JPII 12 (3) (2023) 423-438

Jurnal Pendidikan IPA Indonesia

http://journal.unnes.ac.id/index.php/jpii

METACOGNITIVE CONCEPTUAL CHANGE (MCC) LEARNING MODEL: IMPROVING STUDENTS' CONCEPTUAL CHANGE THROUGH METACOGNITIVE SKILLS, MOTIVATION, AND SCIENTIFIC KNOWLEDGE

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DOI: 10.15294/jpii.v12i3.45737

Accepted: July 6th, 2023. Approved: September 29th, 2023. Published: September 30th, 2023

ABSTRACT

Conceptual change (CC) is a learning process in which students' misconceptions are transformed into more scientific knowledge. The Metacognitive Conceptual Change (MCC) learning model is created by incorporating metacognitive skills and motivation elements into the CC model to make it more effective. It is necessary to look into the MCC model's efficacy in encouraging students' CC. This study aims to evaluate the MCC model's effectiveness in improving conceptual changes in students through metacognitive skills, motivation, and scientific knowledge. This study used the experimental method with a one-group pretest-posttest design. The trial subjects were limited to 25 participants, while the broad trial subjects comprised 60 participants. Data was collected from tests, observations, questionnaires, and documentation. Data analysis techniques used in this study were descriptive, qualitative (n-gain test), and quantitative (paired t-test). The results demonstrate that the MCC learning model successfully raises students' motivation, scientific knowledge, and metacognitive skills (p Sig. 0.05), encouraging the CC process. It is concluded that the MCC learning model effectively improves students' CC by incorporating scientific knowledge, motivation, and metacognitive skills into instructional decisions. The MCC has practical implications for assessing CC through motivation and metacognitive scaffolding.

Keywords: conceptual change; metacognitive skill; motivation; scientific knowledge

INTRODUCTION

In the field, we observe that students who learn chemistry experience difficulties in solving chemical equilibrium problems. Students' mastery and conceptual understanding of chemical equilibrium materials are still low (Garcia-Lopera & Calatayud, 2014; Karpudewan et al., 2015; Syahmani et al., 2017; Quílez, 2021). These difficulties are present because students lack an understanding of chemical concepts. Students' lack of understanding of chemical concepts has been linked to chemistry representation and misconceptions (Rain & Tytler, 2013; Jusniar et al., 2021), but it is also known that students' metacognitive skills and motivation influence learning.

Metacognition is often referred to in the literature as "thinking about one's thinking" (Driessen, 2014). In this study, metacognition comprises metacognitive knowledge and metacognitive skills (Craig et al., 2020; Syahmani et al., 2020). The focus is on metacognitive skills through five aspects (Syahmani et al., 2020), namely: (1) representation (Tytler et al., 2020), (2) planning, (3) monitoring, (4) evaluation (van der Stel & Veenman, 2014; Ozturk, 2016; Wengrowicz et al.,

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2018; Hong et al., 2023), and (5) transfering skills (Heddy & Sinatra, 2013; Schuster et al., 2018, 2020).

Metacognitive skills are related to motivation (Oguz, 2016; Muna et al., 2017; Redondo et al., 2018) and academic achievements (Ohtani & Hisasaka, 2018; Feraco et al., 2023) because they have been evidenced to affect students' conceptual understanding (Cook et al., 2013; Özsoy & Ataman, 2017; Syahmani et al., 2021). Metacognitive skill training positively affects learning performance and motivation (Zepeda et al., 2015; Cheema et al., 2019).

Metacognitive skills and motivation are integral components when considering factors that affect the process of conceptual change (Conradty & Bogner, 2016; Taasoobshirazi et al., 2016) after confronting cognitive conflict (Hadjiachilleos et al., 2013; Yürük & Eroğlu, 2016). Promoting students' self-explanations of concepts they encounter daily, arousing their curiosity and interest, and involving them in the learning process can be one way to boost motivation. In addition to being positively correlated with interest in learning (Labroo & Pocheptsova, 2016; Thomas & Kirby, 2020), metacognition also increases the willingness to learn (McDowell, 2019).

The theoretical framework of our research is presented in Figure 1. Motivation and metacognition skills enhance students' epistemological beliefs and self-efficacy so that they are effective at conceptual change (CC). Epistemological beliefs have been shown to affect conceptual change. We argue that when students have strong metacognitive skills, students will also have strong epistemological beliefs. When they have scientific motivation, such as solving scientific problems, students can use their epistemological beliefs to either use scientifically accurate concepts or experience going through the conceptual change process.

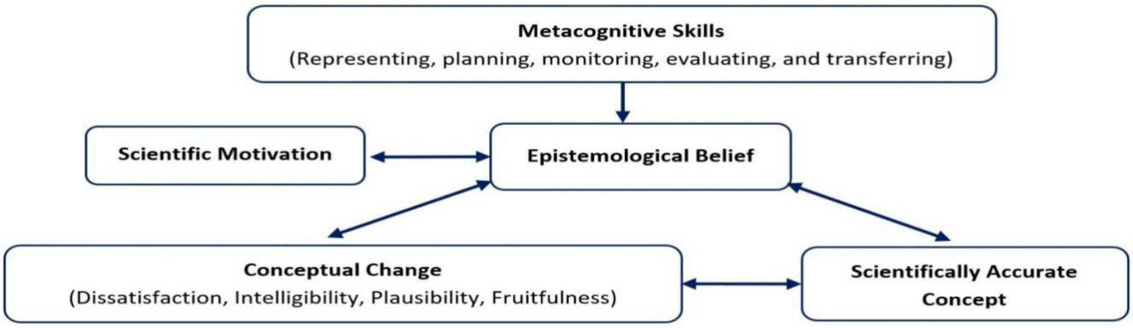


Figure 1. The Theoretical Framework of Research

Figure 1 above shows that, along with increasing students' metacognitive skills, they are more likely to have mature epistemological beliefs. For example, students tend to believe that learning is gradual and requires effort to achieve conceptual change. Conceptual change is a learning process in which learners' misconceptions are transformed into more scientific conceptions, or scientific knowledge goes through multiple stages (Heddy & Sinatra, 2013; Thomas & Kirby, 2020). In other words, CC happens when students develop the ability to build and identify a scientifically accurate and comprehensive explanation, which requires a significant revision of their previously held beliefs based on misconceptions (Asterhan & Resnick, 2020; Thomas & Kirby, 2020).

A misconception is a false belief in one's mental model, which occurs when there is a discrepancy between a student's conceptual understanding and scientific theories from related experts. Experts claim that because some misconceptions are persistent, resilient, and resistant to traditional tell-and-practice teaching approaches and cutting-edge instructional interventions, it is challenging to achieve conceptual change in science education (Vosniadou & Mason, 2012; Asterhan & Dotan, 2018).

Many conceptual changes have occurred in the scientific field due to the development of conceptual models. For example, conceptual changing texts (Ozkan & Selcuk, 2016; Yürük & Eroğlu, 2016); cognitive conflict (Labobar et al., 2017; Samsudin et al., 2019), and inquiry learning (Stieff, 2019; Chen et al., 2021); computer simulations (Dega et al., 2013; Fan et al., 2018), and representational (Tytler et al., 2020; Avargil & Saxena, 2023) have all been used as instructional intervention changes to correct students' misconceptions.

Nadelson et al. (2018) attempt to explain the conceptual change model (CCM) regarding the process of accommodation of conceptual change, which depends on several factors, including students' dissatisfaction with existing ideas (dissatisfaction), understanding of new concepts (clarity), clarity (reasonableness), and usefulness (success). The CCM uses only conceptual change strategies without emphasizing affective factors, requiring sudden changes, and prejudice has not been seen as an opportunity. So, it is necessary to revise the conceptual change model involving metacognition and motivating students (Hong et al., 2016; Syahmani et al., 2020). According to recent studies, using collaborative argumentation to support changes in learning's cognitive, ontological, and intentional aspects can help to promote conceptual change (Heng et al., 2015; Lombardi et al., 2016; Asterhan & Resnick, 2020; McLure et al., 2020; Schwartz et al., 2021).

This study proposes the Metacognitive Conceptual Change (MCC) model as a fresh approach to teaching science. The MCC learning model encourages CC on students with motivation, cognitive conflict strategies, representation, scaffolding metacognitive, and collaborative argumentation in the problem-solving process. In this research, the MCC model encourages CC on students by using cognitive conflict strategies with the discrepant event (Ramsburg & Ohlsson, 2016; Labobar et al., 2017; Syahmani et al., 2022), group work and questioning the argument (Kaya, 2013; Kramarski & Michalsky, 2013) for conceptual change and improving students' understanding (Vamvakoussi et al., 2013). Several studies explore conceptual changes on various topics and contexts, for example, overcoming students' misconceptions and understanding concepts about learning chemistry/science (Avargil, 2019; Vosniadou, 2020; Avargil & Saxena, 2023).

This study uses the topic of chemical equilibrium as a scientific concept. The scientific concepts that students understand are called conceptual understanding. This topic is prone to misconceptions in various concepts, such as predicting the direction of change in equilibrium position and fundamental aspects of chemical equilibrium. For example, students have difficulty deciding the direction of equilibrium change because they do not consider that changing any equilibrium conditions implies other variables' variation. There are numerous other ideas that students have had misconceptions about (Garcia-Lopera & Calatayud, 2014). However, research on the remediation or reduction of misconceptions with conceptual change strategies in Chemical Equilibrium material is still little reported (Chanyoo et al., 2018; Jusniar et al., 2021). Moreover, the research has not optimally involved aspects of metacognition skills and motivation despite its role as a predictor of conceptual change (Muna et al., 2017; Redondo et al., 2018). The Zone of Proximal Development (ZPD) and scaffolding based on metacognitive questioning are two constructivist theories that the authors used to develop their MCC model. The ZPD measures the gap between a child's potential level of development and their actual level of development (the capacity to solve problems with adults' assistance or in collaboration with more competent peers) (Christmas et al., 2013; Kusmaryono et al., 2021). Vygotsky's ZPD concept is closely related to the scaffolding concept (Impedovo et al., 2018; van de Pol et al., 2019).

The purpose of scaffolding is to help students achieve the ability to complete assignments smoothly and independently (Wass & Golding, 2014; Xi & Lantolf, 2021). The environment influences the development of student abilities from actual abilities to potential abilities as a mediator (Eun, 2019). Three mediators from the learning environment can affect the level of development, namely teaching aids, visualization tools, and assistance from others (Mutekwe, 2018). Scaffolding is provided throughout four stages. Stage 1: An improved performance from another assistant. Stage 2: Self-help is used to aid in performance. Stage 3: Development, automation, and fossilization of performance. Stage 4: It becomes necessary to revisit the ZPD as performance becomes less automated.

The MCC model encourages conceptual change in students with motivation, cognitive conflict strategies, representation, scaffolding metacognitive questions, and collaborative argumentation in problem-solving. The developed MCC model syntax is described as follows: (1) Identifying problem context; (2) Selecting plans and strategies; (3) Making solutions in groups while utilizing a monitoring strategy; (4) Analyzing and introducing scientific concepts; (5) Reflecting/evaluating, and (6) Transferring.

The application of the MCC learning model with scaffolding metacognitive questions to (1) improve students' cognitive (conceptual understanding), processes, and metacognitive skills (Hsu et al., 2017; Dori et al., 2018), (2) improve students' understanding, ability to solve the problem, and self-regulation (Sanjaya et al., 2017; Tai et al., 2018; Vrieling et al., 2018), (3) explore strategies that encourage students to engage in learning actively, reflect on their previous knowledge, and evaluate it (De Jager, 2019; Binali et al., 2021), and (4) promote positive affect, motivation, and conceptual change (Heddy & Sinatra, 2013), (5) develop students' expressions of autonomy and competence throughout (Schwartz et al., 2021). How effective is the MCC model in promoting students' conceptual changes? Through metacognitive skills, motivation, and scientific knowledge, this study assesses the effectiveness of the MCC model in promoting students' CC. The study's essential findings are expected to provide considerations for teachers and lecturers to use the syntax of the MCC learning model to improve CC and metacognitive skills to reduce learning loss. In this model, students will learn concepts more efficiently, making the conceptual change easier.

After students learn through the MCC model, they experience conceptual change, and with that, their misconceptions should be changed into more accurate scientific knowledge. On the other hand, the misconception is a further analysis of CC to deepen the analysis when the CC can reduce the misconception.

METHODS

The method used in this research was the experimental method (Creswell, 2015). This study used three science classes at Senior High Schools in Banjarmasin, Kalimantan, Indonesia, to evaluate the effectiveness of the MCC learning model in encouraging students' CC through metacognitive skills and motivation. The study applied a one-group pretest-posttest design, namely, O1 X O2 (Fraenkel et al., 2023).

Eggen and Kauchak (2014) argue that learning can be more effective when students actively organize and discover new information. The learning model is declared effective when producing the desired impact (Nieveen & Folmer, 2013). In the effectiveness test, before and after implementing the MCC model, tests were carried out to measure CC in students through increasing metacognitive skills, motivation, and scientific knowledge.

Table 1 displays the chemical equilibrium learning unit.

Table 1. The Chemical Equilibrium Learning Unit

Meeting	Activity	Description
1st	A	Pre-test (CUT, MCST) and MCAI, ARCS questionnaire
	B	Introducing and demonstrating to students their metacognitive
2nd	C	Dynamic equilibrium (First Real Issue)
	D	Homogenous and heterogeneous equilibrium in the design lab
3rd	E	Constant of equilibrium (Actual Problem 2)
	F	Flash simulation or a virtual lab
4th	G	Quantitative connection inside the equilibrium (Real Problem 3)
	H	Equilibrium Shift in Design Lab
5th	I	Chemical equilibrium in a commercial process (Real Problem 4)
	J	Questionnaires for the MCAI and ARCS and the CUT and MCST posttest

Note: Conceptual Understanding Test (CUT),
Meta Cognitive Activity Inventory (MCAI) questionnaire.
Meta Cognitive Skills Test (MCST), Attention, Relevance, Confidence, and Satisfaction (ARCS) questionnaire

Implementing the MCC model in chemistry learning for each meeting followed three phases: introduction, main activity, and closing. The following are the tasks for each phase: **Introduction:** Motivating learners in the classroom. Students must be informed and driven to learn (Conradty & Bogner, 2016; Thomas & Kirby, 2020).

Main activity: (1) Identifying problem context. This sub-activity includes eliciting students' ideas and preconceptions, motivating them by presenting cognitive conflict, creating cognitive conflict, and identifying problem context (Ramsburg & Ohlsson, 2016; Zohar & Ben-Ari, 2022). The metacognitive question for connecting is**,** '**What concepts were identified in conflict with your preconception?'. In this section, questions that will encourage the students' metacognition are posed to elicit the students' thoughts and advance the conceptual ecologies. By offering cognitive guidance, a teacher can aid students in understanding their own and their friends' concepts. Additionally, the instructor uses metacognitive orientation questions to help students become aware of their preconceptions and prepare for meaningful cognitive conflict, such as 'Why is your expression comprehensible/ plausible?'. Through cognitive guidance and interactive simulations, a teacher assists students in understanding their own concepts (Teichert et al., 2017; Fan et al., 2018) and fosters representational skills in chemistry (Taber, 2013).

(2) Selecting strategies and plans. This sub-activity includes facilitating students' scaffolding to resolve the wrong concept and planning strategies that effectively increase students' understanding of concepts and metacognitive skills (Özsoy & Ataman, 2017; Vrieling et al., 2018). The metacognitive question for planning strategies is, 'What is your best strategy to solve the problem?'.

(3) Making solutions in groups while utilizing a monitoring strategy. This sub-activity includes guiding students to solve problems in groups, posing argumentation-based inquiries to create significant cognitive conflict (Kaya, 2013; Kramarski & Michalsky, 2013; Heng et al., 2015; Hong et al., 2016; Labobar et al., 2017; Asterhan & Resnick, 2020), and monitoring and checking errors in the implementation of the strategy with the metacognitive question 'How effective is the solution in solving the problem?'.

(4) Analyzing and introducing scientific concepts. This sub-activity includes developing scientific concepts, posing stimulus questions, and analyzing and discussing the results of each group's research to bring the students' concepts together (Evagorou & Osborne, 2013; Osborne, 2019). The metacognitive question for analyzing and comprehension is, 'Why do the solution problems condition?'.

(5) Reflecting/evaluating. This sub-activity includes summarizing the results, developing scientific concepts, giving individual tests, and evaluating metacognitive self-reports (Craig et al., 2020). Students reflect and self-assess the learning that has been done (De Jager, 2019; Azevedo, 2020; Iordanou, 2022; Metin Peten, 2022) and verify the obtained results. The metacognitive inquiry for reflection is 'Can you analyze the strong and weak points of the instruction? What have I discovered about my learning process?'.

(6) Transferring. This sub-activity includes expanding understanding and meaningful application of knowledge with challenging assignments and communicating the results. The metacognitive question for transferring is, 'Can I apply an understanding to new situations? Why is your expression comprehensible and plausible?' (Heddy & Sinatra, 2013; Schuster et al., 2018, 2020; Stebner et al., 2022)

Closing: Students make learning conclusions. Teachers give assignments for the next meeting and close the lesson.

This study was conducted in two steps trial. First, we had a limited trial, where we gave a group of 25 participants a pretest, gave treatment where they learned chemistry through the MCC model, and then gave them a posttest. Second, the two groups in the broad trial—which included 60 participants from two different schools—were also subjected to the same tests and treatments. We also conducted a retest 12 weeks after each posttest, though, to strengthen our analysis.

The techniques of collecting the data were test and non-test. There were 20 questions on the conceptual understanding test (CUT), which was a three-tier diagnostic test (TTDT) (Kirbulut & Geban, 2014; Taslidere, 2016) to check on students' CC. To see this, we categorized students into 5 groups. We categorized students with accurate scientific knowledge (scientific concept), lack of knowledge, misconception, lucky guesses, and low confidence (Table 2). The CCs were measured by changes in scientific knowledge scores, and metacognitive skills and motivation were measured to ensure the model was developed following the research MCC model's theoretical framework (Figure 1).

Table 2. Categories the TTDT for Students' Conceptual Understanding

Concept Question	Justification Question	Confidence in Accuracy	Categories
Correct	Correct	Confident	Scientific Concept or Scientific Knowledge (SK)
Correct	Incorrect	Confident	Misconception False Positive (M1)
Incorrect	Correct	Confident	Misconception False Negative (M2)
Incorrect	Incorrect	Confident	Misconception False Negative (M2)
Correct	Correct	Not confident	Less Understanding Concept, Low Confidence (LC)
Correct	Incorrect	Not confident	Lucky Guess (LG)
Incorrect	Correct	Not confident	Lucky Guess (LG)
Incorrect	Incorrect	Not confident	Incomplete Concept or Lack of Knowledge (LK)

The metacognitive skills were measured by six essay questions with the rubric for metacognitive skills and a metacognitive activity inventory (MCAI) questionnaire (Syahmani et al., 2020). Student motivation was assessed using 36-item ARCS (attention, relevance, confidence, and satisfaction) questionnaires (Arumugam & Subramaniam, 2022) with the five-point Likert scale. Strongly agree to strongly disagree were the responses that were given. The performance of metacognitive skills, understanding conceptual, and student motivation were in four categories: 80–100 = very good, 66–79 = good, 56–65 = fair, and 56 = less.

The data were used for descriptive and inferential analysis. More specifically, the analysis looked at how metacognition helped students' conceptual development using the results from the assessment cards as a starting point. N-Gain was used to calculate the magnitude of the improvement, and paired t-tests were used to compare the outcomes of the pretest and posttest (parametric) or Wilcoxon test (non-parametric) with = 5% to determine the occurrence of a significant increase after treatment.

RESULTS AND DISCUSSION

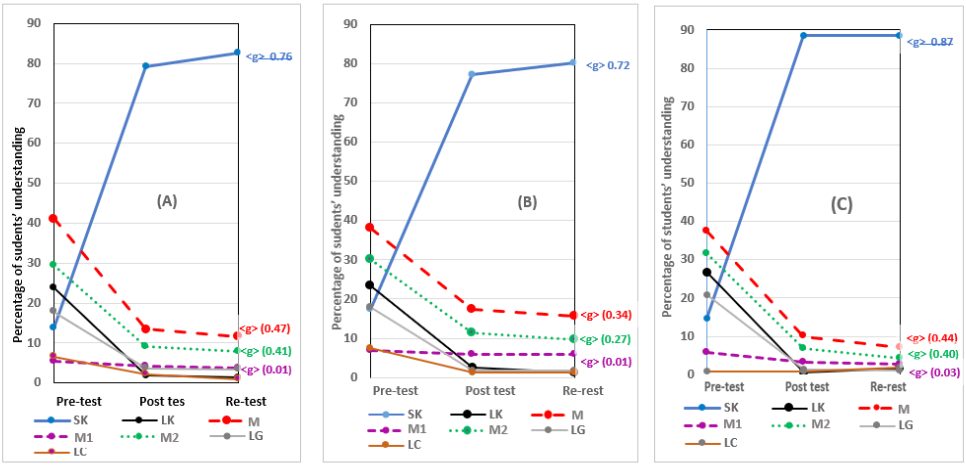
The results of the TTDT (Table 3) show a shift in students' conceptual change. Table 3 shows that, on average, about 65.11% of students who have shifted students' misconceptions (SM) have students' scientific knowledge (SSK).

Table 3. The Result of Students' Conceptual Change from the TTDT

Trial	Pretest	Percentage	Posttest	Percentage	SM to SSK	Percentage
Limited	SM (M1 5.40; M2 35.76)	41.16	SM (M1 4.20; M2 9.20)	13.40	27.76	67.44
Broad (Group 1)	SM (M1 7.00; M2 31.15)	38.15	SM (M1 5.83; M2 11.50)	17.33	20.82	54.57
Broad (Group 2)	SM (M1 5.83; M2 31.67)	37.50	SM (M1 3.17; M2 6.83)	10.00	27.50	73.33
				Average		65.11

Figure 3 shows that the student's scientific knowledge (SK), represented by the blue line, experiences an increasing trend. Conversely, the students' misconception (M), represented by the red line, experiences a decreasing percentage trend in the posttest and pretest. Students who study with the MCC learning model will be more interested in learning and produce greater understanding (a conceptual change occurs from misconception to scientific concept). The kinds of misconceptions found in this study are (1) false positive misconceptions or persistent misconceptions (M1 purple line) in low n-gain category conceptual change and (2) false negative misconceptions or resistant misconceptions (M2 green line) in moderate and high n-gain category conceptual change. False positive misconceptions are harder to change and remove than false negative misconceptions (Shtulman & Lombrozo, 2016). Students need extra effort to inhibit strong misconceptions (Masson et al., 2014; Foisy et al., 2015; Mason & Zaccoletti, 2021) by restructuring their mental models (Bryce & Blown, 2016; Moutinho et al., 2016).

On the other hand, the misconception is a further analysis of conceptual changes to deepen the analysis when the CCs can reduce the misconception. The blue line represents students with scientific knowledge. The percentage increases in the posttest, and knowledge retention remains after 12 weeks (Figure 2). The trend of CCs that occurred shifts from students' misconceptions to scientific knowledge.



(A) Limited Trial, (B) Broad Trial Group 1, (C) Broad Trial Group 2, <g> = n-gain, if the value of (.) means that n-gain has decreased
SK = Scientific Knowledge, LK = Lack of Knowledge, M = Misconception, M1 = Misconception (False Positive), M2 = Misconception (Negative),
LG = Lucky Guess, LC = Lack of Confidence.

Figure 2. Result from Three Tier Diagnostic Test

The following changes in students' misconceptions about chemical equilibrium are found in Table 4: (1) In an equilibrium state, the concentrations of the reactants and products are equal; (2) Cannot link the K value with the chemical composition at equilibrium; (3) The addition of solids or pure liquids will shift heterogeneous equilibrium at constant temperature; (4) If concentrations are changed at a constant temperature, the Qc and Kc value changes; and (5) Cannot determine the K value from the chemical composition at equilibrium; (6) the addition of catalyst will increase Kc value.

Table 4. Trends of Changes in Students' Misconceptions of the Concept of Chemical Equilibrium

Percentage of Misconception in concept	Limited Trial			Broad Trial						Example of a Misconception Description	Information of the scientific concept
				Group 1			Group 2				
	Pre-test	Re-test	n-gain	Pre-test	Re-test	n-gain	Pre-test	Re-test	n-gain		
Dynamic equilibrium	53.60	8.00	(0.98)	36.67	10.00	(0.42)	35.00	10.00	(0.38)	When the reaction is in an equilibrium state, the concentrations of reactants and products are equal.	When the reaction is in an equilibrium state, actually dynamic equilibrium, is a continuous change in concentration in a microscopic system.
Homogenous-heterogeneous equilibrium	38.00	2.00	(0.58)	45.00	21.67	(0.42)	43.00	18.33	(0.43)	Heterogeneous equilibrium contains more than two phases.	Heterogeneous equilibrium contains two or more different phases.
Equilibrium constant	40.00	21.54	(0.31)	60.00	26.67	(0.83)	38.00	14.40	(0.38)	The equilibrium constant for the reaction involves the pure liquid, gas, and aqueous phases.	The equilibrium constant for the reaction involves the gas and aqueous phases.

Quantitative relationship in equilibrium	31.33	5.34	(0.38)	26.11	6.67	(0.26)	32.78	5.00	(0.41)	If concentrations are altered at the constant temperature, the Qc and Kc value changes	If concentrations are altered at the constant temperature, the Qc changes, but the Kc value is constant.
Equilibrium Shift	33.60	16.80	(0.25)	33.33	21.33	(0.18)	44.00	2.67	(0.62)	The equilibrium moves to the right as the concentration rises.	The direction of the equilibrium shift depends on the Qc and Kc values of the equilibrium reaction
Chemical equilibrium in Industrial	36.00	13.33	(0.35)	27.78	6,67	(0.29)	32.22	2.22	(0.44)	The addition of a catalyst will increase the Kc value.	The addition of a catalyst will speed up reaching equilibrium with the Kc constant.
Average score	38.76	11.60	(0.45)	38.15	15.50	(0.37)	37.50	7.00	(0.44)		

For example, the student's misconception of equilibrium shifts on the problem: Predict the direction of the shift if in the equilibrium reaction: $FeSCN^{2+}(aq) \rightleftarrows Fe^{3+}(aq) + SCN^{-}(aq)$ sodium thiocyanate solution is added at a constant temperature. Students choose the correct answer to this question (the equilibrium will shift to the $FeSCN^{2+}$), but they choose the wrong reason, and the students are confident in it. They believe that adding sodium thiocyanate resulted in equilibrium shifting to the $FeSCN^{2+}$. Students believe the concentration of Fe^{3+} decreases, but the concentration of SCN^{-} ions increases. In fact, the addition of sodium thiocyanate solution causes the reaction shift towards the formation of $FeSCN^{2+}$ so that the concentration of SCN- ions and Fe^{3+} will decrease to form a new equilibrium with a constant Kc value. This is in line with Le Chatelier's Principle and the findings of some researchers that the addition of reactants in the equilibrium system causes the reaction to shift toward the product. The $FeSCN^{2+}$ ions become increased (Karpudewan et al., 2015).

The implementation of the MCC learning model will provide five benefits for students. First, learning the context to increase learning motivation. In this model, this benefit could be found in the first stage, which is an introduction. In the lesson plan for the treatment in this study, we provide pictures and videos about the equilibrium between hemoglobin and oxygen in the blood and muscle tissues. It shows that equilibrium happens in the human body, which is close to students. The reaction generally looks like this: As blood passes through the lungs, where oxygen concentrations are high, the hemoglobin system is affected. Hemoglobin binds oxygen as the equilibrium shifts to the right. The equilibrium shifts to the left-hemoglobin release of oxygen as blood leaves the lungs and enters muscles and organs where oxygen concentrations have been depleted (because muscles and organs use oxygen). Since this shift cannot be seen, the teachers connect this process with Flash simulation of equilibrium shifts that occur with $[FeSCN]^{2+}$ to simulate a submicroscopic aspect of the experiments by observing color changes as a result of increasing concentrations of SCN^{-} ions or the increased Fe^{3+} which can result in different reaction and colors (Figure 3).

Second, it involves cognitive conflict, metacognitive activities, and group work to produce conceptual understanding and meaningful retention. In this model, this benefit can be found in the second stage. In the learning process, the teacher shows 4 beaker glasses containing an ionic solution containing $FeSCN^{2+}$, Fe^{3+}, and SCN^{-}, which are always in the equilibrium state and the color orange. If it is stressed, such as in the form of ion addition, it will result in an equilibrium shift, affecting the total molecule of all and changing the solution's colour. The teacher shows that when the beaker glass is added with NaSCN solution, it can turn darker red. Meanwhile, when added to NaOH solution, it results in pale yellow. It is expected to cause cognitive conflict, which does not add up to a student's preconception (when a solution is added with another solution, the color should be paler). The effect of concentration change on the position of equilibrium includes (1) After the addition of some NaSCN to the $[FeSCN]^{2+}$ solution, the color changes from orange into dark red; (2) After the addition of some NaOH to the $[FeSCN]^{2+}$ solution, the color changes from orange into pale yellow.

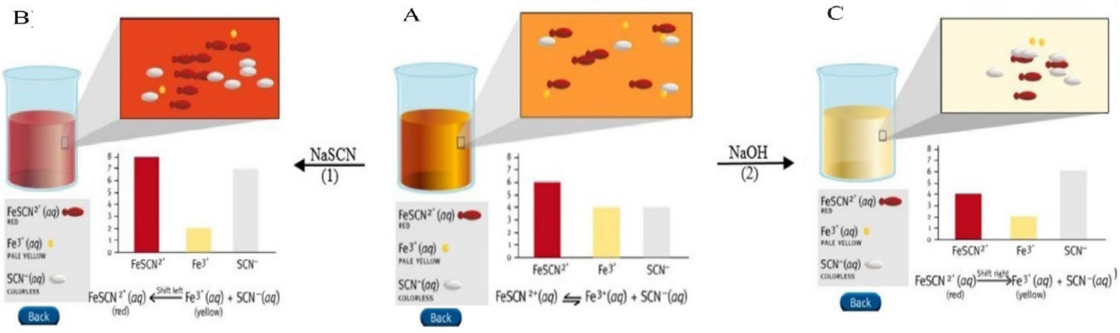


Figure 3. Simulation Result of The Effect of Concentration on Ion $FeSCN^{2+}$ Equilibrium
A. $[FeSCN]^{2+}$ ion in initial equilibrium, the color solution is reddish-orange; B. After the addition of some NaSCN to the $[FeSCN]^{2+}$, it transforms from reddish-orange to dark red; C. After some NaOH was added to $[FeSCN]^{2+}$ solution, from reddish-orange to pale yellow, the color changes.

The process of accommodation of conceptual change depends on several factors, including student dissatisfaction with existing ideas (dissatisfaction), understanding of new concepts (intelligibility), clarity (plausibility), and benefits (fruitfulness) (Nadelson et al., 2018). Allowing students to participate in problem-solving, analysis actively, and collaborative argumentation in group discussions will help achieve this (Evagorou & Osborne, 2013; Kaya, 2013; Kilinc et al., 2017; Aziz & Johari, 2023). The involvement of students in these processes can be seen in the next steps of MCC learning models, which will be discussed in the third benefit of the model.

The third benefit is that the students can plan effective learning strategies, monitor learning progress, and measure their level of understanding with the help of metacognitive scaffolding. This process happened in the third stage. At this phase, the teacher asks the students with the metacognitive scaffolding, "How does this problem be represented from a chemical perspective?". To answer this question, the teachers facilitate the students to choose the strategy that will accommodate them to find the solution to the cognitive conflict. In this phase, students plan on understanding the teachers' demonstration by running a simulation using ICT support (Dega et al., 2013; Wen et al., 2020).

The observed chemical phenomenon at the macroscopic level is the change in the color of the solution in the beaker glass, from orange to dark red. The change in SCN^- reagent concentration that occurs is a change in the microscopic level that can only be observed from the number of molecules formed or decomposed in the form of virtual simulations and graphical displays. If the concentration of a substance is raised, the equilibrium shifts opposite the substance. How can experimental data be explained? The colour of the solution at equilibrium when added NaOH solution (take Fe^{3+} ion) changed from orange to pale yellow. The equilibrium system will change to the right (Fe^{3+} (*aq*) + SCN^- (*aq*)). Reactions occurring: $[FeSCN]^{2+}$ (*aq*) ⇄ Fe^{3+} (*aq*) + SCN^- (*aq*). Fe^{3+} ion concentration in the equilibrium system decreases because the Fe^{3+} ion reacts with OH^- ions to form precipitation $Fe(OH)_3$. This concept will be challenging to explain and understand by the students when the simulation of reaction at the microscopic level does not support the learning.

After the qualitative understanding, they will be guided to test it through quantitative questions about equilibrium shifts. The question is as follows: Finding the equilibrium constant (Kc) at the beginning of the equilibrium shift and the end of the equilibrium shifts (Qc) from Figure 3? Students analyze the simulated data in group discussions. When the concentration SCN^- ion is added, Qc (1) > Kc, which means the reaction will shift in the direction of the reactants ($[FeSCN]^{2+}$). Added concentration OH^- ion, Qc (2) < Kc means the reaction will shift to increase the concentration product (Fe^{3+} and SCN^-). This simulation shows that the reacting system's reactants and products are all in equilibrium. The results are as predicted by Le Châtelier's principle. According to Le Châtelier's principle, an equilibrium system will adjust if external stress is applied to it, partially offsetting the stress as the system moves to a new equilibrium position.

After the students have acquired this knowledge through Flash simulation and mathematical equations, the teacher asks them a question from metacognitive scaffolding: "Can you evaluate the affectivity of the simulation to your understanding?" By asking this question, the students will connect their quantitative proof and qualitative understanding of the cognitive conflict they encountered earlier and then decide whether it is effective or not to understand the conflict.

Lastly, meaningful assignments in the transferring phase significantly increase motivation and strengthen students' skills transfer and understanding of concepts. This process happened at the seventh stage, the transferring stage (Table 2). The teacher first asks two questions that can help to broaden what has been learned from the previous simulation. The questions are as follows:
Question 1: How does the color change occur when the pressure is increased, and the volume is reduced?
Reaction $2NO_2\,(g) \rightleftarrows N_2O_4\,(g)$
Question 2: How does the direction of the equilibrium shift when the temperature is lowered? Explain your reasons!
Reaction: $2NO_2(g) \rightleftarrows N_2O_4\,(g)\ \Delta H = -58\ kJ$

After they can conceptualize and broaden the concept of what they have previously learned, they are asked to exercise what they have learned in another context, which is the reaction in the conditions used in various Haber-Bosh industrial processes to manufacture ammonia. To guide the students to this challenge, the metacognitive scaffolding from the teacher asks whether the understanding gained from the learning process can be transferred to understand a new situation and how the understanding of the new situation using that understanding is plausible. The reaction is as followed: $N_2\,(g) + 3H_2\,(g) \rightleftarrows 2NH_3\,(g)\ \Delta H = -92kJ$.

Then the teacher asks, "In order to obtain excess NH_3 production, what should be done? Try to relate it to the chemical equilibrium shift factor!" this question is related to students understanding after they answer the previous two questions.

When a new concept is assimilated by the conceptual structure, the assimilation process occurs. However, if a student's understanding of an idea conflicts with a newly learned concept, the conceptual system must be adjusted. In the MCC model, teachers conduct metacognitive activities that lead students to consider their understanding of concept levels, learning processes, and abilities to plan, monitor, evaluate, reflect, and transfer knowledge in problem-solving.

Figure 4 shows the result of the metacognition test. The average metacognition shows students have good metacognition skills, as indicated by high n-gain scores. We also check this result with students' own perception of their metacognition, and the graphic shows that students' perception of their own metacognition aligns with our test result, where after they learn through the MCC model, the student thinks that they have better metacognition skill.

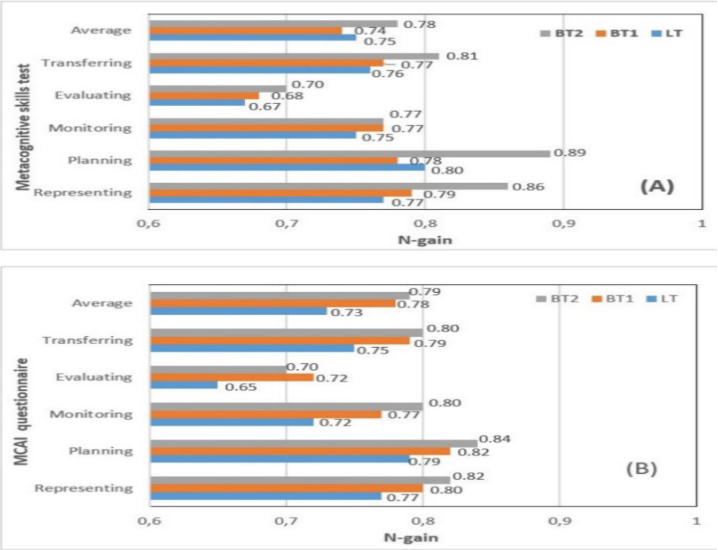


Figure 4. The Result of the Metacognitive Test and MCAI Questionnaire, with Category based on Syahmani et al. (2020)

According to the results, most students have good metacognitive skills, as evidenced by their average n-gain score in the high category, which is > 0.70. Metacognitive skills can be formed with habits that are practiced and rehearsed continuously. The metacognitive skills can improve students' learning outcomes and thinking skills (Popandopulo et al., 2021). Metaconceptual awareness plays a more decisive role in restructuring conceptual understandings (Saçkes & Trundle, 2017) and improves performance in academic achievements (Ohtani & Hisasaka, 2018; Perry et al., 2019).

Descriptive and inferential analysis for metacognitive skill, motivation, and scientific knowledge is shown in Table 5. All groups' students' metacognitive skills, motivation, and scientific knowledge are good after treatment. The inferential analysis shows a significant difference between posttest and pretest scores. Thus, the MCC learning model is effective in increasing metacognitive skills, motivation, and students' scientific knowledge (p Sig. < 0.05) with n-gain > 0.70 (high criteria) for metacognitive skills and students' scientific knowledge, while the motivational aspect with n-gain < 0.70 (medium criteria). These results reinforce the finding that motivational strategies and metacognitive skills effectively develop students' understanding of concepts and cognition (Adadan, 2020; Schuster et al., 2020; Taslidere & Yıldırım, 2023).

Table 5. The n-Gain, t-Test, and Wilcoxon Test for All Groups

Assessment Aspect	**Trial**	**Descriptive Analysis**						**Inferential Analysis**				**Conclusion**
		Average of				**<g>**	**n-gain**	**Paired t-test**		**Wilcoxon test**		
		Pre-test	**K1**	**Post-test**	**K2**			**t**	**p(Sig.)**	**Z**	**p (Sig.)**	
Metacognitive skill	LT	15.67	Less	77.44	Good	0.73	High	-41.23	0.00*	-	-	H_o is rejected
	BT1	18.89	Less	79.26	Good	0.74	High	-52.38	0.00*	-	-	H_o is rejected
	BT2	19.07	Less	82.50	Very good	0.78	High			4.79	0.00*	H_o is rejected
Scientific Knowledge	LT	18.80	Less	81.00	Very good	0.77	High	-21.24	0.00*	-	-	H_o is rejected
	BT1	23.00	Less	78.17	Good	0.72	High	-25.16	0.00*	-	-	H_o is rejected
	BT2	13.80	Less	88.50	Very good	0.88	High			4.82	0.00*	H_o is rejected
Motivation	LT	54.98	Less	79.02	Good	0.53	Medium			-4.37	0.00*	H_o is rejected
	BT1	56.72	Enough	78.83	Good	0,51	Medium			-4.78	0.00*	H_o is rejected
	BT2	54.93	Less	79.22	Good	0,54	Medium			-4.78	0.00*	H_o is rejected

The MCC learning model is based on constructivist learning theory and conceptual change theory. It involves motivation and metacognitive activities to make it easier for students to understand concepts and encourage conceptual change. Implementing the MCC model in the classroom or laboratory requires the support system of model components (lesson plan, integrated worksheet, assessment, and teaching materials). It requires equipment and chemicals for practicum and ICT-based learning resources (such as interactive multimedia, Flash simulation software), as discussed in the following paragraphs. A good MCC learning model support system will impact the success of students' conceptual changes. These results are consistent with the findings of research conducted by Chang et al. (2017), Fan et al. (2018), and Wen et al. (2020) that interactive multimedia, simulation, and ICT can improve students' achievement, metacognition, and conceptual change.

Identifying the origins of CC has inspired the design of pedagogical interventions to promote a deeper understanding of challenging concepts (Osborne, 2019; McLure et al., 2020; Syahmani et al., 2021). Metacognitive activities in the MCC learning model will make concepts more manageable for students to learn, making the CC easier. Constructivist learning and CC theory are used to develop this model.

Metacognitive skills are vital to improving students' conceptual understanding/scientific knowledge. To encourage students' deep learning, teachers must use a high level of metacognition to facilitate metacognitive scaffolding for students. Moreover, there is evidence that training in metacognitive skills positively influences students' conceptual understanding. Therefore, future research focuses on training the MCC model integrated into science, technology, engineering, and mathematics (STEM) to improve students' metacognition and conceptual change through collaborative activities (Yerrick et al., 2018; Lederman et al., 2019; Zheng et al., 2020; Li et al., 2023) and to produce enduring conceptual change and resilient learning of scientific concepts (Asterhan & Resnick, 2020; McLure et al., 2020).

CONCLUSION

The MCC learning model effectively improves students' conceptual change by incorporating scientific knowledge, motivation, and metacognitive skills into instructional decisions. The MCC has practical implications for assessing CC through motivation and metacognitive scaffolding. Teachers can explore what problems students face during learning. Therefore, it allows the teacher to modify and improve the relevant instruction to the depth of students' conceptual understanding. Since the MCC model emphasizes student-centered learning, there is a paradigm shift from (1) students who are given knowledge to those who seek it, and (2) professional development in this area should train teachers in metacognitive practice to support HOTS and conceptual change in chemistry learning.

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