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Effectiveness of i-SMART Learning Model Using Chemistry Problems Solving in Senior High School to Improve Metacognitive Skills and Students' Conceptual Understanding

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Abstract. This study presents i-SMART learning model (***I***dentifying and representing problems, ***S***electing strategies and plans, ***M***aking solutions with monitoring strategies used, ***A***nalyzing and evaluating, ***R***eflecting, and ***T***ransferring). I-SMART effectiveness in improving students' metacognitive skills and conceptual understanding is analysed. The application of i-SMART learning model in metacognitive activities made concepts easier for students to learn, therefore made it positively responded by students.

Keywords: *i-SMART learning model, problem solving, metacognitive skills, conceptual understanding.*

Introduction

The new chemistry concept is inseparable from its chemical representation in the learning process, as a result, students are faced with difficulties such as: (1) the inability to solve chemistry learning problems, especially in the microscopic level (Chittleborough & Treagust, 2007; Nahum, Mamlok-Naaman, Hofstein, & Taber, 2010; Rain & Tytler, 2013; Talanquer, 2011); (2) the inability to understand the chemical concepts and translate the

problems into mathematical statements (Chandrasegaran, Treagust, & Waldrip, 2009); and (3) undeveloped students' metacognition and conceptual understanding for solving the problem (Syahmani, Irhasyuarna, & Kusasi, 2013) .

Indonesia's basis of learning in education revolution is summarized into 4C (critical thinking, creativity, communication, and collaboration), and correspond with the 21st century learning process grouped into four aspects as follows, creativity, critical thinking, problem solving, and metacognition (Greenstein, 2012; Griffin & Care, 2015). The problem-solving process also involves the metacognition aspect (Cooper, Sandi-Urena, & Stevens, 2008; Jacobse & Harskamp, 2012). When students involve metacognitive skills in solving problems, it maximizes their learning potential (Gama, 2004).

Metacognition is the ability to analyse thinking about thinking (Biryukov, 2003; Mevarech & Fridkin, 2006), it is also the capacity to control thinking processes through various strategies such as planning, monitoring, and evaluation (Brown, 1987; Cooper & Sandi-Urena, 2009; Herscovitz, Kaberman, Saar, & Dori, 2012; Whitebread et al., 2009) which is usually defined as 'cognitions about cognitions', or 'thinking about one's own thinking'. It is categorized into two basic aspects namely, knowledge and regulation metacognitive (Kuhn, 2000). Furthermore, two skills are added namely, representation and transferring technique. Representation competence is the acquisition of meaningful understanding in solving chemistry problems (Carolan, Prain, & Waldrip, 2008; Rain & Tytler, 2013). The transfer or application of skills in solving problems improves when students acquire more strategies and knowledge (Billing, 2007; Gama, 2004; Moreno, 2010). Transferring skills are the bases of all creativity, problem solving, and decision making (Sousa, 2012).

Metacognition plays important roles in problem-solving and understanding chemistry concept (Cooper et al., 2008) (Rickey & Stacy, 2000). It also improves problem-solving skills and cognitive retention capacity (Gama, 2004), as well as an essential component of learning and self-regulation (Efklides, 2011). This motivates students (Muna et al., 2017) and help them in planning, applying, and evaluating their results (Schraw & Dennison, 1994). Therefore, an alternative method is developed for improving metacognitive skills and students' conceptual understanding of chemistry.

This study aims to analyse the effectiveness of i-SMART model in improving students' metacognitive skills and understanding of chemistry. Focus issues in this study include: 1) the significant increase in metacognitive skills and students' understanding of chemistry before and after the application of i-SMART learning model; 2) the differences in metacognitive skills and students' conceptual understanding between the groups after the application of i-SMART learning model.

Literature Review

i-SMART model was designed based on previous researches and findings of metacognition. The developed Syntax for the models was summarized in Table 1.

Table 1
Syntax of i-SMART Model

Syntax	Teacher Activities	Student Activities	Metacognitive questioning
Identifying and representing the problem	Bringing up a scientific problem Providing students with guidance in the representation and formulation of hypotheses.	Identifying the problem. Representing them mentally (or visualizing them with a computer program and simulation).	What is the problem about? What is given in the problem? What is representing the problem?
Selecting strategies and plans	Asking students to choose a strategy and develop a problem-solving plan.	Planning strategies for problem-solving.	What strategy is suitable for problem-solving? Why this strategy is used?
Making solution with monitoring strategy use	Guiding students solve problems. Monitoring the implementation of the strategy. Checking/fixing errors.	Try-revise-check activities. Developing a metacognitive skill.	How should the suggested plan be carried out?
Analyzing and evaluating	Asking students to analyse data, evaluate the process, give quizzes, and make conclusions.	Analyzing data and process evaluation for problem-solving. Checking the solution.	Why is the solution to the problem?
Reflecting	Guiding students to reflect on learning.	Participating in the reflection process. Writing down the additional solution	Does the solution make sense? Is there another way to solve the problem?
Transferring	Giving new problems that are educative to students.	Making an investigation to tackle problems in new situations.	Can understanding or skills be applied to new situations?

Research findings and the application of i-SMART model were shown in Table 2.

Table 2
Categorization of the Empirical Papers

Author(s) and year	Scientific skills or concepts being assessed	Metacognitive skills being assessed	Aspects of metacognition in the intervention	Time
Thomas and McRobbie (2001)	Alternative conception and students' metacognition in chemistry.	Metacognition: self-concept.	Metacognitive experience interventions. Informing students about several alternatives for learning concepts.	12 weeks
Polya (2004)	Students' problem-solving ability in mathematics.	Self-directing question.	Metacognitive representation, planning, monitoring, and evaluation.	-
Cooper & Sandi-Urena (2009), Sandi-Urena et al. (2011)	Assessing metacognitive skills in domain- specific context.	Metacognitive skills.	Promoting metacognitive skills than the reflection in problem- solving with Interactive Multimedia Exercises (IMMEX) and Metacognitive Activities Inventory (MCAI).	2.5 weeks
Grotzer and Mittlefehldt (2012)	Conceptual understanding and knowledge transfer.	Metacognitive monitoring, evaluation, and transfer.	Emphasis on the aspects of monitoring, evaluation, and transfer.	16 weeks
Herscovitz et al. (2012)	Conceptual understanding levels: macroscopic, microscopic, symbol, and process.	Metacognitive on chemistry understanding levels.	Posing questions based on metacognitive knowledge and skills.	4–5 months
Thomas (2013)	Students' understanding in physics concept.	Metacognitive orientation and reflection.	Changing the orientation of a classroom environment to stimulate the reflection in physics learning.	6 weeks
Taasoobshirazi and Farley (2013)	Students' metacognition for solving physics problems.	Metacognitive knowledge and skills.	Metacognitive knowledge (declarative, procedural, and conditional knowledge) and skills (planning, monitoring, evaluation, debugging, and information management).	12 weeks
Java (2014)	The problem-solving strategy (GEAR) in mathematics enhances metacognitive skills.	Metacognitive skills	Effect of GEAR strategy intervention towards the metacognitive skills of students with MCAI.	4 weeks
Wang (2015)	Students' construction of scientific explanations in inquiry-based biology activities.	Metacognitive evaluation	Instructions for completing self-evaluation using standard unit ideas.	10 weeks

The i-SMART model is an alternative instructional method designed to improve metacognition skills and students' conceptual understanding of chemistry. This model was developed to facilitate students' thinking and learning ability during the process of representing problems, planning, choosing strategies, monitoring, evaluating, and knowledge transfer in order to improve cognitive performance in the future. The syntax of i-SMART Model consists six steps as follows: (1) identifying and representing problem; (2) selecting strategies and plans; (3) providing solutions with the strategies; (4) analyzing and evaluating; (5) reflecting; and (6) transferring of the acquired knowledge (Syahmani, Suyono, & Imam-Supardi, 2017). The i-SMART implementation by teachers requires scaffolding in the form of metacognitive questions to help students systematically solve problems. It was observed that these questions play important roles in making the students' learning process more efficient. For example, questions help students to: (1) activate their pre-knowledge (Osman & Hannafin, 1994); (2) increase the students' understanding (Kramarski & Zeichner, 2001); (3) improve their cognitive processes (Kaberman & Dori, 2009); (4) enhance students'cognition (Conner, 2007; Syahmani, & Amini, 2019); (5) enhance metacognitive skills (Taylor, Alber, & Walker, 2002); and (6) create awareness of the problem and improve students' ability to solve them (Sanjaya, Muna, Suharto, & Syahmani, 2017). This study relevant with research Kaberman & Dori (2009) guided question posing while using a metacognitive strategy by 12th grade honors chemistry students. Kaberman & Dori (2009) investigated the ways by which the metacognitive strategy affected students' skills to pose complex questions and to analyze them according to a specially designed taxonomy.

Research Method

This research was conducted using three classes in different schools, each consisted of 30 students of 11th grade from the science program at senior high school (Banjarmasin, Indonesia). A preliminary and post-test were performed for the classes (groups) with the same level of knowledge and skills. The group pre and post-test model used was designed O1 X O2 for 10 weeks (Fraenkel, Wallen, & Hyun, 2012). The application of i-SMART learning model helped in developing students' metacognitive skills and conceptual understanding for solving chemistry learning problems. The intervention period takes place on the Chemical Equilibrium learning unit shown in Table 3.

Table 3

Implementation of i-SMART Learning Model

Activity	Description	Time
A	Pre-test MCAI, MCST, and CUT	Week 1
B	The introduction and modelling of students metacognitive	Week 1
C	Dynamic equilibrium (Actual Problem 1); First class observation	Week 2
D	Design Lab – Homogenous and Heterogeneous equilibrium	Week 2
E	Second class observation	Week 3
F	Equilibrium constant (Actual Problem 2)	Week 4
G	Third class observation	Week 5
H	Quantitative relationship within the equilibrium (Actual Problem 3)	Week 6
I	Design Lab – Equilibrium Shift	Week 7
J	Fourth class observation	Week 8
K	Chemical equilibrium in an industrial process (Actual Problem 4)	Week 9
L	Fifth class observation	Week 10
M	Post-test MCAI, MCST, and CUT	Week 10

The learning process began with pre-test (O1), each student was asked to work on metacognitive skills and conceptual understanding, then fill out a questionnaire of metacognitive activity inventory (MCAI), metacognitive skill test (MCST), and conceptual understanding test (CUT). The reliability of MCAI, MCST, and CUT produced Cronbach's α values of 0.91, 0.89, and 0.86 respectively.

The MCAI questionnaire (modified from Cooper & Sandi-Urena, 2009) consisted of 35 items and used a 5-point Likert Scale ranging from 1 for strongly disagree to 5 for strongly agree. While the Metacognitive Skill Test (MCST) consisted of 6 questions with each question having 5 indicators including: representing, planning, monitoring, evaluating, and transferring, shown in Table 4, while the assessment rubric was shown in Table 5.

Table 4

Development of the Metacognitive Skills Aspect

Aspects of Metacognitive	Description	Reference
Representing	Identifying the problem. Representing the problem mentally.	Delvecchio (2011), Polya (2004), Kapa (2002), Cooper & Sandi-Urena (2009), Panaoura et al. (2009), Talanquer (2011), Thomas (2013).
Planning	Developing a problem-solving plan. Breaking the problem down, and Mapping out a solution.	Howard et al.(2000), Kapa (2002), Hartman (2001), Polya (2004), Erskine (2009), Sandi-Urena et al. (2011), Delvecchio (2011).
Monitoring	Trying, checking, and revising.	Polya (2004), Hartman (2001); Cooper & Sandi-Urena (2009), Delvecchio (2011), Grotzer and Mittlefehldt (2012).

Aspects of Metacognitive	Description	Reference
Evaluating	Answering the question, and checking the answer.	Polya (2004), Docktor (2009), Erskine (2010), Wang (2015), Cooper &Sandi-Urena (2009), Delvecchio (2011), Thomas (2013).
Transferring	Make an investigation to tackle problem-solving in a new situation.	Grotzer and Mittlefehldt (2012), MacGregor (2007), Moreno (2010), Delvecchio (2011).

Table 5

Rubric for Metacognitive Skill Test assisted by Metacognitive Questioning

Metacognitive Aspects	Metacognitive questioning	Score
Representing	a. What were the problems presented in the questions?	
	▪ There were no problems presented/written.	0
	▪ Problems were formulated incorrectly.	1
	▪ They were formulated based on those present.	2
	▪ They were formulated in the form of an open sentence.	3
	▪ They were formulated specifically (contains 2 minimal varibles).	4
	b. What was observed from the problems?	
	▪ No data were mentioned.	0
	▪ Mentioned data were inaccurate.	1
	▪ Some data were mentioned.	2
	▪ All data were mentioned.	3
	▪ All mentioned data were completed with their representation.	4
Planning	c. What were the suitable strategies for problem-solving ?	
	▪ No strategy was mentioned.	0
	▪ Problem solving strategies were not suitable.	1
	▪ They were created illogically.	2
	▪ They were created thematically.	3
	▪ They solved the problems.	4
Monitoring	d. How were those strategies implemented?	
	▪ They did not match with the planned strategies.	0
	▪ They were less matched with the planned strategies.	1
	▪ They matched with the small parts of the planned strategies.	2
	▪ They also matched with the big parts of the planned strategies.	3
	▪ They matched with all the planned strategies.	4
	e. How were the strategies monitored?	
	▪ No monitoring of strategies	0
	▪ The monitoring were unsuitable.	1
	▪ Strategy implementation mentioned in a less systematic way.	2
	▪ Strategy implementation was monitored systematically.	3
	▪ They required a correct and logical solution.	4

Metacognitive Aspects	Metacognitive questioning	Score
Evaluating	f. Did the monitoring of the strategy correspond with the plan?	
	▪ No analysis and evaluation of strategy.	0
	▪ Analysis and evaluation were not suitable.	1
	▪ Only a small part of the analysis and evaluation corresponded with the plan.	2
	▪ A big part of the analysis and evaluation corresponded with the plan.	3
	▪ Both the analysis and the evaluation corresponded with the plan.	4
	g. How comprehensive was the understanding?	
	▪ No self reflection on conceptual understanding.	0
	▪ The reflection on conceptual understanding was less correct.	1
	▪ There was a reflection on the conceptual understanding improvement.	2
	▪ There was a reflection on the weaknesses of problem-solving process.	3
	▪ There was a reflection on the strength of problem-solving process.	4
Transferring	h. Were these problems solved using different strategies?	
	▪ The problems were solved using a single strategy.	0
	▪ Attempts were made for different strategies; however, no advancement was made.	1
	▪ Attempts were made for different strategies, and advancements were made.	2
	▪ Modifying the strategies to make it simpler.	3
	▪ Reconstructing the understanding and finding new solution using different strategies.	4
	i. Were the understanding or the skills applied to a new situation?	
	▪ The understanding/skills were not applied in a new situation.	0
	▪ Less success was recorded in applying the understanding/skill to a new situation.	1
	▪ Using the same strategy to solve different problems was quite successfull.	2
	▪ The understanding was applied in a new situation with different strategies correctly.	3
	▪ The understanding and skill were applied in a new situation with different strategies correctly.	4

Students' conceptual understanding tests consisted of six indicators adapted from Anderson & Krathwohl (2001), which included: interpreting, modelling, classifying, comparing, explaining, and concluding. The application of i-SMART model in a group (X) improved students' metacognitive skills and conceptual understanding in each phase of learning. At the end of the study, a post-test (O2) on metacognitive skill was conducted for obtaining the students' score data.

The conceptual understanding test (CUT) consisted of 20 questions of three-tier diagnostic tests. The first tier was multiple questions about chemistry concept being taught,

the second tier was on the reasons for the answers, and the certainty of their answers. This test was adopted from Arslan, Cigdemoglu, and Moseley (2012).

Statistical data analysis was used in this study, MCAI were analysed descriptively, while MCST and CUT analysis used inferential statistic. To determine the significant improvement after treatment, the pre- and post-test results were statistically tested using paired t-test (when data were in accordance with the normality assumption) or Wilcoxon test (when data did not correspond with the normality assumption) with $\alpha = 5\%$, meanwhile, the rate of increase was calculated using n-gain. The t-test and the Wilcoxon test were used to determine the average value for the pre- and post-test of MCST and CUT. This analysis addressed the first research question on the effect of metacognitive instruction on students' skills and conceptual understanding. The use of t-test or Wilcoxon for analysis depended on the data normality. These analyses were calculated using SPSS (version 23). In addition, a descriptive statistic was also calculated for the MCST and CUT administration (n, M, and SD). Cronbach's Alfa was calculated to determine the internal consistency of MCST and CUT instruments.

Furthermore, the Kruskal-Wallis analysis was used to determine the consistency of the mean score between the MCST and CUT tests. This analysis was adopted since the group 3 data did not correspond with the normality assumption. The results showed that all groups were similar and adequate as the data replication group.

Results and Discussion

The application of i-SMART learning model in metacognitive activities made concepts easier for students to learn. This model was developed from constructivist learning, information processing, cognitive psychology, conceptual change, and problem-solving theory.

The first phase was supported by Piaget's personal interaction and Talanquer's representation theory. Therefore, individuals actively identify and develop concepts in the form of cognitive conflicts, providing the data in the form of image representation, and experiencing cognitive conflict (Hadjiachilleos, Valanides, & Angeli, 2013). Students misunderstanding the concept experience conceptual change (Posner, et al., 1982; Carey, 2000), therefore, presenting the concept in disequilibration condition (Kang, 2010; Zhou, 2010).

In the second phase, students were facilitated to prepare and plan for problem-solving (Polya, 2004). The use of learning and planning strategies were effective in improving students' conceptual understanding, problem-solving abilities, and metacognitive skills (Kapa, 2002).

In the third phase, students solved problems with different strategies, and were asked to discuss the experimental results, and provide arguments related to anomalous situations. This allowed interactions among peers in a work group to exchange their ideas

on the experiment. At this stage, cognitive accommodation was attempted, in order to determine the reliability of the result interpretation of the experiments conducted. The metacognitive orientation was performed by asking questions (such as, what do you mean, why, and how is this possible), in order to provide meaningful understanding.

In the fourth phase, students analysed and evaluated the data obtained. In this stage students' conceptual understanding was built based on Piaget & Vigotsky's constructivist theory (Blake & Pope, 2008; Moreno, 2010; Santrock, 2011; Yu, Tsai, & Wu, 2013) by involving them actively and collaboratively in group work for easy learning (Gagne et al., 2005). Zhou (2010) suggested the use of student learning results obtained from their group work and arguments, as the medium for introducing scientific concepts.

In the fifth phase, students reflected on the understanding and skills they acquired in the learning process. This stage aimed to test the students' competency, which was the basis for evaluating their learning process. They were asked several questions such as, what was the concept condition before and after being instructed, the changes observed, and assuming there was a change, which part of the instructions effected it. To test for metacognition (both in knowledge and skills), questions were asked based on students' preconceptions and new conceptions. When there were differences, what causes these changes and the result status, either positive or not. For students, this becomes the basis for self-reflection on their achievements. The addition of reflection is based on the theory of Arends & Kilcher (2011) and Fry et al. (2009) which stated that the importance of reflection activities was for follow-up effort after the learning process.

In the sixth phase, students made use of their knowledge and confirmed the ideas they had acquired in the new situation. This stage was supported by the transfer theory from Moreno and Sousa, which stated that students with strategies and knowledge, were more capable of transferring their experience to a new situation. Therefore, utilizing their knowledge (new concepts) in different physical conditions, and testing its usefulness. In this section, teachers also convinced students that the new concept was understandable, equitable, and beneficial with the metacognitive strategies (She, 2002).

The results of students' conceptual skills and understanding were shown in Table 6.

Table 6

The n-gain Metacognitive Skills and Students' Conceptual Understanding for All Groups

Aspect of assessment	Groups	N	Average of pre-test		Average of post-test		<g>	n-gain category
			N1	K1	N2	K2		
Metacognitive skills	1	30	18.89	Less	79.26	Good	0.74	High
	2	30	19.07	Less	82.50	Very good	0.78	High
	3	30	13.15	Less	75.56	Good	0.72	High
Conceptual understanding	1	30	23.00	Less	78.17	Good	0.72	High
	2	30	13.80	Less	88.50	Very good	0.88	High
	3	30	14.67	Less	77.00	Good	0.72	High

Note. Group 1 (SMAN1XI-MIA5), Group 2 (SMAN2 XI-MIA6), Group 3 (SMAN7 XI-MIA7), N1 and N2 = pretest and post-test scores;
K1, K2 = Performance categories; 80-100 = very good, 66-79 = good, 56-65 = enough, <56 = less;
<g> = n-gain coefficient.

The results of extensive trials based on Table 6 showed that most students possessed good metacognition skills and conceptual understanding with an average score of n-gain > 0.70, therefore, they were classified with the high n-gain category. The results of normality and homogeneity tests were presented in Tables 7 and 8.

Table 7

The Normalized Test of Metacognitive Skills and Students'Conceptual Understanding for All Groups

Group	Test	N	Kolmogorov-Smirnov[a]							
			Metacognitive skills				Conceptual understanding			
			Mean	Statistic	Asymp. Sig. (2-tailed)	Normal distri-bution	Mean	Statis-tic	Asymp. Sig. (2-tailed)	Normal distri-bution
1	Pre-test	30	18.89	0.161	0.061*	Yes	23.00	0.143	0.121*	Yes
	Post-test	30	79.26	0.909	0.054[b*]	Yes	78.17	0.142	0.125*	Yes
2	Pre-test	30	19.07	0.175	0.020	No	13.80	0.181	0.014	No
	Post-test	30	82.50	0.143	0.122*	Yes	88.50	0.192	0.006	No
3	Pre-test	30	13.15	0.174	0.021	No	14.67	0.208	0.002	No
	Post-test	30	75.56	0.250	0.000	No	77.00	0.157	0.058*	Yes

Note. Group 1 (SMAN1 XI-MIA5); Group 2 (SMAN2 XI-MIA6); Group 3 (SMAN7 XI-MIA7)
[a]Lilliefors Significance Correction; [b]Shapiro-Wilk normal distribution; *) Sig. $p > 0.05$

Table 8

The Homogeneity Test of Metacognitive Skills and Students' Conceptual Understanding for All Groups

Group	Test	N	Levene							
			Metacognitive skills				Conceptual understanding			
			Mean	Statistic	*p* sig. (2-tailed)	Homo-gen	Mean	Statis-tic	*p* sig. (2-tailed)	Homo-gen
1	Pre-test	30	18.89	0.481	0.749*	Yes	23.00	0.251	0.953*	Yes
	Post-test	30	79.26	0.934	0.477*	Yes	78.17	1.750	0.167*	Yes
2	Pre-test	30	19.07	2.558	0.051*	Yes	13.80	1.991	0.142*	Yes
	Post-test	30	82.50	1.479	0.233*	Yes	88.50	1.067	0.405*	Yes
3	Pre-test	30	13.15	1.592	0.220*	Yes	14.67	2.763	0.037	No
	Post-test	30	75.56	2.774	0.043	No	77.00	0.618	0.688*	Yes

Note: Group 1 (SMAN1 XI-MIA5); Group 2 (SMAN2 XI-MIA6); Group 3 (SMAN7 XI-MIA7); *) Sig. p > 0.05

Tables 7 and 8 showed that the test data from metacognitive skills and students' conceptual understanding were evenly distributed in group-1. Meanwhile, group-2 and group-3 had either pre- or post-test data that were not evenly distributed (Sig. < 0.05). The homogeneity test showed that data from three groups were all homogeneous (Sig.> 0.05). Therefore, the impact of i-SMART model in group-1 was tested using paired t-tests. For students from group-2 and group-3, data were tested using the Wilcoxon test, since their data were not evenly distributed.

Table 9

Paired t-test and Wilcoxon Test of Metacognitive Skills and Students' Conceptual Understanding

Aspect of assessment	Group	N	Paired t-test					Wilcoxon test			Conclusion
			Mean	Std. error mean	T	df	*p* (Sig.)	Z	Asymp. Sig. (2-tailed)	p (Sig.)	
Metacognitive skills	1	30	-60.376	1.153	-52.380	29	0.000*	-	-	-	*Ho* rejected
	2	30						-4.794	0.000**	0.000***	*Ho* rejected
	3	30						-4.804	0.000**	0.000***	*Ho* rejected
Conceptual understand-ing	1	30	-53.500	2.064	-25.916	29	0.000*	-	-	-	*Ho* rejected
	2	30						-4.820	0.000**	0.000***	*Ho* rejected
	3	30						-4.791	0.000**	0.000***	*Ho* rejected

Note. Group 1 (SMAN1 XI-MIA5); Group 2 (SMAN2 XI-MIA6); Group 3 (SMAN7 XI-MIA7);
* *Pair-Samples T-Test p < 0.05 (2-tailed)*, ***Wilcoxon Signed Ranks Test: p < 0.05 (2-tailed)*, ***Monte Carlo: *p < 0.05 (1-tailed)*

Table 9 showed that the students' metacognitive skills and conceptual understanding had increased in the three groups. Group 1 p-value (Sig. 2-tailed) < 0.05, while for groups 2 and 3 Monte Carlo (Sig. 1-tailed) < 0.05, in addition, Ho was rejected. This means that students' metacognitive skills and conceptual understanding in the three groups during the post-test were significantly higher than the pre-test learning, after i-SMART learning model had been applied.

The increase in n-gain between the three groups after the application of i-SMART model was checked through the mean similarity test of n-gain (Table 11). Kruskal-Wallis test was conducted to determine the significant differences between the three groups as presented in Table 10.

Table 10

Result of Kruskal-Wallis Test on Students' Metacognitive Skill and Conceptual Understanding

Group	N	Metacognitive skills					Conceptual understanding				
		Mean	Chi-Square	*df*	p (Sig.)	Conclusion	Mean	Chi-Square	*df*	p (Sig.)	Conclusion
1	30	79.26	9.097	7.0	0.206*	Ho accepted	78.17	5.254	7.0	0.695*	Ho accepted
2	30	82.50	11.559	9.0	0.181*	Ho accepted	88.50	6.034	8.0	0.720*	Ho accepted
3	30	75.56	13.917	9.0	0.059*	Ho accepted	77.00	6.438	8.0	0.669*	Ho accepted

Note. * Monte Carlo Sig. *p > .05*

Table 10 showed that p-value (Sig.) of students' metacognition skills for the three groups were > 0.05, in order for Ho hypothesis to be accepted. Therefore, no significant difference in n-gain of students' metacognitive skills between the three groups, however, the application of i-SMART model improved students' metacognitive skills placing n-gain at high criteria. This corresponded with p-value > 0.05 (Sig.) of students' conceptual understanding for the three groups, in order for Ho hypothesis to be accepted. This results showed that the i-SMART model improved students' metacognition skills with high consistency as compared between the different groups.

Aspects of Metacognition Skills and Students' Understanding

The results of n-gain test for metacognitive skills and students' conceptual understanding were presented in Table 11.

Table 11

N-gain Result of Students' Metacognitive Skills and Conceptual Understanding

Aspect of metacognitive skills	N-gain			Aspect of conceptual understanding	N-gain		
	Group 1	Group 2	Group 3		Group 1	Group 2	Group 3
Representing	0.79 (h)	0.86 (h)	0.69 (m)	Explaining	0.65 (m)	0.96 (h)	0.77 (h)
Planning	0.78 (h)	0.89 (h)	0.76 (h)	Classifying and modeling	0.53 (m)	0.84 (h)	0.57 (m)
Monitoring	0.77 (h)	0.77 (h)	0.75 (h)	Interpreting	0.65 (m)	0.77 (h)	0.64 (m)
Evaluating/ reflecting	0.68 (m)	0.70 (m)	0.69 (m)	Applying	0.83 (h)	0.92 (h)	0.84 (h)
Transferring	0.77 (h)	0.81 (h)	0.71 (h)	Comparing	0.67 (m)	0.81 (h)	0.63 (m)
				Concluding	0.89 (h)	0.91 (h)	0.89 (h)
Average	0.74 (h)	0.78 (h)	0.72 (h)	Average	0.70 (m)	0.87 (h)	0.72 (h)

Note: *n-gain > 0.70 high (h); 0.30 ≤ n-gain ≤ 0.70 moderate (m); n-gain < 0.30 low (l) (Hake, 1998).*

The results indicated that most students had good metacognitive skills with an average of n-gain score > 0.70. Meanwhile, increased metacognitive skills (e.g. representation ability) affected the improvement of students' conceptual understanding of chemistry. This corresponded with the result of the study conducted by Treagust, Chittleborough, & Mamiala (2003) and Hilton & Nichols, that chemistry was more meaningful when a multiple interconnections of chemical representations was carried out, which directly improved students' conceptual understanding. The lowest aspect of metacognitive skill observed in this study was evaluation/reflection skills with an n-gain score < 0.70, since some students were still unable to reflect on their learning activity and test results. Lovett (2013) suggested that structured reflection activities were needed for encouraging students to practice metacognitive skills after working on a multilevel exam. Therefore, students should complete three activities as follows:

1. remembering exactly how they prepared for the test ("reflection");
2. thinking and creating a detailed list on the mistakes they made during the exam and why it happened ("compare"), and lastly;
3. devising a plan to prepare differently for the next exam.

After these analyses were completed, students wrote reflective notes on their conceptual understanding and learning process. Engaging in metacognitive activity, assuming there were opportunities for practice and feedback, foster students to be reflective learners. This corresponded with the results of metacognitive questionnaires that had been filled in previous trials. The results indicated that the students' metacognitive skills were developed in different categories as shown in Figure 1.
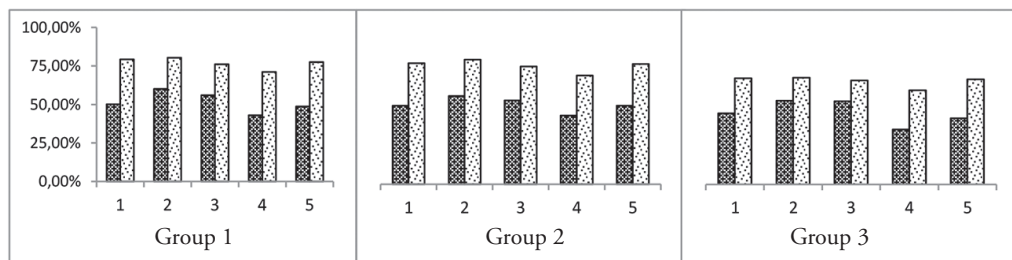
Figure 1. Students' Metacognitive and Self-Assessment before and after the i-SMART Models was Applied

Metacognitive skills were formed with habits practiced consistently; furthermore, teachers played roles in providing guidance for students, due to the wide application of the model. The results of the metacognitive self-assessment questionnaire were used as an indicator for the acquired skills, planning, representing, transferring, monitoring, and evaluating.

Based on Table 11, the i-SMART model generally increased students' conceptual understanding of the chemical equilibrium concept for groups 1, 2, and 3, with the following n-gain coefficients, 0.70 (moderate), 0.87 (high), and 0.72 (high). The highest n-gain obtained were found in the aspects of explaining, classifying, modeling, applying the concepts in calculations, and concluding them in the high category. Then in comparison aspect, students compared the effect of concentration, temperature, and pressure on the direction of the equilibrium reaction in the medium category. The lowest increase was observed in the conceptual understanding, which occurred in the process of interpretation.

Changes in Metacognitive Skills and Conceptual Understanding

The students' metacognitive skills in terms of predicting: when students were faced with scientific problems, most of them predicted the answers as expected, they chose the important information from it, and made chemical representations according to the problems.

The students' metacognitive skills in terms of planning: most students prepared for the investigation to find solutions to the problems faced, they chose the relevant data from those available, they also chose the right and efficient tools for experiment and took the right steps for proper investigation.

The students' metacognitive skills in terms of monitoring: most students followed the plans that had been prepared; however, when there was another alternative for problem-solving, they merged prior knowledge with the new, and work carefully to avoid mistakes. They also changed the strategy when inconsistency was noticed, re-examine the investigation stage for consistency. The results were analysed to check for accuracy by comparing them with the previous results and tested for reliability.

The students' metacognitive skills in terms of evaluation: most students recorded that the expected aim was achieved, meanwhile, the assessment included, the investigation, procedures, results, summary, and conclusion.

The students' metacognitive skills in terms of reflection: the reflective questions guided students in their learning process (Gama, 2004; Ge & Land, 2004; Moon, 2004), namely, problem representation, generating solutions, making justifications, and monitoring and evaluation. These questions were asked in the assessment stage to confirm whether the learning objectives have been achieved (Pulmones, 2010). The results of the implementation of reflective activities fostered careful and in-depth thinking of the steps taken (Kauchak & Eggen, 2013), reflective questions also had a positive influence on deeper understanding (Yu & Wu, 2012). Meanwhile, reflection is an essential part of developing students in the context of learning (Bennett, Power, Thomson, Mason, & Bartleet, 2016). Reflection also aimed to provide feedback-corrective, which was one of the essences of mastery learning (Guskey, 2007). The factors that inhibited self-reflection were namely, low participation in reflection, lack of sufficient knowledge on the concept, and ignorant of the benefits (Aronson, 2011).

The students' metacognitive skills in terms of transferring their acquired understanding and skills to new problems. Meanwhile, feedback-corrective was one of the essences of mastery learning (Guskey, 2007) for further development of students' learning ability.

The results showed that an increase in metacognitive skills led to a higher conceptual understanding and vice versa. The increase of conceptual understanding and metacognitive skills through the implementation of i-SMART on the topic of Chemical Equilibrium was classified with high n-gain category. This was based on the indicators in each aspect of conceptual understanding namely, interpreting, exemplifying, comparing, classifying, explaining, applying concepts, and concluding. The highest conceptual understanding occurred in terms of explaining, followed by classifying, exemplifying, applying concepts, and concluding/deciding aspect. While the lowest value was found in the aspect of interpretation. This occurred since interpretation was more difficult than explaining, classifying, comparing, exemplifying, and applying concepts. It was also influenced by the questions that measured the conceptual understanding of interpretation.

Students that acquired more metacognitive skills through problem-solving process had the ability to design, monitor, and control the whole learning process. They also helped and guided their colleagues in developing a conceptual understanding of chemistry, both in interpreting, giving examples, comparing, explaining, classifying, and conclusion. Therefore, through the process of problem-solving, students easily construct ideas related to the concept, chose the right strategy, became more confident and independent learners, as well as realizing the ability to meet their personal intellectual needs. Furthermore, students determined their learning strategies, compared, and shared them with their colleagues in an effort of solving the problem. This showed that students were more involved in acquiring metacognitive skills (Tan, 2004). These skills guided students in their

learning environment in choosing strategies and improving cognition performance for future purposes. In addition, it improved Students learning capacity and their conceptual understanding of chemistry (Anderson & Nashon, 2007).

The results showed that i-SMART learning model was effective in improving students' metacognitive skills and conceptual understanding. At the beginning of learning using i-SMART model, students needed time to adapt. Furthermore, from the second until the fifth classroom activity, they became accustomed to using the model in problem-solving. The i-SMART model's objectives were to increase students' metacognitive skills and conceptual understanding in accordance with the Becker's et al. (2013), Pernaa and Aksela (2010), and Zoller (2011) theories, which stated that chemistry is inseparable from high-level cognitive skills (HOCS) in the process of solving laboratory-based problems (Zoller & Pushkin, 2007). HOCS adopted the use of problem-solving experience in facilitating the development of metacognitive skills for decision making. A similar opinion was expressed by Sevian & Talanquer (2014) that the study of chemistry required the use of high-level thinking skills in solving chemistry learning problems.

Conclusion and Suggestion

Based on the scientific problems and research results, conclusions were made as follows, i-SMART learning model is effective in:

a. increasing the students' metacognitive skills with an average gain of ($<g>$)> 0.70, which is classified high in the n-gain category. Therefore, the arrangement order of n-gain from high to low range value is namely, the planning> representation> transferring> monitoring> evaluating skill.

b. increasing the students' conceptual understanding with the average gain of ($<g>$)> 0.70, which is classified high in the n-gain category.

Suggestions: a) i-SMART learning model is recommended in teaching practice for improving metacognitive skills and conceptual understanding of chemical concepts; b) the application of i-SMART learning model in future research has the ability to develop metacognitive skills and conceptual understanding,while focusing on students' prior knowledge. Therefore, the result showed that it was difficult for students to improve their metacognitive skills in terms of interpreting the chemical concepts.

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„i-SMART" mokymosi modelio veiksmingumas naudojant chemijos dalyko mokymosi problemų sprendimo būdus vidurinės mokyklos vyresnėse klasėse, siekiant patobulinti meta-kognityvinius įgūdžius ir mokinių konceptualų supratimą

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Santrauka

Pagrindinė besivystančių šalių, tokių kaip Indonezija, švietimo sistemos problema yra silpni mokinių meta-kognityviniai įgūdžiai ir prastas chemijos dalyko supratimas. „i-SMART" (problemų identifikavimo ir atvaizdavimo, strategijų ir planų parinkimo, sprendimų priėmimo naudojant monitoringo sistemas, analizavimo ir įvertinimo, apmąstymo bei perteikimo) mokymosi modelis apima meta-pažinimo naudojimą sprendžiant chemijos dalyko mokymosi problemas. Straipsnyje siekiama ištirti „i-SMART" modelio efektyvumą mokinių meta-kognityvinių įgūdžių ir konceptualaus supratimo gerinimui. Tyrimas buvo atliktas skirtingų mokyklų trijose klasėse (Banjarmasino mieste Indonezije), kuriose buvo po 30 vyresniųjų klasių mokinių. Buvo taikyti preliminarūs ir pakartotiniai testai siekiant nustatyti kiekvienos klasės (grupės) žinių ir įgūdžių lygį. Surinkti testų, stebėjimo ir klausimyno duomenys analizuojami taikant n-pasiekimų (angl. *n-gain*), porinį t (angl. *paired t*), Wilcoxonʻo pažymėtų rangų (angl. *signed-rank*) ir Kruskalʻio-Wallisʻo testus. Remiantis gautais rezultatais: 1) mokinių meta-kognityviniai įgūdžiai statistiškai

reikšmingai padidėjo n-pasiekimų dydžiu ir priskiriami prie aukštų; 2) taip pat, statistiškai reikšmingai išaugo mokinių konceptualaus supratimo n-pasiekimų dydis, kuris pasiekė aukštą įvertinimą n-pasiekimų kategorijoje. Daroma išvada, kad sukurtas „i-SMART" mokymosi modelis yra efektyvus tobulinant meta-pažinimo įgūdžius ir studentų konceptualų supratimą.