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How to Identify Misconception Using Certainty of Response Index (CRI): A Study Case of Mathematical Chemistry Subject by Experimental Demonstration of Adsorption

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A B S T R A C T S

The purpose of this study was to identify misconceptions using the certainty of response in undergraduate students through a case study of mathematical chemistry subject by experimental demonstration of adsorption. The concept of mathematical chemistry was conveyed to students by using an explanation video. The video also directs students to do practical experiments on adsorption. The data obtained can be used to determine the isotherm adsorption model that fits with their experimental phenomena. Students analyze the data obtained by using their understanding of the mathematical chemistry concepts that have been taught. Misconceptions on students were analyzed using pretest-posttest by giving 20 questions followed by the guess level (CRI). Based on the answers given, students' understanding of the concepts being taught can be identified as understanding the concept, lucky guess, do not understand the concept, and misconceptions. This research can be used as a reference to identify misconceptions in students and can be applied in various subjects.

A R T I C L E   I N F O

1. INTRODUCTION

A misconception is a term that refers to the difference in thinking between a person's concept and the concept of scientific theory determined by experts. Someone who has a different understanding of the actual concept means that person has experienced a misconception (Gurel *et al.,* 2015). To measure conception, several diagnostic tools have been developed and used by many researchers, including interviews (Chen *et al,* 2009), multiple-choice tests (MCTs) (Liu *et al.,* 2011), word association (Malek-Ahmadi *et al.,* 2011), Certainty of Response Index (CRI) (Mustari *et al.,* 2020), two-tiers (Kılıç & Sağlam, 2009), three-tier diagnostic test (Caleon & Subramaniam, 2010), and four-tier diagnostic test (Maharani *et al.,* 2019).

These various diagnostic methods of misconceptions have been widely applied to measure misconceptions in chemistry students, including misconceptions about redox titration which is used in the response Index technique. The multiple-choice test method with open reasons has been used to diagnose misconceptions among undergraduate students about acid-base argentometric titrations (Widarti *et al.,* 2017). Method of the three-tier test was used to assess high school students' understanding of acids and bases (Cetin-Dindar & Geban, 2011). The interviews method was used to diagnose misconceptions on covalent and ionic bonding materials (Luxford & Bretz, 2014), and the two-tier method was used to diagnose misconceptions in Separation of Matter (*Tuysuz et al.,* 2009). From the research that has been reported, no one has discussed how to identify misconceptions in undergraduate students in chemistry subjects.

Therefore, the purpose of this study was to identify misconceptions using the certainty of response in undergraduate students through a case study of mathematical chemistry subject by experimental demonstration of adsorption. The concept of mathematical chemistry was conveyed to students using an explanation video. The video also directs students to do practical experiments on adsorption. The data obtained can be used to determine the isotherm adsorption model that fits with their experimental phenomena. Students analyze the data obtained by using their understanding of the mathematical chemistry concepts that have been taught. Misconceptions on students were analyzed using pretest-posttest by giving 20 questions followed by the guess level (CRI). Based on the answers given, students' understanding of the concepts being taught can be identified as understanding the concept, lucky guess, do not understand the concept, and misconceptions. This research can be used as a reference to identify misconceptions in students and can be applied in various subjects.

2. METHODS

In this study, we used the Certainty of Response Index (CRI) to identify misconceptions. CRI was used to identify and distinguish between students who have misconceptions and students who do not know the concept. CRI is a measure of the respondent's level of confidence/certainty in answering each question given. CRI is given along with each question to identify the level of students' guesswork in answering the questions. The level of certainty of answers is reflected in the CRI scale given in **Table 1.**

Table 1. CRI and criteria.

CRI	Criteria
0	(Totally guessed answer) 100% guessed
1	(Almost guess) guess rate between 75-99%
2	(Not sure) guess rate between 50-74%
3	(Sure) guess rate between 25-49%
4	(Almost certain) guess rate between 1-24%
5	(Certain) guess rate between 0%

To analyze students' misconceptions, we conducted a pretest and posttest. The pretest and posttest questions were the same questions containing 20 multiple-choice questions in each question followed by the CRI level guess. By using this method, we could identify students' understanding based on the answers to the questions and the level of guesswork, namely students understand the concept, lucky guess, do not understand the concept, and misconceptions.

To convey the concept of mathematical chemistry, we made an explaining video. The video also guided the student to do a practical experiment on the adsorption process. The student was asked directly to use some adsorbents such as carbon or zeolite to adsorb the curcumin solution as a model of wastewater. the changes in the concentration (ppm) of wastewater were measured using a TDS meter. The data obtained from the experimental results were analyzed to determine the suitable adsorption model with their experimental phenomena by relying on their understanding of the mathematical chemistry concept being taught.

3. RESULTS AND DISCUSSION
3.1. Learning Preparation

There are several stages in preparing for the analysis of misconceptions, including:
(i) Determine the material to be tested, for example in this paper, the material to be used regarding mathematical chemistry.
(ii) Making pre-test questions, pre-test questions function to determine students' understanding prior to getting knowledge. **Table 2** shows an example of a pre-test item with 5 multiple choices. Multiple choice is provided as a distractor, in the choice options the answers that are thought to be answers to the misconceptions that occur in students are presented. After answering the questions, students are asked to give a CRI score for each answer they choose. Identification using the CRI depends on the honesty of students in filling out the CRI. To identify students' consistency in answering questions and improve the accuracy of the misconception analysis, at least 3 questions were made for each concept so that the consistency of answering questions correctly or incorrectly, and the CRI value given can be detected.

**Table 2.** An example of a pre-test post-test question.

No	Pre-test
1	A function has an independent variable and a dependent variable. The independent variable is a variable that can be considered as input or input for the system and its value can be taken arbitrarily. While the dependent variable is a variable whose value changes as a result of changes in the value of the independent variable. The independent and dependent variable of a function $y = 2x+3$ is …. a. y independent variable and x dependent variable b. x independent variable and y dependent variable c. 2 independent variables and 3 dependent variables d. 2 dependent variables and 3 independent variables e. y independent variable and $2x + 3$ dependent variable

2   If there is a function *y=mx + C,* the independent variable and the dependent variable are ....
    a. *y* independent variable and *x* dependent variable
    b. *x* independent variable and *y* dependent variable
    c. *m* independent variable and dependent variable *C*
    d. *C* independent variable and m dependent variable
    e. *y* is independent variable and *mx + C* is the dependent variable
3   The independent variable and the dependent variable of the function *P* = 10*Q* + 8 are....
    a. *P* independent variable and *Q* dependent variable
    b. *Q* independent variable and *P* dependent variable
    c. 10 independent variables and 8 dependent variables
    d. 10 independent variables and 8 dependent variables
    e. *P* independent variable and 10*Q* + 8 dependent variable
4   It is known that the linear equation *f(x) = ax + b*. If *f*(2) is equal to 7 and *f*(5) is equal to 16, then
    the equation of the linear function is...
    a. *f(x) = x + 3*
    b. *f(x) = x - 3*
    c. *f(x) = 3x + 1*
    d. *f(x) = 3x - 1*
    e. *f(x) = 3x - 3*
5   Known data on the results of chemical reactions:

No	[X]	[Y]	v
1	0.2	0.2	0.00220
2	0.2	0.6	0.00198
3	0.2	0.6	0.00198

The curve that describes the functions v and [Y] is ....
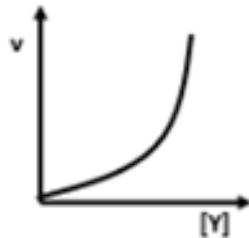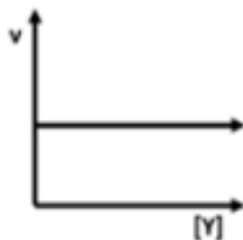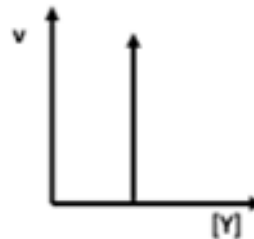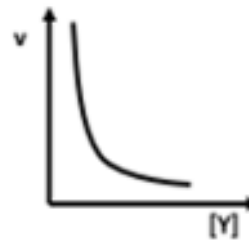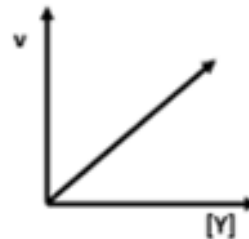
6   The following is the particle size data of pumpkin carbon after separation using a mesh sieve...

Mesh size	Converting mesh size to microns	Frequency (%)
10	2000	1.49
18	1000	1.34
35	500	2.88
60	200	5.00
120	125	30.50
150	100	12.31
200	74	37.60
250	55	7.43

The bar chart of the most appropriate mesh size and frequency is....

a.

b.

c.

d.

e.
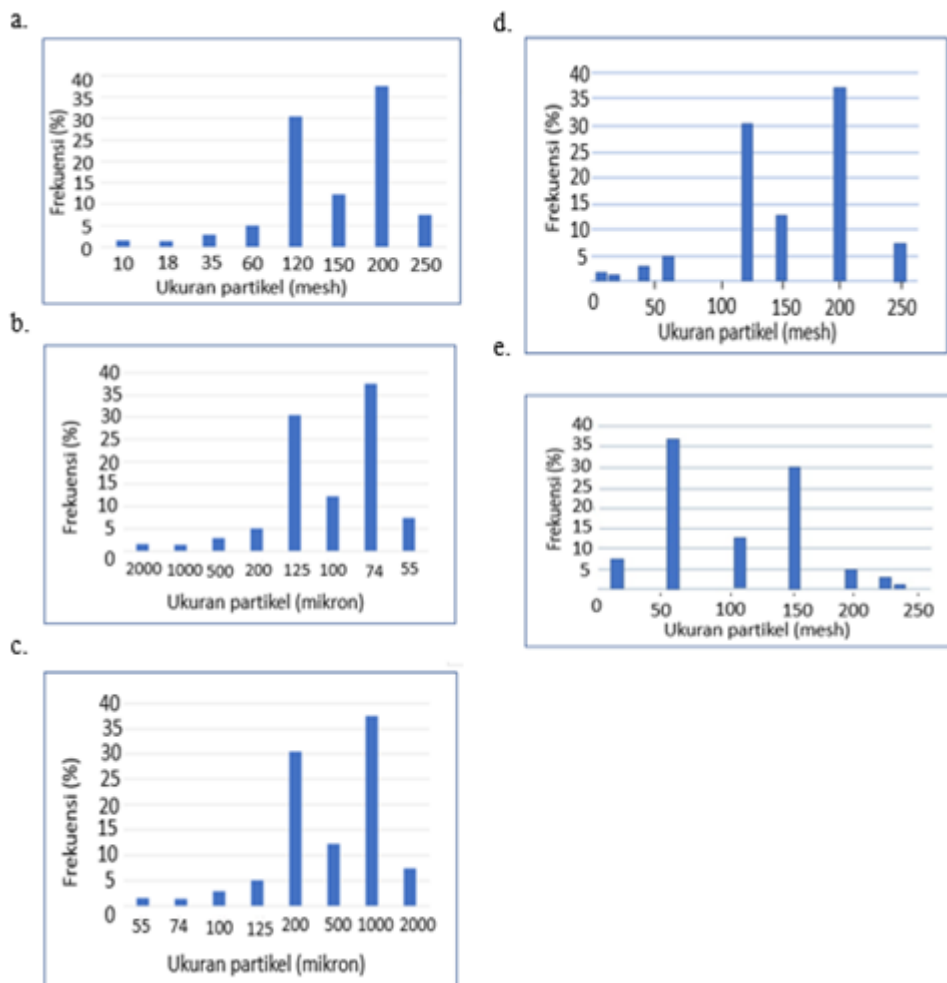
7   The following is the particle size data of pumpkin carbon after separation using a mesh sieve...

Mesh size	Convert mesh size to microns	Frequency (%)
10	2000	1.49
18	1000	1.34
35	500	2.88
60	200	5.00
120	125	30.50
150	100	12.31
200	74	37.60
250	55	7.43

The bar chart of the micron size with the most appropriate frequency is ….

a.
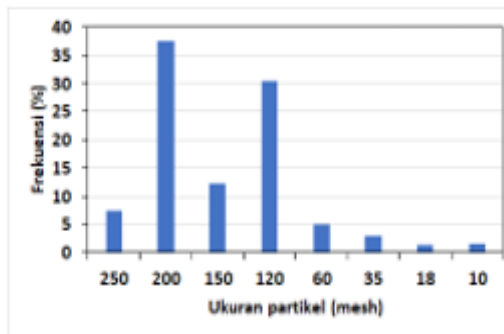
d.
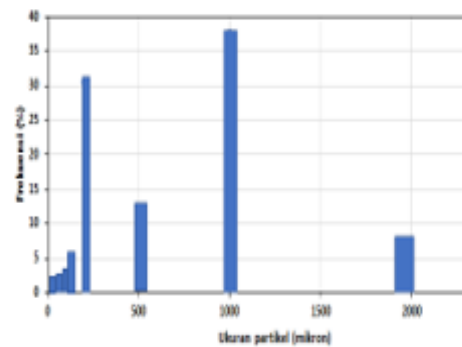
b.
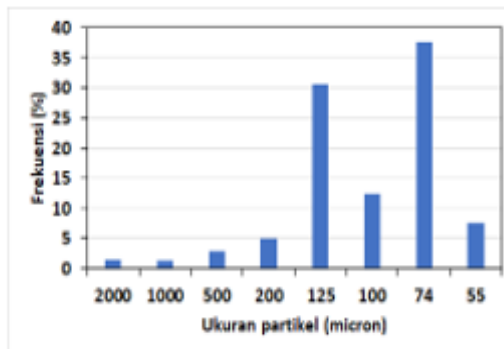
e.
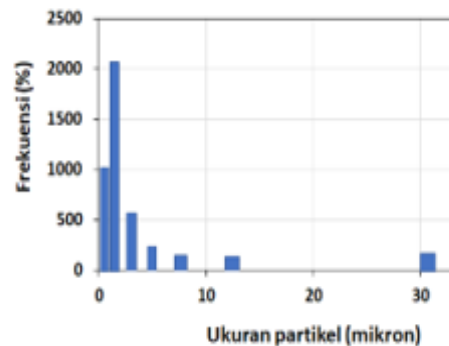
c.
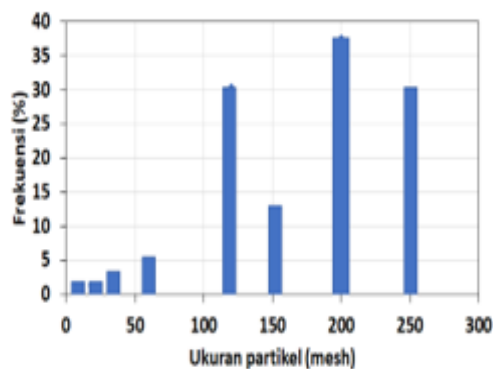
8   A linear function is a function whose independent variable has the highest power of 1. This function is said to be linear because the curve of the function in the Cartesian diagram has a straight-line curve. An example of a linear function is…

a. $2x^2 + 3x + 5 = 0$

b. $6x + y + 9 = 0$

c. $(2x + 3)(x - 2) = 0$

d. $5x^3 + 4x + 6 = 0$

e. $(3x + 1)(2x + 2) = 0$

9   Know an equation $y = \frac{2}{x} + 5$. The curve image of the equation is....

a

d.

b.

e.

c.
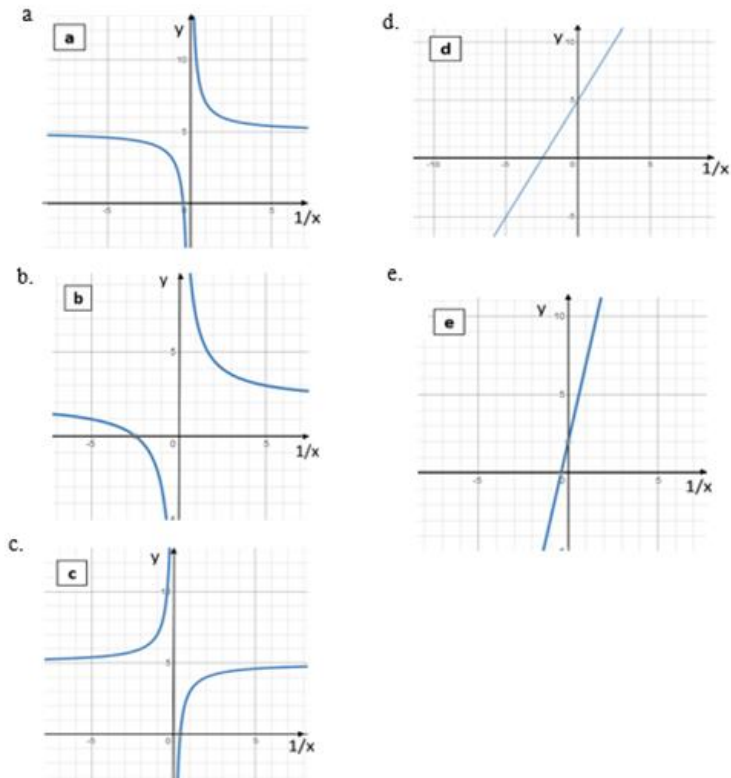
10   By knowing an equation $Q = \frac{2}{p} + 5$, if you want to make it as a linear function, then the possible curve of the equation is....

a.

c.

b.

d.

e.
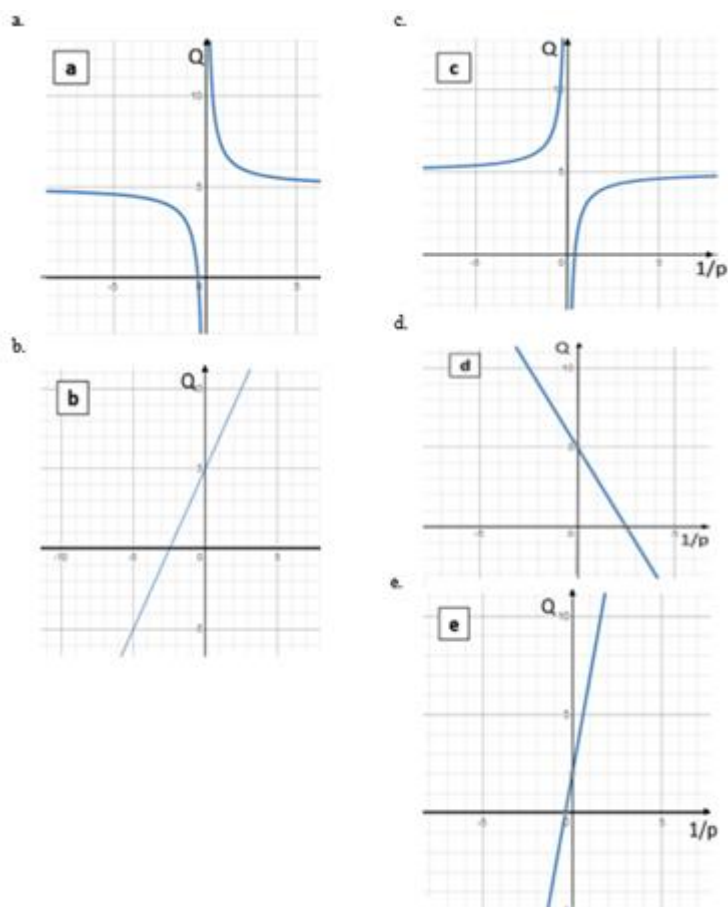
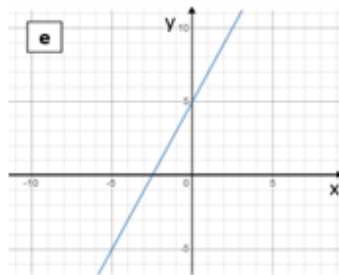11   Know an equation $y = \log x + C$. A possible curve image of the equation is....
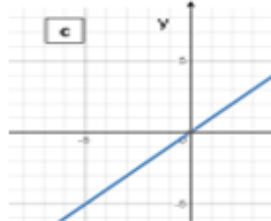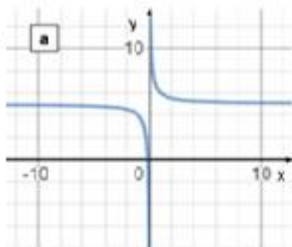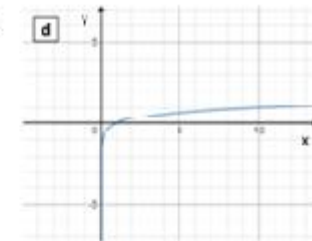
a

b.

c.

d.

e.
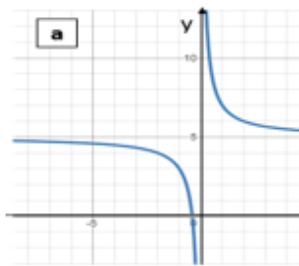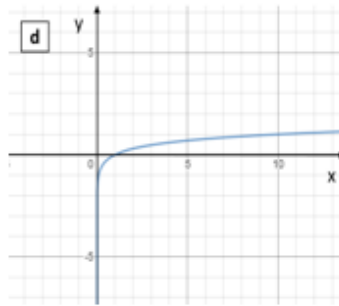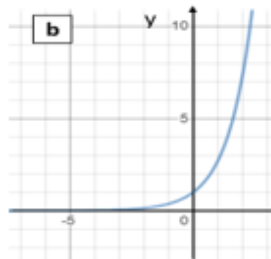
12   Curve of from equation $y = \log x + 5$ that is.... (x axis = $\log x$)

a.

b.

c.

d.
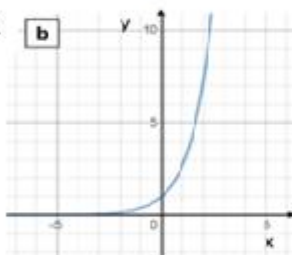
c.

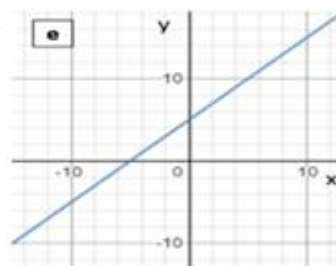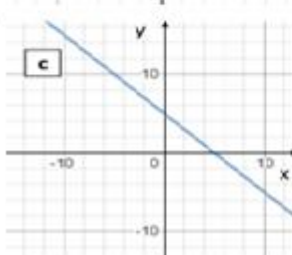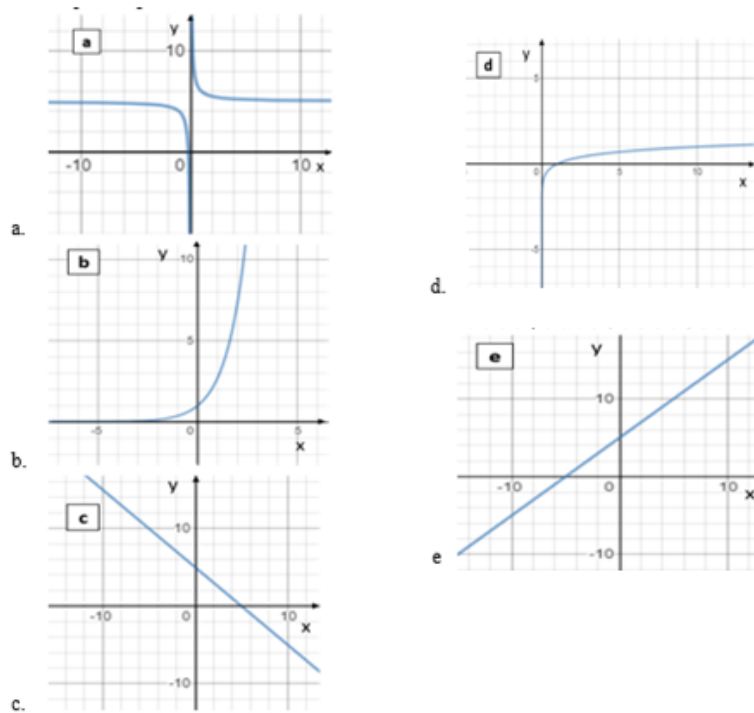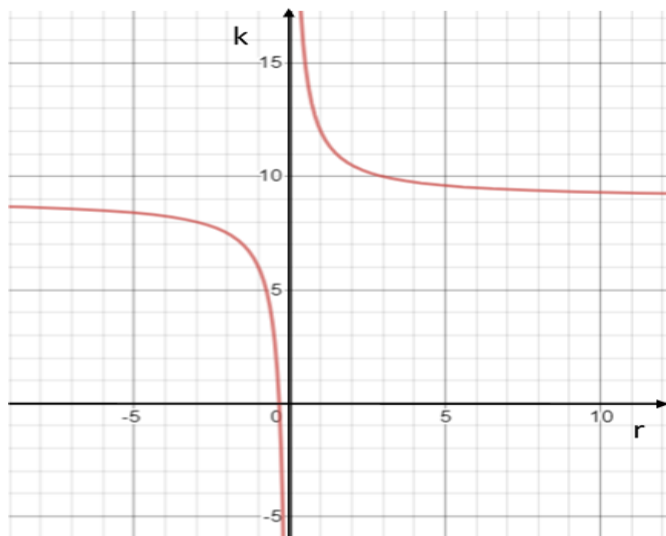13   The curve of equation $y = x^5+3$ is....

a.

b.

c.

d.

e.

14   The curve of equation $k = \dfrac{3}{r} + 9$ is...

To produce a linear curve, the equation k can be changed to .....

a. $k = \dfrac{3}{r} + 9$

b. $k - 9 = \dfrac{3}{r}$

c. $k = 3\left(\dfrac{1}{r}\right) + 9$

d. $r = \dfrac{3}{k} - 9$

e. $\dfrac{1}{k} = \dfrac{r}{3} + 9r1$

15 The independent variable and the dependent variable of the function $k = 7r - 19$ are r and k, respectively. If a curve is made, the x-axis of the equation is ….
    a. k
    b. $7r$
    c. r
    d. -19
    e. $7r - 19$

16 When the function $y = ax + b$ will be drawn a curve, the y-axis of the curve is ….
    a. y
    b. ax
    c. x
    d. $ax + b$
    e. b

17 A linear equation is an algebraic equation, where each term contains a constant or a constant multiplication by a single variable. This equation is said to be linear because this mathematical relationship can be described as a straight line in the Cartesian coordinate system, which can be written as a function y=mx+c. Given a function $log\ q_e = log\ q_s - (\beta \varepsilon)^2$, where qe is the theoretical isotherm saturation capacity, β is the Dubinin-Radushkevich isotherm constant, ε is the Polanyi potential associated with the equilibrium condition. The function has the independent variable ε^2 and the dependent variable log q_e. q_s and β are constants. If you want to make a linear curve of the equation, the x-axis and y-axis of the equation are ….
    a. axis x = log q_s and axis y= log q_e
    b. axis x = q_s and axis y = q_e
    c. axis x = ε^2 and axis y = log q_e
    d. axis x = ε^2 and axis y =β
    e. axis x =log qe and axis y = log q_s

18 Adsorption isotherm is a relationship that shows the distribution of the adsorbent between the adsorbed phase on the adsorbent surface and the bulk phase at equilibrium at a certain temperature. Several models are commonly used to explain adsorption isotherms including Freundlich, Langmuir, Temkin, Dubinin-Radushkevich, Flory-Huggin, Fowler-Guggenheim, and Hill-de Boer. It is known that the Temkin isotherm adsorption model has the equation $q_e = \beta_T (log\ A_T . C_e)$. The linear equation (in the form of $y = mx + c$) of the adsorption model is $q_e = \beta_T (log\ C_e) + (\beta_T\ log\ A_T)$. If a curve is made, the x-axis and y-axis of the linear equation are….
    a. axis x = qe and axis y = β_T
    b. axis x = log C_e and axis y = q_e
    c. axis x = β_T and axis y = q_e
    d. axis x = A_T and axis y = C_e
    e. axis x = log C_e and axis y = q

19   It is known that the Langmuir isotherm adsorption model has the equation $q_e = \dfrac{q_m.K_L.C_e}{1+K_L.C_e}$. If the X-axis is $\dfrac{1}{C_e}$, and the Y-axis is $\dfrac{1}{q_e}$, if you want to make a curve that has a straight curve as *y = mx + c* (linear equation) of the adsorption isotherm model is ….

a. $C_e/q_e = (C_e/q_m) + (1/b*q_m)$

b. $1/q_e = (1/b*q_m)*(1/C_e)+(1/q_m)$

c. $\dfrac{1}{q_e} = \dfrac{1}{q_m.K_L}\dfrac{1}{C_e} + \dfrac{1}{q_m}$

d. $q_e = q_m - (1/b)*(q_e/C_e)$

e. $q_e/C_e = b*q_m - b*q_e$

20   It is known that the Freundlich isotherm adsorption model has the equation $q_e = K_F.C_e^{1/n}$. The linear equation (in the form of *y = mx + c*) of the adsorption model is $\log Q_e = \log k_f + \dfrac{1}{n}\log C_e$. If a linear curve is made, the X-axis and Y-axis of the curve are, respectively...

a. K_F and q_e

b. *log qe* and *log K_F*

c. *log K_F* and *log C_e*

d. *log K_F* and *log q_e*

(iii) Making learning media. In this study, we made a video demonstration to convey the material about mathematics for chemistry to undergraduate students. The main material about mathematical for chemistry was explained in the video. On the other hand, we also explain mathematical chemistry concepts by conducting practical experiments on the adsorption process. Students are directed to analyze the results of adsorption using mathematical concepts that have been studied. Experimental practice activities will improve students' learning experience in analyzing real data.

3.2. Learning Process

The learning process done in this study can be described in the following:

(i)   The learning process begins by giving pretest questions to students to identify students' preconceptions about mathematical for chemistry.

(ii)   After knowing the students' initial knowledge, the next step is to provide learning materials. The process of providing learning materials is a very important stage because at this stage it can show the factors for the occurrence of misconceptions. The provision of learning materials can be done with various learning methods such as lecture methods, discussions, experiments, questions, and answers, etc.

(iii) After students receive the material that has been delivered, the next step is to give post-test questions. The purpose of giving the post-test is to find out the extent to which students' achievement of the material or teaching materials after participating in learning activities.

3.3. Analysis of the Misconceptions of the Questions

Table 3 shows the provisions for differentiating students' knowledge. The CRI method is usually based on a scale between 0-6 **(Table 3)**. The number 0 indicates not knowing the concept at all to answer a question or the answer is guessed in total (100%), while the number 5 indicates full confidence in the answer to answer a question (question), there is no element of guessing at all. In other words, when a student is asked to provide CRI along with each answer to a question (question), the student is actually asked to give an assessment of himself for the certainty that the student has to determine the answer to a question.

Table 3. Provisions for distinguishing between knowing the concept, misconception, and not knowing the concept for individual respondents.

Answer criteria	Low CRI Value (< 2.5)	High CRI Value (>2.5)
True answer	The correct answer but low CRI value means not knowing the concept (lucky guess).	The correct answer and High CRI value mean mastering the concept well.
Wrong answer	The wrong answer and low CRI value mean not knowing the concept.	The wrong answer but a high CRI value means there is a misconception.

3.3.1. Understand the Concept

A student is said to understand the concept if the student answers the answer correctly and has a high CRI, which means the student has mastered the concept well. Several factors can cause students to understand the concept, namely internal factors, and external factors. Internal factors that affect students include interest, motivation (Bal-Taştan *et al.,* 2018), basic abilities (Yuliani & Saragih, 2015), cognitive abilities (Beaty & Silvia, 2013), etc. And external factors include learning models, learning media, school facilities, learning styles (Pashler *et al.,* 2008), etc. By optimizing these factors, innovative learning will be created. One example of a student understanding the concept is shown in **Figure 1.**

3.3.2. Lucky Guess

A student is said to be a "Lucky guess" if the student answers the answer correctly but has a low CRI score. An example of a student experiencing a "Lucky guess" is shown in **Figure 2.**

3.3.3. Misconception

A student is said to have a misconception if the student answers the wrong answer but has a high CRI or trust score. Several factors cause students to experience misconceptions, including students' initial knowledge (preconception) (Bowen *et al.,* 2003), learning stages of cognitive development stages that are not in accordance with the concept, limited student reasoning (Hammer *et al*., 1996), students' ability to capture and understand a concept (Feltovich *et al.,* 1988), etc. These factors can cause students to experience misunderstandings in connecting or understanding a concept or commonly called misconceptions. An example of a student experiencing a misconception is shown in **Figure 3.**

3.3.4. Do Not Know the Concept

A student is said to not know the concept if the student answers the answer incorrectly and has a low CRI or trust score. An example of a student experiencing a misconception is shown in **Figure 4.**

Figure 1. Example of student answer with understanding the concept.

Figure 2. Example of student answer with a lucky guess.

Figure 3. Example of student answer with misconception.

Figure 4. Example of student answer with does not know the concept.

4. CONCLUSION

In this study, the results show that one way to identify misconceptions is using the Certainty of Response Index (CRI) using a mathematical chemistry model. Mathematical chemistry concepts are conveyed to students using video explanations. The video also directs students to do a practical experiment on adsorption. Students analyze the data obtained by using their understanding of the mathematical concepts being taught. Students' misconceptions were analyzed using pretest-posttest by giving 20 follow-up questions with guesses (CRI). Based on the answers given, students' understanding of the concepts being taught can be identified as understanding concepts, lucky guesses, not understanding concepts, and misconceptions.

5. ACKNOWLEDGMENTS

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6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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