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Using Analogies to Dispel Misconceptions about Chemical Equilibrium among Students Studying Agricultural Science

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ABSTRACT

This study examined how analogies influence third-year senior high school students' views of dynamic chemical equilibrium. Six participants willingly shared their understanding of the concepts of chemical equilibrium through semi-structured questionnaires distributed before and after a teaching session. The example aimed to show students how their misconceptions about chemical equilibrium correlate with other logical scenarios. The study's findings demonstrated that a student's capacity to comprehend and relate the analogous events to the target concepts being taught and their ability to handle the computations required by the analogy are crucial factors in determining whether they would succeed. Teachers must help students connect the analogy and the primary concepts to include them in their lesson plans. Teachers should also help students with the calculations needed for the simulation by providing guidance and support. This will help students comprehend and apply the ideas of chemical equilibrium in real-world situations.

Keywords: Agricultural Science Education, Analogical Instruction, Chemical Equilibrium, Conceptual Change, Misconceptions

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I. INTRODUCTION

A key concept in agricultural science education is chemical equilibrium, which includes ideas essential for comprehending plant nutrition, soil chemistry, and environmental interactions (Smith & Jones, 2019). Nevertheless, despite its importance, misconceptions that prevent students from understanding this challenging idea frequently require assistance. Because the dynamic equilibrium state is abstract and complex, it might be difficult for students studying agricultural science to understand (Brown & Green, 2020). Teachers increasingly use analogical reasoning as a workable instructional strategy in response to these difficulties. Analogies connect concrete scientific ideas and well-known occurrences as cognitive aids to improve students' comprehension (Johnson et al., 2018). An analogy provides learners with concrete links and real-world scenarios that help them bridge the gap between theoretical knowledge and practical applications in agricultural science education. Smith and Jones (2019) research indicates that using analogy-based teaching strategies in chemical equilibrium has demonstrated encouraging outcomes in terms of helping students' conceptual shift. Teachers try to close the gap between students' preexisting knowledge frameworks and abstract scientific notions using analogies. For example, they propose that students can be given a concrete visualization of the notion by comparing the dynamic process of a chemical reaction attaining equilibrium and well-known events, like a tug-of-war between two teams. They also stress how helpful analogies are as scaffolding devices for learning, enabling learners to draw links between previously learned material and new information. This method improves understanding and encourages more in-depth interaction with the material. However, the effectiveness of analogies depends on a few things, such as how well the analogy is used and how well it corresponds with students' past knowledge (Riddle & Lo-Fan-Hin, 2023).

Students' engagement and comprehension of chemical equilibrium are greatly influenced by their motivation to learn science, especially when using analogies to dispel misconceptions among agricultural science students.

Chemical equilibrium-related activities, such as idea exploration, experimentation, and the search for supplementary materials to enhance understanding, are more likely to be actively engaged in by science-motivated. This motivation propels them to invest time and effort in understanding complex equilibrium ideas, improving their topic comprehension, and dispelling misconceptions. Limitations, such as time constraints or restricted access to materials, can present significant obstacles to science learners' engagement with concepts of chemical equilibrium and may impede their ability to effectively correct misconceptions (Amponsah et al., 2013). Because their discipline is interdisciplinary and requires them to reconcile theoretical knowledge with practical applications in agricultural environments, agricultural science students may confront specific challenges (Taylor & Green, 2019). These restrictions may hinder their ability to conduct the practical study and experimentation essential to grasp chemical equilibrium concepts fully.

Moreover, students' attitudes, beliefs, and experiences about scientific education might significantly impact how well they can dispel common misconceptions about chemical equilibrium (Amponsah & Mohammed, 2019). A growth mindset can be cultivated by having positive views on science education, which motivates students to take on obstacles and keep trying to dispel myths (Brown & Johnson, 2017). However, negative attitudes or preconceived assumptions about science could hinder learning by keeping students from being willing to try out novel concepts and points of view (Olde Bekkink et al., 2016). Lately, education research has concentrated on creating teaching strategies to correct students' misconceptions regarding chemical equilibrium. There is mounting proof that students can better understand equilibrium principles using the constructivist learning methodology.

Milne et al. (2019) developed a disc analogy to help students visualize dynamic equilibrium at the molecular level and prevent mistakes. Like this, Abdu et al. (2023) helped students create mental models of dynamic equilibrium by using a "liquid transfer" analogy. Constructivists view learning as a process of conceptual change (Zajda & Zajda, 2021) that entails reorganizing previously held conceptual frameworks to make it easier to absorb new information (Mohammed & Amponsah, 2021). Four elements were identified by Heddy et al. (2018) as supporting conceptual change: dissatisfaction with existing concepts, plausibility given current knowledge, intelligibility of new conceptions, and capacity for expansion.

Analogies are a common feature of the new constructivist teaching methods. These tactics seek to direct learners toward scientific ideas by building on their preexisting conceptions. Analogies were created by Saricayir et al. (2019), Campolat et al. (2018), and Harrison and Buckley (2015) to clarify the idea of dynamic equilibrium. Nevertheless, more research is still needed to realize the full potential of analogies, despite these studies' suggestions that they help improve comprehension of equilibrium's dynamic nature. Furthermore, researchers are still conducting empirical investigations to determine how analogical teaching can help students overcome learning challenges in chemical equilibrium. This study aims to determine how much analogical training can help senior high school agricultural science students clear up misconceptions regarding chemical equilibrium. Chemistry teachers may find use for the learning exercises and related student worksheets created in this study. The following is the research question that is addressed:

1. How might students' conceptual understanding of the evolution of reactants and products before equilibrium be changed by analogy?
2. In what ways does analogy help students understand the system's state when it is in equilibrium?

II. LITERATURE REVIEW

2.1 Misconceptions in Chemical Equilibrium

According to Li et al. (2024), chemical equilibrium refers to a delicate balance between forward and reverse reaction rates, stabilizing reactant and product concentrations over time. Students sometimes need help with misconceptions about this idea despite its essential importance. The false notion that equilibrium denotes the complete cessation of processes is one prevalent fallacy. This misconception ignores equilibrium's dynamic character, which allows reactions to continue at constant rates even when concentrations settle (Smith & Brown, 2018). The notion that equilibrium implies an identical concentration of reactants and products is another common mistake. As a result of different reaction circumstances and stoichiometric parameters, concentrations rarely reach absolute equality even when they reach a stable state. These misunderstandings, which frequently result from simplistic explanations or inadequate comprehension, hinder students' ability to apply equilibrium concepts successfully, particularly in situations like agriculture, where a grasp of chemical reactions is essential. Thus, dispelling these myths is essential to promoting a more thorough understanding of chemical equilibrium. By highlighting the intricate relationship between reactions at equilibrium and the subtle differences in concentration ratios, instructors may equip students to appropriately apply equilibrium concepts in various real-world situations, including agricultural settings.

2.2 Challenges Faced by Agricultural Science Students

For students struggling to understand chemical equilibrium, the discipline of agricultural science poses unique challenges because of its interdisciplinary nature (Taylor & Smith, 2017). Unlike standard chemistry programs, agricultural science students must apply chemical principles to concrete, real-world scenarios such as soil nutrient cycling, fertilizer application, and pesticide degradation (Barak & Hussein, 2018). This calls for a solid understanding of the abstract ideas underlying chemical equilibrium and the capacity to apply this understanding to efficient agricultural methods. The intricate nature of these two challenges highlights the urgent need for creative pedagogical strategies designed to meet agricultural science's particular requirements and educational contexts (Taylor & Smith, 2017). Agricultural science's multidisciplinary needs and practical complexities are frequently too complex for traditional teaching approaches to address effectively (Barak & Hussein, 2018). Therefore, there is an urgent need for instructional methodologies that close the knowledge gap between theory and practice, giving students the tools they need to successfully negotiate the complexity of chemical equilibrium in the context of agricultural systems.

Furthermore, agricultural science students need help beyond simple academic understanding. They also have to deal with the dynamic nature of agricultural systems, which adds complexity to chemical equilibrium processes due to crop diversification, soil composition, and climate fluctuation (Gupta et al., 2019). As such, effective instructional strategies must clarify the basic ideas of chemical equilibrium and help students thoroughly comprehend how these ideas are applied in the complex web of agricultural relationships and processes. Essentially, resolving the difficulties that agricultural science students confront in comprehending ideas related to chemical equilibrium calls for a comprehensive strategy that combines theoretical knowledge with real-world application and contextual awareness (Barak & Hussein, 2018). Teachers can enable students to successfully negotiate the complexity of chemical equilibrium in agricultural contexts by using cutting-edge pedagogical practices that meet the requirements of agricultural science education.

2.3 Utilizing Analogies to Address Misconceptions

Analogical reasoning has emerged as a promising strategy for remedying chemical equilibrium misconceptions among science students (Hamnell-Pamment, 2024). Analogies are potent cognitive tools, facilitating conceptual understanding by bridging abstract scientific concepts with familiar everyday experiences (Keefer & Landau, 2016). Within the domain of chemical equilibrium, analogies can be wielded to establish parallels between dynamic equilibrium processes and commonplace phenomena, such as the regulation of water levels in a bathtub or the ebb and flow of traffic on a highway (Pekmez, 2010). By leveraging analogies, educators can provide students with tangible connections and visual representations that aid in visualizing and comprehending abstract equilibrium concepts more effectively (Riddle & Lo-Fan-Hin, 2023). For instance, likening the balance of reactants and products in a chemical reaction to the delicate equilibrium of water levels in a bathtub elucidates the notion of equilibrium as a dynamic interplay between opposing forces striving for balance (Keefer & Landau, 2016).

Similarly, drawing parallels between the equilibrium achieved in a chemical reaction and the harmonious traffic flow on a well-managed highway reinforces the concept of equilibrium as a state of stability despite ongoing processes (Widarti, 2023). Moreover, analogies offer a means of contextualizing abstract concepts within students' everyday experiences, enhancing engagement and promoting deeper conceptual understanding. By grounding chemical equilibrium principles in relatable analogies, educators can demystify complex scientific phenomena and empower students to grasp fundamental concepts more intuitively. This approach not only aids in dispelling misconceptions but also cultivates a holistic understanding of chemical equilibrium by integrating theoretical knowledge with real-world applications. In essence, the strategic utilization of analogies represents a valuable pedagogical tool for addressing misconceptions and enhancing conceptual clarity in science education. By tapping into familiar experiences and leveraging visual representations, analogies facilitate the translation of abstract scientific concepts into accessible frameworks, fostering more profound understanding and proficiency among students.

2.4 Implementation of Analogical Teaching Strategies

Careful selection of parallels that align with students' existing knowledge and experiences is necessary to effectively apply analogical teaching methodologies (Harrison & Buckley, 2015). The selection of analogies should be predicated on their pertinence, lucidity, and capacity to elucidate basic equilibrium concepts (Pekmez, 2010). Instructors must offer clear direction and scaffolding to further assist students in comprehending the fundamental parallels between the target topic and the comparison (Gray & Holyoak, 2021). This may entail interactive exercises, talks, and practical simulations to assist knowledge transmission and strengthen conceptual understanding. In order to develop metacognitive abilities and enhance conceptual understanding, instructors can also push students to critically examine and assess parallels (Wade-Jaimes et al., 2018). Carefully choosing parallels that align with students' past knowledge and experiences is essential for effectively applying analogical teaching methodologies (Harrison & Buckley, 2015). The selection of analogies should be predicated on their pertinence, lucidity, and ability to depict basic equilibrium concepts (Widarti, 2023) eloquently. In addition, teachers need to give students clear direction and support so they can understand the fundamental parallels between the target idea and the comparison (Gray & Holyoak, 2021). This procedure could involve involving students in interactive exercises, promoting group discussions, and carrying out practical simulations to strengthen conceptual comprehension and ease knowledge transfer. These methods help students understand concepts more deeply and encourage active participation and hands-on learning, both critical for retaining conceptual knowledge.

Additionally, teachers must push students to critically analyze and assess parallels to develop metacognitive abilities and a deeper comprehension of the underlying ideas (Wade-Jaimes et al., 2018). Teachers may help students develop into more critical and thoughtful thinkers who can identify and apply the value of analogy in various situations by encouraging them to consider the advantages and disadvantages of analogies. A comprehensive strategy that includes deliberate analogy selection, clear direction and scaffolding, interactive and experiential learning activities, and support for critical analysis and reflection is necessary to apply analogical teaching techniques successfully. Teachers can design engaging learning experiences that help students enhance their metacognition and better comprehend concepts by incorporating these components into their lesson plans.

2.5 Impact of Analogical Teaching on Conceptual Understanding

Studies reveal that analogous instruction significantly improves students' conceptual understanding of chemical equilibrium in agricultural science courses (Campolat et al., 2018). Analogies are powerful tools for bridging the gap between academic concepts and real-world applications in agriculture because they provide specific examples and visual representations (Hamnell-Pamment, 2024). Furthermore, analogical reasoning encourages attentive listening and active participation, making it easier to comprehend equilibrium concepts sophisticatedly (Gray & Holyoak, 2021). Analogical reasoning is associated with increased conceptual clarity, excellent problem-solving skills, and better student knowledge retention (Campolat et al., 2018). This shows that using analogies helps students understand complex ideas and develops their ability to apply what they have learned in various situations.

Additionally, analogous instruction promotes learning transfer by enabling students to quickly adapt equilibrium principles to various agricultural settings and real-world contexts (Siano et al., 2023). Thus, incorporating analogous teaching methodologies into agricultural science curricula is a potent pedagogical strategy for encouraging better comprehension of concepts and making applying theoretical information in real-world situations easier. Teachers can help students better understand the relevance and practical application of equilibrium principles in agricultural activities by using analogies to contextualize abstract concepts. This will enable students to become more competent and productive practitioners.

III. METHODOLOGY

3.1 Research Design

This study used a case study research method to examine students' notions of chemical equilibrium before and after the intervention to ascertain how much their understanding of chemical equilibrium changed due to receiving analogous instruction. By utilizing the qualitative paradigm, the study openly acknowledges the subjective roles that participants and researchers play in constructing knowledge. These studies may be vulnerable to subjectivity, bias, and selectivity, but they may also provide insights about comparable cases.

3.2 Participants

Out of twenty-five students enrolled in the Agricultural Science program, six third-year senior high school students, ages seventeen to eighteen, were purposefully chosen. The individuals were selected to represent three groups: average (P3 and P4), low (P5 and P6), and high (P1 and P2) achievers. There was one girl and five boys in the group. According to their chemistry teacher, the mole idea, chemical equations, chemical bonding, and the Rate of chemical reactions are among the foundational topics in chemistry that the kids have mastered. In Ghana, even with this preparation, students enrolled in the agricultural science program have historically done worse in chemistry than their general science program counterparts.

3.3 Chemical Equilibrium Concept Achievement Test

The chemical equilibrium concept test consisted of three multiple-choice questions with open-ended sections that let students explain their selections. The exam evaluated the students' understanding of dynamic equilibrium before and after the instruction. Researchers created test items using common misunderstandings in the literature, such as the idea that reactant and product concentrations are equal at equilibrium (Onyenenue, 2016). When the exam was piloted with 37 students who shared similar characteristics with the study participants, it showed good reliability (Cronbach's alpha = 0.76).

3.4 The Intervention

Students replied to concept questions about the dynamic nature of chemical equilibrium by indicating whether they agreed with the statement. The instructor then explained the purpose of the analogy to the class. The purpose of the analogy was to demonstrate:

a. How reactant and product concentrations change as a system approaches equilibrium.
b. The preservation of concentrations after achieving balance
c. The difference in the rates of forward and backward responses that come before and after equilibrium.

Not all the attributes of the analogy represented those of chemical equilibrium systems; the teacher emphasized as she discussed the parallels and discrepancies between the analogy and the target equilibrium notion. For example, the comparison showed a molecule with a single disc, even though a molecule may consist of several atoms. Moreover, the analogy differed from the one (Widarti, 2023), depicting a closed system in which reactants and products were mixed within the same apartment.

Table 1

Comparison between Analog and Target Concepts

Number	Analog	Target Concept
1.	A tray filled with a mixture of red and blue discs1.	1. A system of chemical equilibrium Products and a chemical equilibrium system
2.	The number of discs is coloured blue.	2. The concentration of reactants provided for the reaction.
3.	The number of discs is coloured yellow.	3. The concentration of products formed from the reactants.
4.	The time the discs started to turn.	4. The beginning of the chemical reaction.
5.	Only blue discs were present at the beginning.	5. Only reactants are present at the beginning of the reaction.
6.	As the discs alternate between blue and yellow and back to blue.	6. Reactions are occurring both forward and backward. It follows that the reaction is reversible.
7.	The number of rotated discs per minute. From blue to yellow and from yellow to blue.	7. The Rate of chemical reaction. From the Rate of the forward reaction To the Rate of backward reaction

The next part of the lecture involved simulating a dynamic equilibrium and assuming the following hypothetical first-order reversible reaction: $A (g) \rightleftharpoons B (g)$. The study calculated the reverse reaction rate as [rate reverse] and posed the forward reaction rate as [Rate forward]. Students began with 24 reactant molecules and used the rate equation $Rate = k[A]$ to determine how many reactant molecules (A) were converted to product molecules (B) in one minute. After the first minute, students counted and recorded the amount of reactant and product molecules after rotating the determined number of discs to the red side. Up to the fifth minute, this computational process was repeated every one-minute interval, visually representing the reactant and product molecules transformed by flipping discs to their opposite sides.

Table 2 presents the forward and reverse reaction rate fluctuation throughout the first five minutes of the simulation activity. It also shows the reaction rate for each minute over five minutes. The table sheds light on the dynamic character of the equilibrium process by showing how the rates of both reactions vary during each time interval.

Table 2

Variation of Rate of Forward and Reverse Reaction for the First Five Minutes

Time interval/min reaction	Rate of forward reaction	Rate of backward
0 – 1	12	0
1 – 2	6	3
2 – 3	5	4
3 – 4	4	4
4 – 5	4	4

Table 3 shows the concentration of reactant and product molecules for the first five minutes of the simulation activity. It visually represents the dynamic equilibrium process by highlighting how the concentrations change as the reaction moves closer to equilibrium. We rounded any fractional values to whole numbers during the calculations.

Table 3:

Variation of Concentration of Reactants and Product for the First Five Minutes

Time/min	Concentration of Reactants	Concentration of Products
0	24	0
1	12	12
2	9	15
3	8	16
4	8	16
5	8	16

IV. FINDINGS & DISCUSSIONS

4.1 Results

This study aimed to evaluate how analogous education affected students' comprehension of the dynamic elements of chemical equilibrium after the intervention. We contrasted the pretest and posttest results to see how the students conceptualized chemical equilibrium. The six individuals were divided into three groups: above average (P3 and P4), below average (P5 and P6), and high achievers (P1 and P2). Tables 4 through 6 provide a complete summary of the study's findings. Six students (P1 through P6) have preconceived notions and postconceptions about how the reactant chlorine gas concentration (Cl_2 (g)) changes when a reaction gets closer to equilibrium. These are shown in Table 4.

Table 4

Students' Concepts of How the Concentration of a Reactant Changes as the Reaction Gets Closer to Equilibrium

Preconceptions	Post conceptions
P1: The Cl_2 (g) concentration rises because of the reaction in a closed container, preventing heat loss.	P1: The Cl_2 (g) concentration will drop because reactants are used to generate the products.
P2: When heat is applied to the system, the reactants are subjected to high temperatures, which causes the concentration of Cl_2 (g) to rise.	P2: As additional reactants are needed to generate the products, the concentration of Cl_2 (g) decreases.
P3: Because the reaction is taking place in a closed container, some of the Cl_2 (g) that is created will be added to the initial amount that was already there, increasing the concentration of Cl_2 (g).	P3: As additional reactants are needed to generate the products, the concentration of Cl_2 (g) drops.
P4: Because the heat generated during the reaction destroys part of the chlorine, the concentration of Cl_2 (g) falls.	P4: Because part of the Cl_2 (g) is destroyed by the heat generated during the reaction, the concentration of Cl_2 (g) falls.
P5: Subsequently, the reaction will use some of the Cl_2 (g) coupled to the NOCl to produce Cl_2 (g), causing Cl_2 (g) to rise because not all of it is being used to form the increased product.	P5: The concentration of Cl_2 (g) will result from the backward reaction using some of the Cl_2 (g) connected to the NOCl, as none of the Cl_2 (g) is being consumed.
P6: Cl_2 (g) will drop since some leaked out of the container when exposed to the atmosphere.	P6: Because Cl_2 (g) was within the container and exposed to the atmosphere when it was taken out, its concentration will drop.

Each student expresses their initial idea of how the concentration of Cl_2 (g) changes during the reaction in the assumption's column. P1 proposes, for instance, that the concentration rises due to the reaction in a closed container, which stops heat loss. In a similar vein, P2 proposes that the concentration rises because of the addition of heat, but P3 thinks the concentration rises because of some Cl_2 (g) being generated in addition to the initial amount. The post-conceptions column, on the other hand, shows the students' updated comprehension following the intervention. In this instance, the students offer revised justifications regarding their exposure to analogous learning. For example, P1 now knows that reactants are employed to make products, which causes the concentration of Cl_2 (g) to fall. Likewise, P2 admits that the concentration drops as more reactants are needed to generate the product. The table shows how students' conceptualizations of Cl_2 (g) concentration change from initial misconceptions to more precise understandings of dynamic equilibrium processes when exposed to analogical instruction.

Similarly, P2 acknowledges that the concentration decreases when more reactants are required to produce the product. The table illustrates how students' Cl2 (g) concentration conceptualizations shift from early misconceptions to more accurate understandings of dynamic equilibrium processes when exposed to analogical training.

Table 5

Students' Conceptions about how the Concentration of a Product Evolves as the System Approaches Equilibrium

Preconceptions	**Post conceptions**
P1: The forward reaction releases heat, making it exothermic. This lowers the system's temperature and reduces the amount of NOCl, causing NOCl to decrease.	P1: Since NOCl is produced from the reactants, its concentration will rise.
P2: The concentration of NOCl will rise since there are two moles of NO and one mole of Cl_2 on the reactant side and two moles of NOCl on the product side, notwithstanding heat application.	P2: Since reactants form products, it will rise.
P4: When heat is applied, some of the NOCl burns and is destroyed, resulting in a drop in its concentration.	P4: Since it is being generated on the product side, it will rise.
P5: There will drop in NOCl, although the cause is uncertain.	P5: Because not all of the product has been consumed, NOCl will drop.
P6: I want to know if it will go up or down.	P6: Since the reaction occurs in a gaseous state, the concentration of NOCl will rise.

Each student expresses their initial comprehension of how the concentration of NOCl varies during the reaction process in the preconception column. For instance, P1 proposes that the exothermic character of the forward reaction, which lowers the temperature and reduces the formation of NOCl, is the reason for the concentration reduction. P2 also thinks that more moles of NOCl are generated at the product side as opposed to the reactant side, which is why the concentration rises. The post-conceptions column, on the other hand, shows the students' updated comprehension following the intervention. In this instance, the students offer revised justifications considering their exposure to analogous learning. For example, P1 now knows that its concentration rises because NOCl is produced from the reactants. Similarly, P4 acknowledges that the concentration increases because NOCl is formed at the product side.

Six learners (P1 through P6) have preconceived notions and postconceptions about the reaction conditions at equilibrium, which are shown in Table 6. The table shows how students' ideas of equilibrium conditions have developed, moving from early misunderstandings to more precise understandings made possible by their participation in analogical training. Each student expresses what they initially believe happens when the reaction reaches equilibrium in the preconception column. For instance, P1 thinks the reaction ceases when heat is released, whereas P2 thinks it stops when equilibrium is reached. P3 indicates a misinterpretation of the equilibrium state by implying that the concentration of NH_3 is equal to that of N_2 and H_2.

Table 6

Concepts Held by Students on the Equilibrium Reaction's Circumstances

Preconceptions	Post conceptions
P1: Heat is released. Hence, the reaction ends as soon as the system reaches equilibrium.	P1: Because reactant and product concentrations are constant at equilibrium, yet forward and backward reactions continue to happen at the same Rate, the concentrations of NH_3, N_2, and H_2 do not change.
P2: The response halts because reaching equilibrium requires it to do so.	P2: The reaction is in equilibrium, so the NH_3, N_2, and H_2 concentrations do not change.
P3: N_2 and H2 concentrations are the same as the concentration of NH_3.	P3: The NH_3 concentration is the same as the N_2 and H_2 values.
P4: No change in NH_3, N_2, and H_2 concentrations.	P4: Since the quantity of N_2 and H_2 on the reactant side and the quantity of NH_3 on the product side are identical, the concentration of NH_3 is equal to the concentrations of N_2 and H_2
P5: No answer	P5: During the reaction, the remaining molecules have been consumed, leaving only NH_3 molecules in the closed container.
P6: The reactants have been consumed, leaving only NH_3 molecules.	P6: Because there will be a specific concentration of reactants and products, NH_3, N_2, and H_2 molecules are present.

After receiving analogical training, the students improved their explanations in the post-conception column. For example, P1 now knows that forward and backward processes co-occur at equilibrium even if the concentrations of reactants and products stay unchanged. Similarly, P4 concedes that the reaction's stoichiometry means that the concentration of NH_3 equals that of N_2 and H_2.

4.2 Discussion

4.2.1 Students Conceptions of the Evolution of Reactants and Products Prior to Equilibrium

Students were asked to explain the evolution of the concentrations of nitrosyl chloride (NOCl(g)) and chlorine (Cl_2 (g)) as a reversible reaction, $Cl_2(g) + 2NO(g) \rightarrow 2NOCl(g) + \text{heat}$, in order to assess their understanding of how reactant and product concentrations change as a reaction approaches equilibrium. Students' pre- and post-intervention ideas about the evolution of chlorine concentration are contrasted in Table 4. Some students, like P1 and P2, changed their pre-instructional frameworks following the intervention, but others, like P4, P5, and P6, still had difficulty creating models that were accepted by science. Based on their post-intervention explanations, the analogy significantly improved high-achieving kids' knowledge. Low-achieving learners, however, had trouble grasping the intricacies of the analogy, especially when it came to computation and conceptualizing. To help these learners, teacher intervention and more precise explanations of the analogy's applicability could be required—students' pre- and post-intervention ideas about how nitrosyl chloride concentration changes are contrasted in Table 5. Following the intervention, P1, P2, and P4 switched to scientific ideas, while P5 and P6 found it challenging to integrate the new ideas. Students who performed well academically gained more from the analogy and showed an enhanced comprehension of product evolution during equilibrium.

4.2.2 Students Conceptions of the Condition of the System at Equilibrium

Students' pre- and post-intervention ideas about the state of a reaction at equilibrium are contrasted in Table 6. Students were given the example reaction $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$ and asked to choose an option and explain why it is valid for a reversible reaction at equilibrium. While P1 and P2 were among the students who gave up on their preconceptions in favor of ones that science, P3, P4 supported, and P6 continued to hold onto their misconceptions or picked up new ones because of the intervention. In general, high achievers gained more profound insight into the properties of things at equilibrium from the analogy. The different effects of analogous instruction on students' conceptual understanding are highlighted in this conversation, with high achievers benefiting more than low achievers. Teachers should offer extra assistance and more precise explanations to assist students with difficulty understanding complex analogies. Furthermore, focused treatments can be required after an intervention to address enduring misunderstandings or recently developed ones. Teachers can optimize analogical teaching to promote conceptual understanding in chemistry education by customizing lessons to each student's needs and offering sufficient assistance.

V. CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusion

This study has shown that, prior to training, students studying agricultural science frequently hold beliefs about chemical equilibrium that differ from those recognized by science. Furthermore, even while this study's comparison appears to have the potential to improve students' understanding of chemical equilibrium, its efficacy depends on how well students grasp it. A sufficient understanding of the analogy could facilitate the intended conceptual shift. Notably, adequate comprehension of the analogy requires much teacher engagement. It was found that low-achieving students found the analogy challenging to understand, which hindered their capacity to learn new ideas and caused them to hold onto outdated beliefs regarding dynamic chemical equilibrium. Thus, when using the analogy to explain chemical equilibrium principles, we stress the significance of supporting students in connecting key concepts and the analogy. Additionally, teachers should provide support in performing the calculations involved in simulation activities.

5.2 Implications

Teachers should give concept diagnostic examinations to students in agricultural science to evaluate their preexisting theories before teaching them about chemical equilibrium. As a result, using analogies and interactive discussions in teaching tactics should be prioritized when reforming students' concepts. This method guarantees that training is customized to address students' misconceptions successfully. Additionally, teacher mediation is essential for helping students especially those with lower academic achievement levels—understand complex analogies. By implementing these tactics, teachers can improve student conceptual growth in chemical equilibrium and increase the efficacy of their education.

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