	35,00(7)	70,00(14)	17,14(6)	62,50(25)	45,22(52)
		18 (E)	40,00(8)	40,00(8)	11,43(4)	25,00(10)	26,09(30)
		19 (C)	15,00(3)	10,00(2)	0,00(0)	2,50(1)	5,22(6)
		20 (C)	15,00(3)	30,00(6)	14,29(5)	17,50(7)	18,26(21)
		21 (D)	75,00(15)	60,00(12)	68,57(24)	87,50(35)	74,78(86)
		22 (E)	80,00(16)	50,00(10)	57,14(20)	80,00(32)	67,83(78)
		25 (A)	45,00(9)	40,00(8)	25,71(9)	62,50(25)	44,35(51)
		26 (A)	90,00(18)	40,00(8)	28,57(10)	65,00(26)	53,91(62)
		27 (D)	80,00(16)	65,00(2)	40,00(14)	92,50(37)	69,57(80)
		28 (C)	15,00(3)	30,00(6)	14,29(5)	17,50(7)	18,26(21)
		29 (B)	15,00(3)	30,00(6)	14,29(5)	17,50(7)	18,26(21)
		30 (A)	70,00(14)	75,00(10)	40,00(14)	92,50(37)	69,57(80)
		31 (B)	30,00(6)	30,00(6)	2,86(1)	62,50(25)	33,04(38)
		32 (A)	75,00(15)	70,00(14)	40,00(14)	92,50(37)	69,57(80)
		Average	75,00(15)	70,00(14)	40,00(14)	92,50(37)	69,57(80)

The results of the study showed that the percentage of pre-service chemistry teacher students who answered 12 questions about the concept of reaction order (items 1, 2, 3, 4, 5, 6, 9, 10, 35, 36, 37, 38) correctly reached 56.38% of the total respondents. These items assessed indicators such as identifying the order of reaction based on rate data, interpreting the relationship between concentration and rate, and distinguishing reaction order from stoichiometric coefficients. Reaction order is a fundamental concept in chemical kinetics that relates reaction rate to reactant concentration. The low understanding at Level III (37.14%) may be due to the mathematical complexity in determining reaction order, especially when it involves experimental data analysis. (Bain & Towns, 2016). However, a significant increase at Level IV (70.83%) indicates that problem-based learning and laboratory experiences can improve conceptual understanding (Chandrasegaran et al., 2007). A common misconception occurs when students assume that the reaction order is the same as the stoichiometric coefficient, even though the reaction order is determined experimentally (Gkitzia et al., 2011). This is reinforced by the finding that Level III students still have difficulty distinguishing between reaction order and stoichiometry, while Level IV students are better able to apply this concept in more complex contexts (Cakmakci, 2010).

Rate Law Concept 53.04% of pre-service chemistry teachers correctly answered 12 questions about the rate law, namely on numbers 7, 8, 13, 14, 15,16, 23, 24, 33, 34, 39, 40 with a striking difference in the scores of the four levels. The rate law is often a source of misconception because students tend to memorize formulas without understanding their physical meaning (K. Taber, 2002). The finding that Level III had the lowest understanding (50.71%) may be due to a lack of kinetic data analysis skills, such as the use of initial rate methods or integration of rate equations (Justi, 2003). The increase at Level IV (65.63%) shows that inquiry-based learning and the use of computational simulations can help students visualize the relationship between concentration and reaction rate (Plass et al., 2012). Additionally, Level IV students may have been exposed to more real-world cases (e.g., complex reactions such as chain reactions) that strengthen their understanding (Bretz, 2001).

Concept of Factors Affecting Reaction Rate Only 27.63% of the total respondents answered correctly 16 questions regarding the concept of reaction rate factors in numbers 11,12, 17, 18, 19, 20, 21, 22, 25, 26, 27, 28, 29, 30, 31, 32. These items addressed key indicators such as identifying the role of temperature, concentration, surface area, and catalysts in affecting the speed of reaction. Factors such as surface area, catalyst, temperature, and concentration are often understood separately without conceptual integration (Çalik & Ayas, 2005). Common misconceptions include assuming that catalysts change the equilibrium or that temperature only affects the rate of endothermic reactions. (Voska & Heikkinen, 2000). The low level of understanding at Level III (26.07%) may be because students have not experienced contextual learning, such as inquiry-based experiments. (Duit & Treagust, 2003). The increase in Level IV (59.22%) shows that laboratory experiences and real case discussions such as catalysts in industry can reduce misconceptions (Johnstone et al., 1994)

B. Analysis of Answer Consistency

Pre-Service Chemistry Teachers in Three Concept Categories In addition to analyzing the understanding of pre-service chemistry teachers in the three concept categories by calculating the percentage of those who answered correctly for each question number at each level, an analysis of the consistency of answers was also conducted in the six concept categories. The purpose of this analysis was to determine the level of understanding of each concept. The results were calculated by identifying the number of pre-service chemistry teachers who answered all questions in each concept correctly. The results of the analysis are shown in Table 3.

Table 3. Percentage of consistency of pre-service chemistry teachers' answers in three concept categories

No	Concept Category	Pre-Service Teacher Student Level				Amount
		I N=20	II N=20	III N=35	IV N=40	N=115
1	Reaction Order	0.00 (0)	10.00 (2)	2.86 (1)	10.00 (4)	6.09 (7)
2	Law of Rate	0.00 (0)	5.00 (1)	5.71 (2)	12.50 (5)	6.96 (8)
3	Reaction rate factors	5.00 (1)	5.00 (1)	2.86 (1)	12.50 (5)	6.96 (8)

Table 3 shows that only 6.09% of respondents were able to answer all questions related to the concept of reaction order correctly, 6.96% on the rate law, and 6.96% on the factors affecting the reaction rate. This finding indicates that most pre-service chemistry teachers still have difficulty in understanding the fundamental concepts of chemical kinetics, even though the respondents who answered correctly came from Levels II, III, and IV. This low percentage can be attributed to several factors, including misconceptions that are deeply embedded since early learning and the lack of a learning approach based on mathematical and contextual modeling (Jusniar et al., 2020). Recent studies have shown that students often assume that reaction order is the same as stoichiometric coefficients, or do not understand that rate laws must be determined experimentally (Firdaus et al., 2021). In addition, poor understanding of factors such as catalysts and temperature suggests that students tend to memorize concepts without understanding their underlying mechanisms. (Tal et al., 2021).

The differences in understanding between levels (II, III, and IV) indicate that higher academic experience has not completely overcome misconceptions. This is in line with research Adadan & Oner (2014), who found that misconceptions about reaction rates often persist into advanced grades due to a lack of inquiry-based learning and interactive simulations. Approaches such as problem-based learning (PBL) and the use of virtual laboratories have been shown to improve conceptual understanding (Darby-White et al., 2019), However a implementation is still limited in many institutions. Therefore, more effective learning strategies are needed, such as integrating technology and real case studies, to help students build a more holistic understanding of chemical kinetics.

C. Misconceptions of Pre-service Chemistry Teachers

Based on the analysis of understanding and consistency of answers of pre-service chemistry teachers in the six categories of concepts, several alternative concepts were identified that at least 10% of the total respondents chose the alternative concept. The value of 10% was chosen as the minimum value to be able to eliminate students' alternative conceptions. (Achterberg et al., 2017). The answers to the twenty questions show that the respondents have different conceptual understandings. Table 4 shows the alternative conceptions given by the respondents for the two-level questions and the single questions. Data on alternative conceptions can be useful information for lecturers in planning classroom teaching. Alternative conceptions were given by the respondents in all questions as shown in Table 4.

Table 4. Percentage of Alternative Concepts of Pre-service Chemistry Teachers regarding the Concept of Reaction Rate

Question Number (Correct Answer)	Alternative Concept	Pre-Service Teacher Student Level				Amount
		I N=20	II N=20	III N=35	IV N=40	N=115
2 (E)	The decay rate of the sample is constant (B)	27.5	31.34	40	34.69	32,89
	The decay rate of the sample is increased as the mass of the sample decreases (D).	55	42.86	40	34.69	32.89

Question Number (Correct Answer)	Alternative Concept	Pre-Service Teacher Student Level				Amount
		I N=20	II N=20	III N=35	IV N=40	N=115
4 (B)	it obeys the equation ln[A]t=ln[A]0-kt (A)	27.5	20	44	18.37	25.50
	it obeys the equation [A]t=[A]0-kt (C)	15	14.29	16	12.24	14.09
6 (E)	The value of t½ is constant (B)	30	20	20	12	20.13
	The rate of sample loss increases with decreasing concentration. (C)	32.5	40	40	28	34.23
	The rate of sample loss decreases with decreasing concentration. (D)	30	34.29	32	34.69	32.89
	The value of each successive half-life is 4 times the previous half-life. (F)	27.5	31.43	40	34.69	32.89
8 (C)	The exponent value in the rate law is obtained from the coefficients in the balanced equation (A)	55	42.86	40	34.69	32.89
	The rate law is stated based on the law of mass action which describes the relationship between the concentrations of reactants and products. (B)	27.5	20	44	18.37	25.50
10 (A)	The higher the concentration of both reactants, the higher the rate (B)	15	14.29	16	12.24	14.09
	The overall reaction order is 2, therefore increasing the concentration of either reactant will increase the rate to the power of 2 (C)	30	20	20	12	20.13
	There is no effect on the reaction rate because the order with respect to one reactant is zero (E)	27.5	31.43	40	34.69	32.89
12 (C)	The concentration of both reactants is the same, so the collision ratio is better (B)	55	42.86	40	34.69	32.89
	The concentration of Y is much higher than the concentration of X and this causes the reaction to complete more quickly (D)	27.5	20	44	18.37	25.50
14 (B)	The concentration of A at its half-life is twice its initial concentration (A)	15	14.29	16	12.24	14.09
	The concentration of A at its half-life is the same as its initial concentration (C)	30	20	20	12	20.13
16 (C)	Data obeys the zero-order reaction rate (A)	27.5	31.43	40	34.69	32.89
	Data obeys first order reaction rate (B)	55	42.86	40	34.69	32.89
	The value of k will be equal to the concentration of the reactant because it is constant (D)	27.5	20	44	18.37	25.50
18 (E)	The activation energy value is not determined at the rate (F)	15	14,29	16	12.24	14.09

Question Number (Correct Answer)	Alternative Concept	Pre-Service Teacher Student Level				Amount N=115
		I N=20	II N=20	III N=35	IV N=40	
	The higher the temperature, the higher the activation energy (Ea) (D)	30	20	20	12	20,13
20 (B)	The reaction has the highest energy in its transition state. (A)	27,5	31,43	40	34,69	32,89
	The reaction has the lowest energy in its transition state. (C)	55	42,86	40	34,69	32,89
	The reaction has the lowest activation energy (D)	27.5	20	44	18.37	25.50
22 (A)	Increasing temperature decreases the activation energy. (B)	15	14,29	16	12,24	14,09
	Increasing temperature increases the rate constant (E)	30	20	20	12	20.13
	Since the two reactions have the same activation energy value, their rate constants are also the same. (G)	27.5	31.43	40	34.69	32.89
24 (A)	The rate law is derived directly from the rapid rate mechanism. (B)	55	42.86	40	34.69	32.89
	The rate law is derived from the law of mass action. (C)	27,5	20	44	18.37	25.50
26 (A)	The reverse reaction is exothermic and the activation energy of this reverse reaction does not involve the ΔH value. (B)	15	14.29	16	12.24	14.09
	The reverse reaction is endothermic and the activation energy for the forward and reverse reactions is the same. (C)	30	20	20	12	20.13
28 (B)	The activation energy of the catalyzed and uncatalyzed pathways is the same, but the mechanisms are different. (A)	27.5	31.43	40	34.69	32.89
	The activation energy of the catalyzed pathway is lower than that of the uncatalyzed pathway and the mechanism is different. (C)	55	42.86	40	34.69	32.89
	The activation energy of the catalyzed pathway is higher than the uncatalyzed pathway and the mechanism is different. (E)	27.5	20	44	18.37	25.50
	Without increasing temperature, the activation energy and the mechanism of the catalyst and uncatalyzed pathways are the same. (F)	15	14.29	16	12.24	14.09
30 (A)	The substance is formed in one elementary reaction and consumed in the next reaction. (B)	30	20	20	12	20.13
	The substance is formed in one elementary reaction and consumed in the next reaction. (B)	27.5	31.43	40	34.69	32.89
	The substance is not present in the final product. (D)	55	42,86	40	34,69	32,89

Question Number (Correct Answer)	Alternative Concept	Pre-Service Teacher Student Level				Amount N=115
		I N=20	II N=20	III N=35	IV N=40	
32 (A)	HCOOH and ZnO are in different phases and the presence of ZnO decreases the rate. (B)	27,5	20	44	18.37	25.50
	HCOOH, CO_2 and H_2 are present in the same phase and the presence of ZnO decreases the rate. (C)	15	14,29	16	12,24	14,09
	HCOOH and ZnO are in different phases and the presence of ZnO increases the rate. (D)	30	20	20	12	20,13
34 (A)	Step 2 is a step speed determination (B)	27,5	31,43	40	34,69	32,89
	The rate law is obtained directly from the overall reaction equation. (C)	55	42,86	40	34,69	32,89
	The rate law is derived from the law of mass action. (D)	27,5	20	44	18.37	25.50
36 (A)	The half-life is related to the concentration of the reactants at any time during the reaction. (D)	15	14.29	16	12.24	14.09
38 (B)	As time increases, the rate of conversion of G molecules into H molecules also increases. (A)	30	20	20	12	20.13
	The rate of conversion of G molecules into H molecules per second is a constant. (C)	27.5	31.43	40	34.69	32.89
40 (C)	O_2 is produced twice as fast as N_2O_5 is consumed. (A)	55	42.86	40	34.69	32.89
	NO_2 is produced at half the rate of N_2O_5 being consumed (B)	27.5	20	44	18.37	25.50
	N_2O_5 is consumed twice as fast as NO_2 is produced (D)	15	14.29	16	12.24	14.09
	NO_2 is consumed twice as much as N_2O_5 is consumed (E)	30	20	20	12	20.13
	O_2 is produced at half the rate that N2O5 is consumed. (F)	15	14.29	16	12.24	14.09

The table shows that the least alternative conception is in question number 2 where only 1 alternative conception is provided, which is only 8.05% overall, although the total percentage does not reach 10%, there are 12.5% of preservice level I chemistry teachers who choose this answer as an alternative conception, this indicates that the answer is quite believed to be true. While in question numbers 4 and 6, the variation of answers is still spread with different reasons with the highest percentages of 18.79% and 24.83% respectively. Table 4 shows that questions 14 provide the least misconceptions, which is 14% of respondents who answered this choice as a misconception. The highest percentage of misconception is for question number 10 at 57%.

Alternative conceptions in this study refer to incorrect reasoning or beliefs chosen by respondents in response to diagnostic questions. When an alternative conception is chosen by a respondent with high confidence (as measured by confidence level indicators), it is categorized as a misconception. Therefore, a misconception is essentially a deeply held alternative conception that is believed to be correct by the student. For example, the belief that "the rate law is obtained directly from the balanced reaction equation" was selected by 32% of respondents. This shows that the alternative conception (confusing stoichiometry with reaction order) is not only misunderstood but also strongly believed, making it a persistent misconception. Likewise, the assumption that "increasing temperature increases activation energy" (believed by 20%) reflects a fundamental misunderstanding of the collision theory and energy profile of reactions. Hence, the higher the percentage of students selecting an incorrect alternative conception with high confidence, the stronger the indication of a misconception. This connection helps educators identify not just mistakes, but misunderstandings that require targeted conceptual change strategies in instruction.

In general, the analysis of answers on the FTIDCK instrument shows that pre-service chemistry teacher students involved in this study have limited understanding of the concept of reaction rate. In general, from the table above, it can be concluded that the misconceptions that occur in pre-service chemistry teacher students on the topic of reaction rate include: 1) that the rate of sample decay is constant (32%); 2) The rate of sample decay increases with decreasing sample mass (32); 3) not being able to distinguish between zero, one and two reaction orders (14%); 4) assuming that the t1/2 value is constant (20%), 5) The rate of sample loss increases with decreasing concentration (30%), 6) the reaction order value is determined based on the coefficients in the balanced reaction equation (30%); 7) The rate law is stated based on the law of mass action which describes the relationship between the concentration of reactants and products (25%); 8) The higher the concentration of the two reactants, the higher the rate (14%); 9) The concentration of the two reactants is the same, so the collision ratio is better (20%); 10) The concentration of A at its half-life is the same as its initial concentration (25%), 11). The higher the temperature, the higher the activation energy (Ea) (20%); 12) The activation energy value does not determine the rate (14); 13) The reaction has the highest energy in its transition state (32%); 14) An increase in temperature decreases the activation energy (14%); 15) An increase in temperature increases the rate constant (20%); 16) The rate law is obtained directly from the fast rate mechanism (32%); 17) The rate law is obtained from the law of mass action (25%); 18) The reverse reaction is exothermic and the activation energy of this reverse reaction does not involve the ΔH value (14%); 19) The activation energy of the catalyzed and uncatalyzed pathways is the same, but the mechanisms are different (32%); 20) The activation energy of the catalyzed pathway is lower than the uncatalyzed pathway and the mechanisms are different (15%); 21) The activation energy of the catalyzed pathway is higher than that of the uncatalyzed pathway and the mechanisms are different (5%); 22) Without increasing temperature, the activation energy and mechanisms of the catalyst and uncatalyzed pathways are the same (5%); 23) The catalyst is formed in one elementary reaction and consumed in the next reaction (20%); 24) The catalyst increases its rate without involving a chemical reaction (10%); 25) The substance is not present in the final product (10%); 26) determining the presence of the catalyst and its reaction mechanism (24%); 27) The rate law is obtained directly from the overall reaction equation (32%); 28) The half-life is related to the concentration of the reactants at any time during the reaction (14%); 29) The rate law is derived from the law of mass action (25%); 30). The average reaction rate is obtained by dividing the concentration of the product per unit time (20%); 31) The average reaction rate is obtained by adding the concentration of the reactants per unit time (10%).

Many pre-service chemistry teachers have difficulty understanding the relationship between half-life (t½) and reaction order, assuming that half-life is always constant and not being able to distinguish between zero, first, and second reaction orders. (Tümay, 2016). This happens because traditional learning tends to emphasize memorizing mathematical formulas without deep conceptual understanding. (Bain et al., 2020). Further studies showed that students often assume that reaction rates depend only on stoichiometric coefficients, not on the actual reaction mechanism (Ahiakwo & Isiguzo, 2015). As many as 20% of respondents in this study believed that increasing temperature increases activation energy

(Ea), while 14% thought that the catalyst did not change the Ea value. This finding is consistent with research Habiddin & Page (2023), which shows that students often misinterpret Ea as "minimum reaction energy" instead of "kinetic barrier" due to a lack of understanding of collision theory. In addition, the misconception that "the reverse reaction does not involve ΔH" (14%) indicates ignorance of the relationship between Ea, potential energy, and reaction thermodynamics (Taber, 2017).

Some respondents (20%) believed that catalysts are “formed and consumed in the reaction”, while 10% thought that catalysts are not involved in the chemical reaction at all. This misconception is in line with the findings Taştan et al., (2010) who reported that more than 60% of pre-service chemistry teachers were unable to explain the mechanism of catalysis microscopically. This error arose due to the lack of use of computer simulations or particulate modeling in teaching (Wang et al., 2021). In addition, the belief that “catalysts increase the rate without changing the mechanism” (5%) indicates a lack of understanding of how catalysts lower Ea via alternative reaction pathways. (Cooper & Klymkowsky, 2013). As many as 32% of respondents thought that the rate law could be determined directly from the balanced reaction equation, and 25% believed that the rate law was the same as the law of mass action. This is supported by research Liebermeister & Klipp (2006), who found that students tend to equate reaction stoichiometry with reaction order due to teaching that focuses too much on mathematical calculations without experimental context. This error is also related to the inability to distinguish between empirical rate equations and reaction mechanisms (Talanquer, 2023).

CONCLUSION AND RECOMMENDATIONS

This study shows that the conceptual understanding of pre-service chemistry teacher students on the topic of reaction rate is still relatively low. Although most students are able to answer the initial level questions correctly, many are unable to provide appropriate reasons, indicating quite serious misconceptions. Only about 6-7% of respondents were able to answer all questions correctly on the concept of reaction order, rate law, and factors affecting reaction rate. In general, more than 60% of students showed a wrong understanding of several important subconcepts in this topic.

Recommendations Lecturers need to review the concept of reaction rate at all levels of pre-service chemistry teacher students to strengthen their conceptual understanding by using appropriate learning strategies. Misconceptions experienced by pre-service chemistry teacher students can be useful information for lecturers to plan learning in class. Lecturers can develop appropriate learning methods so that students can construct scientific concept knowledge correctly.

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