

Research Article

# Analysis of Students' Misconceptions Assisted by the Certainty of Response Index (CRI) Through the Discovery Learning Model on Chemical Equilibrium Material

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## ABSTRACT

Conceptual errors or misconceptions are individuals' perceptions that do not align with scientific concepts recognized by experts. This study aims to identify the misconceptions experienced by 11th-grade students on chemical equilibrium, assisted by the Certainty of Response Index (CRI) and utilizing the Discovery Learning model. The research employed an experimental method with a pre-experimental design. The population of this study comprised all 11th-grade students at MAS Syamsuddhuha, with the sample being a single class, namely XI IPA 3. The data collection instrument was a multiple-choice test accompanied by reasoning and a CRI scale, administered after the learning intervention. The analysis results indicated that 43.14% of the sample still experienced misconceptions. The types of misconceptions on chemical equilibrium concepts were as follows: dynamic equilibrium (33.33%), equilibrium constant for concentration (Kc) (46.30%), partial pressure constant (61.11%), the relationship between Kc and Kp (38.89%), degree of dissociation (33.33%), equilibrium shift according to Le Chatelier's principle (65.74%), and chemical equilibrium in industry (38.89%). The findings demonstrate that misconceptions persist among students regarding understanding chemical equilibrium concepts.

**Keywords:** Misconceptions; Chemical Equilibrium; Certainty of Response Index; CRI

## 1. INTRODUCTION

Education is incredibly essential for the country because it provides people with knowledge that they may utilize to shape their future. Humans are the primary focus of educational activity, with students serving as the subjects. To reach students' future aspirations, these activities must be carried out with the proper goals and in partnership with all aspects of education, including educators (Sutirna, 2019). Education is extremely significant in a person's life since it can help to sustain higher levels of human quality. Quality education will generate individuals with talents, creativity, critical thinking abilities, and an open mind. According to Rachman, chemistry has the potential to boost pupils' creativity and critical thinking abilities. Thus, chemistry is one of the most important courses to teach pupils (Priliyanti et al., 2021). However, many pupils have difficulty mastering chemistry. This is because chemistry is an abstract and complicated science that necessitates a thorough grasp (Suriati et al., 2020). Most students find chemistry to be a tough and uninteresting subject. As a result, chemistry is among the courses that students despise (Muderawan et al., 2019).

According to Zakiyah et al. (2018), a number of the students' challenges in learning chemistry are primarily brought on by their ignorance of teaching strategies, their inability to make connections between ideas, their inability to comprehend literary sources, and the requirement that they apply their language, math, and logic skills. Students typically struggle to understand complex topics and handle issues involving a lot of mathematical calculations when studying chemistry. Poor academic performance is hence one effect of these students' learning challenges. Conceptual comprehension is a crucial component of learning since it helps students grasp all disciplines (Nora Yuliani et al., 2018). Mastering something with your intellect might be perceived as understanding. A concept is an idea or a person's thought based on their encounter with an abstract object or event (Wicaksono & Fifana Artha, 2022). Every concept in a subject is interrelated. If pupils learn a concept correctly, they will be able to proceed and comprehend the next concepts, because the initial concept is critical to understanding the subsequent concept. In contrast, if a concept is incorrectly understood, it might have an impact on the understanding of subsequent concepts (Mukhlisa, 2021).

Suparno in Mukhlisa (2021) defines conceptual errors or misconceptions as a person's perceptions that do not align with scientific concepts recognized by specialists. This misperception may endanger pupils. Misconceptions, according to

Pakpahan (2020), can originate from students' everyday experiences as well as during teaching and learning activities. Teachers must be able to express the material correctly when teaching and learning because learning is the process of creating new knowledge, abilities, and behaviors for someone when they engage with various information and surroundings (Unaida & Fakrah, 2022). In addition to knowing the material and concepts, teachers must also grasp how to work on it and impart the subject matter to students effectively to be considered professionals (Unaida & Fakrah, 2022).

Mistakes in chemistry learning cause misunderstandings among students. These mistakes often occur and indicate errors in reading sources. When studying chemistry, there are still many misconceptions, one of which is the material on chemical equilibrium. Students who do not understand the concept of chemical equilibrium will face difficulties that can lead to conceptual errors. According to Sukirman, this error is interpreted as a deviation from the correct thing that is systematic, consistent, and random/incidental in a certain context (Agustin Ratnasari et al., 2021). If students have experienced misconceptions, it will result in errors in answering questions, students who experience misconceptions when answering questions usually do not have sufficient conceptual understanding. Judging from the development of science, misunderstandings such as knowledge about various applications of chemistry as an aspect of life are very worrying, so teachers need to analyze the misunderstandings experienced by students. Students who face misconceptions when responding to questions are more likely to lack appropriate conceptual comprehension. Given the advancement of science, misunderstandings such as knowledge of numerous applications of chemistry as a part of life are very concerning, thus teachers must investigate the misunderstandings experienced by pupils.

The Certainty of Response Index (CRI) is used to assess students' comprehension levels. The CRI approach is used to assess students' self-confidence and belief in the subject presented by the teacher (Kefi et al., 2021). The CRI is defined as the respondent's level of belief or certainty in answering each question. CRI is usually measured on a scale and provided with the response to each question. These types of conceptual errors or misconceptions are common in chemical equilibrium materials. Indriani's research in (Marfu'a S & Astuti R. T, 2022) indicates that students struggle to learn the material and have a poor understanding of chemical equilibrium. The concept of dynamic equilibrium is thought to be high; the equilibrium constant is thought to be low, and the factors influencing the shift are thought to be low. Numerous studies have been conducted on misunderstandings, such as those by Usu and Alim Marhadi (2019), Marfu'a S. and Astuti R. T. (2022), Putri & Subekti (2021), and Basyiroh et al. (2022). Saleem Hasan (1999) presented the following response scale:

**Table 1.** CRI Response Scale

CRI	Description	Criteria
0	If the answer to the question is 100% guessed	Low
1	If the answer to the question is 75%-99% guessed	
2	If the answer to the question is 50% - 74% guessed	
3	If the answer to the question is 25% - 49% guessed	Medium
4	If the answer to the question is 1% - 24% guessed	
5	If the answer to the question is no element of guessing at all (0%)	

## 2. RESEARCH METHOD

The research method used was an experiment with a pre-experimental design procedure that employed a One-Shot Case Study in a quantitative approach. Experimental research is a research method that uses controlled conditions to determine the effect of treatment on others. The design utilized involves treating one group and then observing the results (Sugiyono, 2019). This study was carried out at MAS Syamsuddhuha during the odd semester. Class XI IPA served as the study's population. The study's sample consisted of 27 members of class XI IPA 3. Purposive sampling was used for the sample process. The chemistry instructor who instructed class XI IPA was taken into consideration when using the sampling technique. Chemistry teachers' interviews, final exams (posttests), and observations of the school environment were the first steps in the data collection process. The tests consisted of multiple-choice questions with justifications and a confidence level (CRI scale). Table 2 of the study design utilizing the One-Shot Case Study design is shown in the following.

**Table 2.** Research Design

Group	Treatment	Post-test
Experiment	X	O

The data analysis stage used is descriptive evaluative analysis, which is the process of collecting data and comparing it to existing criteria such as students understanding the concept, students do not understand the concept, students

understanding the concept but unsure, and misconceptions. In this data analysis, the researcher used the CRI, which was developed by Aliefman Hakim in Yaspin Yolanda (2021). The modified CRI see in the **Table 3**.

**Table 3.** CRI Assessment Criteria

Answer	Reason	CRI Value	Description
Correct	Correct	> 2.5	Understand the concept
Correct	Correct	< 2.5	Understand the concept but unsure
Correct	Wrong	> 2.5	Misconception
Correct	Wrong	< 2.5	Don't understand the concept
Wrong	Correct	> 2.5	Misconception
Wrong	Correct	< 2.5	Don't understand the concept
Wrong	Wrong	> 2.5	Misconception
Wrong	Wrong	< 2.5	Don't understand the concept

Based on the analysis of students' answers, a percentage calculation will then be carried out using the formula:

$$P = \frac{f}{n} \times 100\%$$

Information:

P = Group percentage number

f = Number of students in each group

N = Number of students

The average percentage of understanding for all pupils was then summarized. Then, students' misconceptions were examined for the questions with the highest percentage of student misconceptions.

### 3. RESULTS AND DISCUSSION

#### 3.1 Results

Before conducting the research, the researcher verified the questions with a Chemistry Education lecturer from Malikussaleh University. The questions were then assessed on students from class XII IPA 1 who had already studied the content. The test included 20 multiple-choice questions. The exam questions that were administered to class XII IPA 1 students were then evaluated for validity, reliability, level of difficulty, and discriminating power. The findings from 20 trial questions yielded 17 valid questions, which were used as the final test (posttest). The following table shows the findings of the analysis of students' misconceptions about chemical equilibrium material. **Table 4**, displays the total percentage statistics for each question item in each category of student understanding. According to the research, the concept understanding group has the largest percentage (44%), followed by misconceptions (43%), concept not understanding (12%), and concept understanding but unsure (1%).

**Table 4.** Percentage of Overall Student Concept Understanding

No	Category Percentage							
	PK		PKTY		MK		TPK	
	Student Answer	(%)	Student Answer	(%)	Student Answer	(%)	Student Answer	(%)
1	24	88.89	0	0.00	3	11.11	0	0.00
2	12	44.44	0	0.00	15	55.56	0	0.00
3	27	100	0	0.00	0	0.00	0	0.00
4	23	85.19	4	14.81	0	0.00	0	0.00
5	5	18.52	0	0.00	22	81.48	0	0.00
6	18	66.67	1	3.70	3	11.11	5	18.52
7	0	0.00	0	0.00	18	66.67	9	33.33
8	0	0.00	0	0.00	27	100.00	0	0.00
9	14	51.85	2	7.41	6	22.22	5	18.52
10	0	0.00	0	0.00	15	55.56	12	44.44
11	18	66.67	0	0.00	6	22.22	3	11.11

12	22	81.48	0	0.00	3	11.11	2	7.41
13	10	37.04	0	0.00	9	33.33	8	29.63
14	27	100	0	0.00	0	0.00	0	0.00
15	0	0.00	0	0.00	24	88.89	3	11.11
16	0	0.00	0	0.00	21	77.78	6	22.22
17	0	0.00	0	0.00	26	96.30	1	3.70
Average		43.57%		1.53%		43.14%		11.76%

**Table 4**, shows that the homogeneous and heterogeneous equilibrium material indicator has the highest percentage of conceptual understanding (92.59%), while the equilibrium shift material indicator with Le Chatelier's principle has the lowest percentage of conceptual understanding (25%). Several material indicators show a proportion of understanding the concept but not sure, including 7.41% for homogeneous and heterogeneous equilibrium, 3.70% for finding the Kp price, and 1.85% for computing the concentration constant (Kc). The highest percentage of misconceptions occurs in the equilibrium shift material indicator employing Le Chatelier's principle (65.74%), while the lowest percentage occurs in the homogeneous and heterogeneous equilibrium material indicator (0%). The highest percentage of not comprehending the concept is found in the degree of dissociation material indication (29.63%), while the lowest percentage is found in the dynamic equilibrium and homogeneous and heterogeneous equilibrium material indicators (0% each).

**Table 5.** Percentage of Students' Conceptual Understanding of Chemical Equilibrium Material (Indicator)

No Questions	Material Indicator	PK	PKTY	MK	TPK
1,2	The concept of equilibrium and balance dynamic	66.67	0.000	33.33	0.00
3,4	Homogeneous equilibrium and heterogeneous	92.59	7.41	0.00	0.00
5,6	Calculating fixed price concentration (Kc)	42.59	1.85	46.30	9.26
8,9	Determining partial pressure (Kp) in a state balanced	25.93	3.70	61.11	9.26
10,11	Connecting Kc price and Kp	33.33	0.00	38.89	27.78
13	Describes the degree of dissociation of a reaction equilibrium	37.04	0.00	33.33	29.63
14,15,16,17	Estimating direction of change equilibrium with the use of le chatlier principle	25.00	0.00	65.74	9.26
7,12	Explain material production chemical industry based on reaction equilibrium	40.74	0.00	38.89	20.37
	Total	45.49	1.62	39.70	13.11

### 3.2 Discussion

Misconceptions can be generated by flaws in how teachers and students use concepts. Conceptual processing errors occur when the concepts supplied by the teacher do not correspond to the conceptions accepted by pupils (Rohman et al., 2023). Misconceptions can also occur when students do not pay attention when the teacher is explaining the material in front of them; as evidenced by the observation sheet, some students do not listen to what the teacher explains, and there is a lack of communication when students do not understand the material being explained. Misconceptions can also emerge when pupils do not read the reading material being examined, particularly abstract concepts. Students frequently have misconceptions about dynamic equilibrium concepts, such as calculating concentration constants (Kc), determining partial pressure (Kp), connecting Kc and Kp values, degree of dissociation, equilibrium shifts according to Le Chatelier's principle, and chemistry in industry. The following are examples of CRI-related misconceptions.

#### a. Dynamic Equilibrium

The dynamic equilibrium indicator question item appears in question number two, where Misconceptions arise. Misconceptions about this concept account for 55.56%. The second question indication asks students to explain the mechanism of equilibrium in chemical processes, as well as the definition of dynamic equilibrium. In this question item, students who have misconceptions do not understand that dynamic equilibrium always experiences changes towards products and changes back to reactants, implying that in dynamic equilibrium, the reaction occurs continuously in two opposite directions at the same reaction rate. Some pupils who have misconceptions when answering questions are less precise, yet they deliver the right answers with confidence. This is also described by Basyiroh et al. (2022) in their study. According to the interview results, students struggled to answer questions concerning dynamic equilibrium since they didn't fully understand the idea. They tend to recall the information in the book mechanically rather than truly understanding it. This makes it difficult for them to apply the concept of dynamic equilibrium to questions that demand it.

## b. Concentration Equilibrium Constant ( $K_c$ )

The concept of equilibrium constant concentration ( $K_c$ ) in the instrument is discussed in questions 5 and 6. 46.30% of students have misconceptions about this concept. Questions 5 and 6 show an example of a misconception about this idea. Students have more misconceptions about this issue when they answer question number 5 than question number 6. The indicator for question number 5 in the question requires students to explain the formula for equilibrium constant concentration ( $K_c$ ) using the given heterogeneous equilibrium reaction equation. In this question, students who have misconceptions select the incorrect answer, but the formula and justifications provided are right, and the level of confidence chosen is high. Students assume that while determining the equilibrium constant, the concentration formula is unaffected by phase. Students believe that while creating the equilibrium constant formula, all phases can be included, whether liquid, gas, solid, or solution.  $K_c$ , which is the equilibrium concentration constant, requires a statement of the substance in concentration or molar units to calculate it. The equilibrium constant ( $K_c$ ) is the ratio of the product of the molarity of each reactant raised to the power of its coefficient (Marfu'a & Astuti., 2022). However, many students are still wrong in determining the  $K_c$  formula in the reaction. In this question, students still confuse the phases involved in determining the equilibrium concentration constant so that the choice of answer is not quite right. They also assume that  $K_c$  in equilibrium does not require a prior division of volume to obtain the concentration of each substance involved in the reaction, but rather directly uses the number of moles in the  $K_c$  formula. Students struggle to understand the equilibrium constant material because they do not know how to write and compute the  $K_c$  number. Their lack of mathematical ability additionally complicates this computation. Some students argue that  $K_c$  is a constant measured in moles. They believe that while calculating  $K_c$  in equilibrium, there is no need to divide the volume first to determine the concentration of each chemical participating in the reaction. Instead, they just enter the number of moles into the  $K_c$  formula. Some students believe that  $K_c$  is calculated by multiplying the reactant concentration and dividing it by the product concentration. However, because the pupils' interpretation differs from the right scientific concept, they are classified as having misunderstandings.

## c. Partial Pressure Constant ( $K_p$ )

The concept of partial pressure equilibrium constant ( $K_p$ ) on the instrument is discussed in questions 8 and 9. In this concept, 61.11% of students experience misconceptions. Question 8 illustrates one type of misperception in this idea, and on average, all students suffer from misconceptions. The indicator for question number 8 is the presentation of a homogeneous equilibrium reaction equation in which students explain the equilibrium constant formula based on partial pressure ( $K_p$ ). The selection of incorrect answers to questions that use formulas believed right with a high level of confidence, causes pupils to be classified as misconceptions. In this question, students believe that the partial equilibrium constant is the product of the reactants divided by the product of the products. However, students fail to consider which phases are involved in calculating the partial pressure equilibrium constant. Students chose this incorrect response because they believe that all phases can be included, despite the fact that the gas phase is the only one engaged. According to Kitti (Usu & Alim Marhadi, 2019), the equilibrium constant formula compares the product of the equilibrium concentration of the substance on the right side (product) to the product of the equilibrium concentration of the substance on the left side (reactant). This product is increased to the power of the individual reaction coefficients, not the sum. Brady (Dayatul Akbar, 2019) states that only gas-phase compounds are employed to compute the equilibrium constant value of a gas's partial pressure ( $K_p$ ). The concentration of solids (s), pure liquids (l), and solutions (aq) is not determined. The graphic above demonstrates that there is a discrepancy in comprehension between students' concepts and expert concepts, indicating that pupils have misconceptions. Students believe that all phases can be incorporated, although the actual notion only includes the gas phase.

## d. Relationship between $K_c$ and $K_p$

The concept of the relationship between  $K_c$  and  $K_p$  in the question instrument is represented by questions 10 and 11. Students who have misconceptions about this idea account for 38.89%. Question 10 is the most common example of a misconception about this topic. The indication for question number ten is provided as an equilibrium reaction equation. Students can calculate the value of  $K_p$  using the value of  $K_c$  obtained in equilibrium. Students are labeled as having misconceptions when they answer questions erroneously, yet the explanations provided are valid. It's just that the final computation result is incorrect, so the answer choice is not right with a high level of confidence. Students understand how to compute the formula used to discover the solution, but when finding the value of  $\Delta n$ , there is an error, as the student does not calculate the coefficient for  $\Delta n$ , resulting in an error in the final result. This computation error is caused by the students' inadequate mathematical abilities.

## e. Degree of Dissociation

The degree of dissociation is covered in question number 13 of the instrument. The percentage of misconceptions in this content indicator is 33.33%. Given an equilibrium reaction equation and the question indication, students can use their

knowledge of the moles in equilibrium to calculate the degree of dissociation. In this part, students experience two sorts of misconceptions. The first is when the answer and rationale offered are incorrect but with high confidence; the second is when students answer the question correctly but give the wrong reason and have a high level of confidence. The degree of dissociation is defined as the ratio of decomposed molecules to the original molecules (Cahya et al., 2019). According to Susila (Usu & Alim Marhadi, 2019), the original reactant's moles can be estimated by estimating the number of moles of the reactant that break down using the known moles of the product according to the coefficient ratio. subsequently, the degree of dissociation ( $\alpha$ ) is divided. Students who have misconceptions about this idea are still unsure how to determine moles in equilibrium. As a result, students are unable to distinguish between initial and decomposable moles. Students presume that the moles mentioned in the question are the ones that are immediately separated to determine the degree of dissociation. In the second level of questions, some pupils provided no reasons at all. So the student almost definitely answered the question because he was confident in his choice of answer.

#### f. Direction of Equilibrium Shift According to Le Chatelier's Principle

The concept of determining the direction of equilibrium shift using Le Chatelier's principle is discussed in questions 14, 15, 16, and 17. 65.74% of students have misconceptions about this concept. The most common misconceptions are questions 15, 16, and 17. Almost all pupils have misconceptions about these questions. Indicators for questions 15, 16, and 17 show the equilibrium reaction equation, allowing students to determine the direction of the equilibrium shift using Le Chatelier's principle. In question 15, students are expected to be able to determine the effect of pressure on equilibrium changes using the coefficients of a balanced reaction. According to Le Chatelier's principle, variations in pressure might impact the shift in equilibrium, depending on the treatment used. This demonstrates that there is a reverse reaction in which the concentration of reactants or products increases from the original concentration before the addition of a reactant (Petrucci, 1987, p. 200). This demonstrates how concentration can affect equilibrium variations based on the activity conducted. Students who have misconceptions about question 15 are still incorrect in determining the reaction that does not undergo a shift in equilibrium. If the pressure changes, either by increasing or decreasing the volume, the equilibrium shifts toward the reaction with the fewest coefficients, and vice versa. However, to ensure that the equilibrium does not shift when the pressure changes, the number of right coefficients is equal to the number of left coefficients. In this question, students who have misunderstandings demonstrate a high level of confidence but are incorrect in answering the question and providing justifications. Students who choose this high level of confidence are automatically classified as having misconceptions. The problem in question number 16 is nearly identical to question number 15, with the exception that students are required to be able to calculate the shift in equilibrium toward HBr gas when the temperature is reduced and H<sub>2</sub> and Br<sub>2</sub> gases are added. When a temperature change causes a shift, it is critical to consider whether the reaction produces heat (exothermic) or absorbs heat (endothermic). If the reaction is exothermic, increasing the temperature reduces the number of reaction products while increasing the number of reactants. However, students believe that increasing the temperature will shift the equilibrium towards HBr. With these arguments and replies, pupils are classified as misunderstandings because of their high level of confidence. Meanwhile, the difficulty in question number 17 is the same as in question number 16, which is the effect of temperature on the equilibrium reaction equation. In this question, students are supposed to guess what will happen if the temperature in the reaction equation is increase.

#### g. Chemical Equilibrium in Industry

The instrument appears in questions 7 and 12 of the industrial chemistry concept. 38.89% of people have misconceptions about this concept. The question with the greatest misconceptions is number seven. The indicator for question 7 is supplied with a question about ammonia production using the Haber-Bosch method. The best conditions for generating chemicals in industry based on equilibrium reactions are to increase pressure while decreasing temperature. In this question, students are supposed to choose the best treatment for producing ammonia. Students who have misconceptions believe that the best ammonia results are reached by reducing the concentration of reactants and pressure, which is contradictory to the concept of equilibrium reaction. Increasing the pressure and decreasing the volume of the equilibrium mixture will drive a shift towards more ammonia production. The reaction to the right is exothermic and decreasing the temperature can increase more efficient conditions in the exothermic reaction (Petrucci, 1987, p. 212). Factors that can affect the optimum conditions for NH<sub>3</sub> production are exothermic reactions at low temperatures will shift the equilibrium to the right, but the reaction is slow (optimum conditions 400-600°C). Then if the number of moles of reactants exceeds the number of moles of products, and the pressure is increased, it will drive a shift in equilibrium to the right. However, it is important to limit the system pressure according to the capacity of the equipment and pay attention to safety factors (pressure ranges from 150-300 atm). Furthermore, reducing the concentration of products (NH<sub>3</sub>) continuously will drive a shift in equilibrium to the right, meaning that the concentration of reactants will be greater than the concentration of products. Because low temperatures slow down the reaction process, a catalyst is added, the catalyst used is usually iron (Fe) with a mixture of Al<sub>2</sub>O<sub>3</sub>, KOH and other salts. Catalysts do not shift the equilibrium to the right, but rather accelerate the overall reaction rate. So, it can be concluded that the conditions suitable for optimal ammonia production must consider several factors.

## 4. CONCLUSION

The study's findings suggest that students in class XI IPA 3 MAS Syamsuddhuha have misconceptions about chemical equilibrium content. The general percentage of students who have misconceptions is 43.14%, whereas the equilibrium material indicator has a 39.70% misperception rate. Misconceptions among students include dynamic equilibrium (33.33%), calculating the equilibrium constant value of concentration ( $K_c$ ) (46.30%), determining partial pressure ( $K_p$ ) in equilibrium (61.11%), the relationship between  $K_c$  and  $K_p$  (38.89%), degree of dissociation (33.33%), direction of equilibrium shift using Le Chatlier's principle (65.74%), and chemistry in industry (38.89%).

## RECOMMENDATIONS

Based on the findings of this research, it is recommended that chemistry teachers use diagnostic tools such as the Certainty of Response Index (CRI) to identify and address students' misconceptions, especially in abstract topics like chemical equilibrium. The use of CRI enables educators to assess not only the correctness of student responses but also their level of confidence, allowing for more targeted remediation. Educational institutions are encouraged to implement the Discovery Learning model more consistently in chemistry instruction, as it supports students in constructing their own understanding and reducing misconceptions through exploration and guided inquiry. Future researchers are advised to expand the scope of CRI-based analysis to other challenging chemistry topics, such as thermodynamics or reaction kinetics. In addition, further studies may integrate digital platforms for CRI implementation to enhance efficiency in data collection and analysis.

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## AUTHOR'S CONTRIBUTIONS

All authors discussed the results and contributed to from the start to final manuscript.

## CONFLICT OF INTEREST

The authors declare no conflict of interest

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