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Chemistry Reading Activity in Metacognitive Knowledge

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Abstract

An exploration of chemical reading performances of fifteen chemistry teacher candidates was conducted to reveal qualitatively metacognitive knowledge during chemistry reading activities. A think-aloud protocol had been carried out for reading performance, which is a technique to verbalise one's thought. For a question posing purpose, two articles were designed to stimulate the readers' thought in a metacognitive level that was divulged in-depth by self-interviewing questions. The reading performance was measured using the normal reading rate and think-aloud reading rate to reveal the pattern of chemical reading activities. A phenomenological reduction method was used to analyse and describe the reading performance. This study elicited that declarative knowledge was mostly used on the reading preparation, procedural knowledge in reading processes, situational knowledge on maintaining the reading activity, and strategic knowledge on the termination process. The four knowledge were constructed by the self-organisation, task comprehension, as well as strategy and knowledge to integrate every sources. The presence of chemical equations, chemical representations, and terminology on the chemical reading had influenced the chemical reading pattern. The successful chemical reading activity requires the readers' personal aspect and the strategy designed for understanding the reading.

Keywords: chemistry reading activity; metacognitive knowledge; phenomenological reduction; think-aloud protocol.

Introduction

Reading an academic article, like a chemical reading, simultaneously produces cognitive and metacognitive activities in one's self (Khezrlou, 2012; Korpershoek, et al., 2015; Leopold & Leutner, 2015), due to some mental activity in the mind. These activities are elaborating retention time and performance, detecting errors in prior knowledge, and sorting symbols in readings (Eitel & Kuhl, 2016; Garcia-Rodicio & Sanchez, 2014; Green & Redford, 2016). While reading, one finds knowledge structures in texts with a sophisticated epistemological belief (Norris & Phillips, 2012). If someone is in this belief mode, someone will show some metacognitive behaviours such as choosing strategies for understanding, applying prior knowledge to solve problems, and checking progress consistently (Pulmones, 2010). Through posing questions after the reading activity could become an indicator to reveal both cognitive (Demirdogen & Cakmakci, 2014) and metacognitive level related to one's understanding about the chemistry and the context of the reading (Ghasempour et al., 2013; Herscovitz et al., 2012; Kaberman & Dori, 2009).

This metacognitive aspect is difficult to observe since the process occurs inside one's mind (Dunlosky & Metcalfe, 2009; Grotzer & Mittlefehldt, 2012; Schraw et al., 2012). A problem faced when one would study

metacognition was the fuzziness of its terminologies that seemed on the various components and their relation to each other (Zohar & Dori, 2012). In terms of metacognitive knowledge, some experts viewed it as the aspect of cognition (Eldar et al., 2012; Flavell 1979), while others said it contained some dimensions of knowledge (Favieri, 2013; Sperling et al., 2004). This case became more difficult to understand since it was added by some partial studies of its components (e.g. Chiu & Linn, 2012; Handel et al., 2014; Marulis et al., 2016; Molenaar et al., 2014). These partial studies elicited complications in studying metacognitive knowledge as a complete process in a learning activity. Therefore, this study will try to handle this case by analysing the whole component of metacognitive knowledge.

Exposing metacognition could be easier when using a think-aloud protocol (Herscovitz et al., 2012; Kaberman & Dori, 2009), which is a technique to verbalise one's thought (Jacobse & Harskamp, 2012). The benefit of this technique is to give the sight of process of memory and actual thinking when one is reading, understanding, strategising, processing, and deciding (Charters, 2003; Overton et al., 2013; Wilhelm, 2001) for revealing the metacognitive strategy, metacognitive judgment, and metacognitive knowledge (Ben-Eliyahu & Bernacki, 2015; Binbarasan-Tüysüzoglu & Greene, 2015). A phenomenological study could get a whole description of those metacognitive phenomena (Thomas & McRobbie, 2013; Vierkant, 2017). This research is conducted to explore phenomenologically the metacognitive knowledge in the reading activity of a chemical article from a think-aloud activity for a problem-posing purpose.

Research Method

2.1. Context and participant

This was a qualitative study of 15 undergraduate students that were chemistry teacher candidates in their third years at a public state university in Yogyakarta, Indonesia. All of them were females between the age of 19 to 21 years old. They were in the international programme that used Indonesian Language and English (bilingual class) during their courses. All participants had obtained the basic chemistry course in the first year and the chemical equilibrium course in the second year. They participated voluntarily in this research outside the regular class activities. Ethical consideration was used to protect the data of participants (Sadowski & McIntosh, 2015; Taber, 2014) which was stamped in an agreement between each participant and the researchers. The participants were encoded by letters A to O.

2.2. Instruments

Two chemical readings had been designed to stimulate the metacognitive strategy in the reading activity. The first reading was an article about the application of chemical equilibrium in human teeth. The second reading was about chemical equilibrium in esterification. Those articles were arranged overlapping with other chemistry domains and other disciplines, that fulfilled some criteria about the chemical reading as mentioned before, to stimulate the participants as readers in order to pose problems in question-form at metacognitive level. The articles had been validated by two experts in related disciplines, and some suggestions form the experts had been used to consummate the reading.

Moreover, there were 39 questions of metacognitive knowledge exploratory arranged to reveal another metacognitive aspect that was not observed during the reading and posing question activities. The questions were made based on the component of metacognitive knowledge dimension on Table 1. The questions were open-ended questions and had been validated by two experts on chemistry education and psychological education. Some suggestion from experts had been used to complete the questions' visibility.

Table 1. Matrix of Interrelation Component of Metacognitive Knowledge Dimension

	Declarative (what)	Procedural (how)	Conditional-Situational (why)	Conditional-Strategic (when)
Person	Strength; weakness; motivation; anxiety	Making assumption; interaction with others (team) for solving problems	Believe positively to the things conducted; organize the strength; control the anxiety; and boost the motivation	Believe positively to the things conducted; organize the strength; control the anxiety, and boost the motivation
Task	Information given; goal, information sources needed; skills needed	Using the sources; organization of the sources	Check the appropriateness of the method; check the accomplishment of the goal	Check the appropriateness of the method; check the accomplishment of the goal
Strategy	List the methods that can be conducted; select the method; organize the skills; control the learning process	Ways to finalize the procedure; ways to apply the procedure; ways to conduct the procedure in different situation	Use certain methods in learning; conduct the procedure sequentially on the task completion	Use certain methods in learning; conduct the procedure sequentially on the task completion
Integration knowledge	Identification of the strategy towards the task by considering the strengths and weaknesses	Implementation of the strategy chosen on organization of task completion by considering the assumptions	Analysis of completion process conducted towards the appropriateness and accomplishment of the task based on self-judgment	Evaluation of completion process conducted towards the appropriateness and accomplishment of the task based on self-judgment

2.3. Procedure

A think-aloud protocol was used in this reading procedure for collecting data about metacognitive activities during reading the article. First, each participant was given the article and had been given a simulation of the procedure of think-aloud for recording. Each participant had been requested to vocalise or verbalise their thoughts in front of the recorder during the reading time. There was no pause activity during reading, posing the question until answering the questionnaire. For validating the think-aloud technique as mentioned by Overton et al. (2013), the reading activity was conducted one-by-one (not in a group), without researchers' interruption, at the comfortable place that the participant selected before, and in their spare time.

Before each participant began to read, they were asked about some terminologies of chemical equilibrium that had become the problems in understanding about the chemical equilibrium. These terms are chemical equilibrium, dynamic equilibrium, heterogeneous equilibrium, chemical equilibrium constant, Le Chatelier principle, chemical equilibrium shift direction, and gaseous equilibrium. These terms were selected because they tended to undergo some systematic error and random error (Atasoy et al., 2009; Ozmen, 2008).

The first reading activity was conducted for the first article by self-interviewing which the participants should answer the 39-questions by their own self. Each participant answered the preliminary term-question, read the article, arranged their two-problem, and interviewed themselves used an audio recorder. A month after the first test, the second test was undertaken for the second article. The test was begun with preliminary term-question. Nevertheless, the metacognitive knowledge exploratory questions were given by the test instructor to the participants specifically (the questions).

Data recorded about the reading activities, question-posing activities, and self-interview were recorded by participants' approval. Audio and paper-based documents were encrypted by special code to enclose participants' data. Transcriptions of data were checked by the participants and independent reviewers to inspect the time accuracy of each passage segment and the word precision of the think-aloud activity. Coding data of the analysis were verified through a focus group discussion with the experts related.

2.4. Data analysis

The data collected were transcribed chronologically and validated by the participants. How they read the articles was transcribed and marked in the specific coding consisting of the reading pattern and reading parameters. The transcription was arranged embedding and sequentially between the textual word and think-aloud word. Every segment (sentences, equations, and figures or

graphs) was measured to the reading rate as think-aloud rate. The rate was converted to reading pattern graph for each reading activity. A normal reading rate was determined as the total words on the text divided by the time consumed. The difference between the think-aloud rate and the normal rate was represented by delta.

A phenomenological reduction method was used to analyse the reading phenomena (Atasoy et al., 2009; Chopra et al., 2017; Ozmen, 2008; Sadowski & McIntosh, 2015). All data were reduced (horizontalization of data). It was carried out by deleting the statements of think-aloud expressions that were not related to the activities on each parallel segment of reading the article, posing the questions, and answering the questionnaire. After this reduction, the data would be encoded and categorised in the same theme that represented the specific expressions and findings of metacognitive strategy in the reading activity of the chemical article. The coding from the reading pattern was used to find "neomatic" themes (what the phenomenon is) and the coding from the think-aloud activity and self-interview was used to find "neosis" themes (how the phenomenon is). Then, data verification was conducted to clarify and reinforce the themes. The "neomatic" themes were unified as a formulation of the textural definition, but the "neosis" themes were as the structural definition. By blending the textural and structural definitions and adding with data interpretation, the themes were merged to be the essential definition of metacognitive knowledge in chemistry reading activity.

Results and Discussions

3.1. What do I prepare for reading activity?

The first article was more contextual for the participants than the second one. However, the second article was closer to the participants' expectations rather than the first one. According to the participants, when they knew that they would read the article about chemical equilibrium, their mindsets had predicted that the article would be full of formulations, integral, derivative, and nominal data. They confessed that all of them had a similar perception of the topic, and they had some difficulties mastering it during the first year. The quotation below showed this perception (the quotation is translated from Indonesian Language).

A: *yeah, I don't know, I mean, eh... the chemical equilibrium tends to the computation, doesn't it?*

B: *In my idea, this chemical equilibrium will contain thermodynamics or many numeric data such as temperature, volume, etc. I have been so confident but the text was different towards my expectation.*

But this perception was reduced by their curiosity and motivation to confront the challenge. They called this reading so challenging because they usually read voiceless and they predicted that it would be not easy as usual as they read.

At this step, the declarative knowledge held the important thing to start the effective reading to reach the goal. As the readers, there were two types of reading planning styles conducted by these participants, which were organised-preparation and dilapidated-preparation. The organised preparation was a strategized reading planning that was conducted by students to reach the goal. In this style, the students began to recognise the detailed thing they faced (task), and then they asked themselves about what they had (person), what they should do (strategy), and what they needed for reconsideration before undertaking the reading (knowledge integration). The dilapidated preparation was an unsystematically independent style in designing the action for reading. This style began to recognise the important thing they faced (task), then they try to get something familiar from themselves (person) to determine the simplest way (strategy) by reconsidering some advantages (knowledge integration).

The style selected by ones for this chemical reading activity depended on their

habit of reading in general, perception of the task, and estimations about themselves. Habits were more impactful than others because they tended to do what they usually do. The voiceless reading habits tended to be more difficult to undertake in this think-aloud protocol. Their perception of the reading's topic-chemical equilibrium-was shaped by their experiences and the preliminary insights about it. Their difficulties while studying the chemical equilibrium contributed to the uninteresting perception of the text, even though they had not read the text yet (had no idea about the text). These difficulties also made them underestimate and judge themselves because the reading was not understandable.

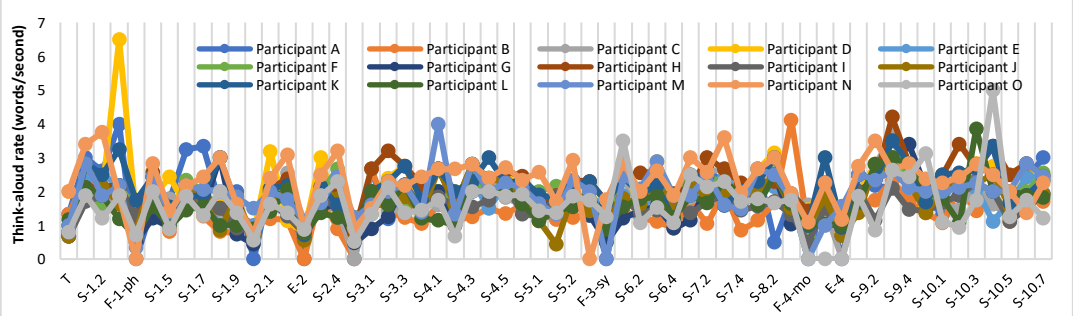
3.2. How do I read?

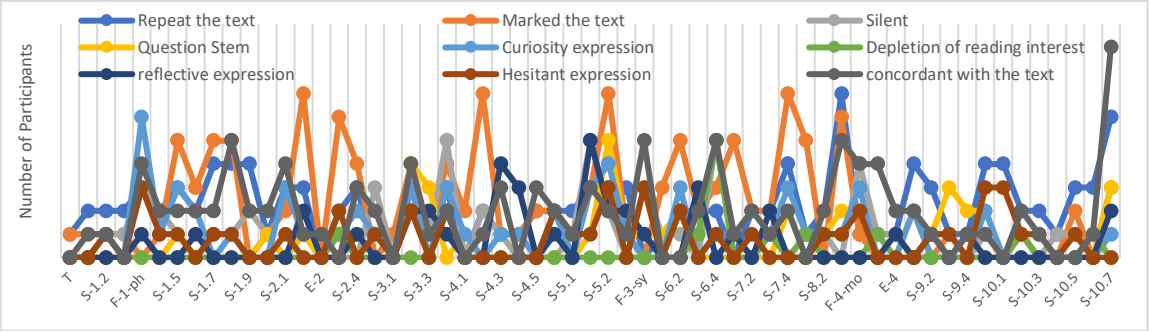
There were three applicable methods for their preparation in chemical reading activity, which were curious-based, visual-based, and continuous-based. The method selected determined their procedural knowledge during the reading performance. The curious-based reading style was undertaken by students that had higher curiosity towards the chemical aspect in the article, as limited as in-context about the text. The visual-based style was a combination of the imagination and cohesiveness towards the chemical aspect of the article to the contextual experiences. The continuous-based style was used by students that thought the simple ways to get a whole understanding of the article. The style selected by participants did not impact the propriety and correctness of the result of the chemical articles reading performance.

The selected style depended on their understanding of declarative knowledge, and their interest in chemical readings. Declarative aspects discussed before determined how one should position themselves to undertake the chemical reading performance. The process-oriented participants who liked to improve insights tended to select the curios-based style (participants C, D, F, G, J, L, and M). The process-oriented participants who relished on the contextual and representation preferred to visual-based (participants I, K, and O), while continuous-based was preferred to the result-oriented participants (participants A, B, E, H, and N).

The detail of the reading pattern of the first article was shown in Figure 1. In the figure, the trend of decelerating the reading rate was undertaken by the chemistry teacher candidates, in all reading performance styles, all chemistry representations (phenomenology, symbolic, and model figure separately), and all chemical equations. The phenomenological representative showed the context of the reading and conveyed to the readers the things that were discussed in the text. Some participants (like participants B, C, D, I, and L) determined the phenomenological figure as the starting point for reading performance. There were two phenomenological representatives on the first reading: (1) at the beginning or first paragraph (the 56th word); and (2) in the middle or in the fifth paragraph (the 509th word).

Figure 1. Think-aloud of Reading Pattern (up) and Reading Expression (down) for Article 1

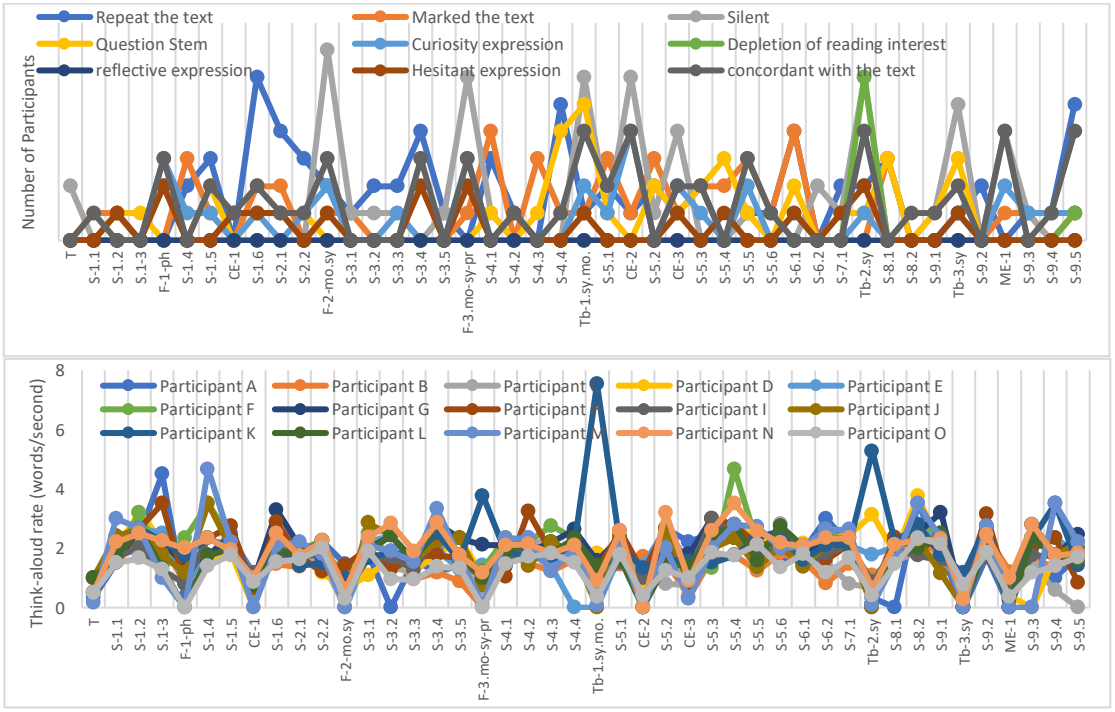




Note: the abbreviation T (title), S-X.Y (on paragraph X sentence Y), E (equation), and F (figure: 'ph' for phenomenology, 'sy' for symbol, and 'mo' for model

The phenomenological figures had stimulated the reflective expression for all reading performance styles (compared to Figure 1). By phenomenological representative, the reader could compare the experiences and preliminary insight related to the information on the figures. These reflective expressions were followed by curiosity expressions, as shown in Figure 2. The graph indicated that the expressions were not undertaken by all participants. Some less think-aloud participants did not voice and stay on silent while understanding the phenomenological representatives.

Figure 2. Think-aloud of Reading Pattern (up) and Reading Expression (down) for Article 2



Note: the abbreviation T (title), S-X.Y (on paragraph X sentence Y), E (equation), and F (figure: 'ph' for phenomenology, 'sy' for symbol, and 'mo' for model

The decelerated reading rate on chemical equation was not followed by the increasing of reflective expression. The chemical equations were accused the chemical reading itself. On these chemical equations, all expressions were also decreasing. For these participants, how to vocalise the chemical equation was out for appreciation. Although they were the chemistry teacher candidates, they had some difficulties to vocalise the

chemical equation. Most of them confessed that they often observed and analysed mentally on their mind. For examples, the equation from first article (E-1 and E-2) and second article (CE-1) as followed (all think-aloud activities are translated from Indonesian Language).

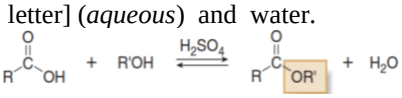
[E-1] $Ca_5(PO_4)_3OH(s) \rightleftarrows 5Ca^{2+}(aq) + 3PO_4^{3-}(aq) + OH^-(aq)$

(Type 1) $Ca_5(PO_4)_3OH$[spelling by letter](*solid*) have an equilibrium with $5Ca^{2+}$[spelling by letter](*aqueous*) plus $3PO_4^{3-}$[spelling by letter](*aqueous*) plus OH^-(*aqueous*)

(Type 2) Oh, equilibrium. Is it the dissociation reaction to be its ions?

[E-2] $Ca_{10}(PO_4)_6(OH)_2(s) + 8H^+(aq) \rightarrow 10Ca^{2+}(aq) + 6HPO_4^{2-}(aq) + 2H_2O(l)$

(Type 3) $Ca_{10}(PO_4)_6(OH)_2$[spelling by letter](*solid*) plus $8\ H^+$[spelling by letter] (*aqueous*) oh acid, becomes $10Ca^{2+}$[spelling by letter](*aqueous*) plus $6HPO_4^{2-}$([spelling by letter] (*aqueous*) and water.

[CE-1] 

(Type 4) RCOOH group, reacted with R'OH, it is alcohol, catalysed by H_2SO_4 produce RCOOR' and water

Type 1 showed that the reader just only read the symbols by spelling the letters of chemical compounds. On type 1 of the chemical equation think-aloud, some participants only read the compounds without the substance's phase. The puzzling things for readers were how to spell the double forward-reverse arrow and how to spell the chemical names of the compound. The fuzziness encouraged the readers to remain silent. Type 2 showed the reader voiced about their interpretation of the reaction. This second type was undertaken by critical-think-aloud readers because they thought that the way they interpreted the reaction was more important than how to spell it. The silence before interpreting this equation was conducted to arrange the knowledge about the reaction by seeking for the familiarity and connecting each insight. Type 3 was the combination of type 1 and type 2. This third type just only interpreted the common and important symbols of the reaction as such H^+ for the acidic condition, OH^- for the basic condition, H_2O for water, etc. The interpretation was limited to what the reaction is (not on how the reaction occurred). Type 4 occurred in a specific chemical reaction such as it had a structural formula form, an additional treatment (e.g. catalyst, temperature, and heat), etc. The fourth type of the chemical equation think-aloud was also observed on CE-2 and CE-3 that had similar presenting style (see Figure 2). When the chemical equation was combined with the model or the structure of a compound, some mental processes occurred in readers' mind to identify and visualise the process that may be existed towards the reaction.

The symbol in the first article showed that it had a lower curiosity expression than the model and the phenomenology. The graph presentation was less interesting compared to the diagram of a chemical. The second article combined some representations to be a figure. Some metacognitive expressions were detected in the think-aloud of the combined representations in the second article. Table 6 gave the example of the think-aloud of participants G, H, and I as the representatives for each reading performance style. The continuous-based (participant I) showed that the participant had a similar reading pattern both on the dependent and independent chemical combined representations. The result-oriented (participant H) did not change their strategy on reading when finding the chemical representation. The curious-based (participant G) indicated that the think-aloud expression increased towards more dependent combined representations. By understanding the model figure, it was considered as an inhibitor in reaching the goal (question-posing) because it wasted time. The reading rate of the three dependent representations was the lowest compared to the independent and two-dependent representations. The dependent chemical representation could help readers interact with the passage and construct the knowledge from the text. For the visual-based, comparing the information to the experiences was undertaken while they were reading slowly. When they did not find similar experiences, they just only concurred with

the information they read and thoroughly searched for an explanation about the figures in the text written.

Back to the Figure 1 and Figure 2 that some decelerating patterns that indicated the interesting reading spot for readers were observed on S-1.5, S-4.2, S-6.2, S-6.4, S-7.4, S-9,5, and S-10.2 in the first article (Figure 1) and on S-2.1, S-3.3, and S-5.5 in the second article (Figure 2). The decelerating on S-1.5, S.4.2, and S-9.5 was affected by the numerical data given in the text. The readers thought, numerical data were important to understand the text, especially in chemical equilibrium, since on their perception before that the chemical equilibrium related to computations, equations, and numbers. The other spots (S-1.5, S-2.1, S-3.3, S-5.5, S-6.2, S-6.4, S-7.4, and S-10.2) drew attention from the readers by the terms mentioned in the texts. When they found the unfamiliar terms, they decelerated their speed on reading and took more attention to find the explanation of the terms mentioned. In Figure 1, the spots mentioned were marked by the readers as the important parts of the text. In figure 2, they were not marked because the terms were familiar, even they found another insight about them.

3.3. Why do I keep to read?

There were some reasons that made the readers keep reading the article based on their style until the end. In this case, conditional-situational knowledge acted on why they conducted the reading performance. By this conditional knowledge, the readers had regulated their sources on declarative knowledge to the performance on procedural knowledge. The reasons of readers keep reading was influenced by some impetus factors to the chemical reading. There were three types of the readers based on the impetus, which were an inquisitive-reader, an obliged-reader, and a challenged-reader. Table 2 shows the characteristics of each reader type.

Table 2. Reader Impetus of Chemical Reading in Conditional-Situational Knowledge

Factor Impetus	Inquisitive Reader	Obliged Reader	Challenging Reader
Nature	Understand chemical information based on the curiousness	Understand chemical information based on the task demand	Understand chemical information based on the eagerness
Task comprehension	Focus on the technique required	Focus on producing the questions	Focus on simplifying the instruction
Belief	I start to finish well	The result's correctness is not important	My will is I must try
Self-empowerment	Using the dominant strength that is curiousness, defeat the anxiety	Prohibiting the laziness to cover the weakness is responsible for the task	Be calm to control the anxiety
Strategy organization	The difficulties towards the text comprehension function to be the alert for the question posing	Finishing the reading is the only way to finalize the task for the question posing	I do not know the task definitely but I know what I have to do, just keep to read

First, the inquisitive reader referred to the readers who kept going on reading because their curiousness about the article guided them in seeking knowledge. This reader style was motivated by a wish to measure themselves. This style endeavoured to accomplish the task given and to return the paper not blank. Second, the obliged-reader implied to the reader who was burdened by the responsibility to accomplish the task given. This style was used by the readers who had not enough strength in the question-posing. A little bit of curiosity combined with the responsibility to conduct the task pushed them to keep reading. Last, the challenged-reader was the reader who desired to face the challenging task. This reader liked something new for them and tried to get out from the comfort zone of the knowledge for new experiences.

The five impetus factors composed the specific strategy that the readers executed during the reading performance. During reading, the readers monitored their mind about the information read. By checking their reading performance, they could judge the propriety of their understanding towards the

reading methods and the goal. The higher conditional-situational knowledge readers should check their reading to make sure the precision of the reason on why they keep reading. Moreover, it would be carried out in order to change the strategy if the previous strategy was not effective. This checking was verified by considering the time used and the time left.

They would accelerate their reading rate if the readers considered that the time left was minimal, the text was not important to understand in-depth, and after linger on the text that needed extra time for grasp such as on chemical equation, representative figures, numerical data, and terms' explanation, as shown in Figure 1 and 4. They would elucidate their voices if they thought the first voice was not clear for themselves and for the instructor, or if they wanted to emphasise the marked things in the text. Figure 1 and Figure 2 showed some marked text spots in each article and compared to Figure 1 and Figure 2 gave a trend on decreasing of the reading rate.

They would decelerate their reading rate if they found the interesting things and essential information in the text. They would speak louder if they realised their voices weaken and the recorder went far from the mouth. Some louder voices indicated some metacognitive expressions about the text such as hesitant expressions and concordant expressions. Analysis of Figure 1 compared to analysis of Figure 2 indicated that the louder voices were not only increasing the speed but also decreasing the speed. These louder voices not only expressed the emotional statement but also emphasised the important things about the text based on the readers' perspective. The readers would be voiceless if they were puzzled to speak their minds. Figure 1 and Figure 2 showed some silent spots when reading. For the first and second articles, the most of silent spots were on chemical representative figures, chemical equations, and mathematical equations.

They would select to read sequential or not depending on their self-judgment about their organisation strategy. They confessed that they read sequentially in order to be more structured, clearer, chronologic, not overlapping, and proper to the procedure. Some participants stated the sequential reading performance had been indoctrinated from the past. The non-sequential reading pattern is found in the phenomenological figure presented on the first page of the text. The phenomenological figure drew the readers' attention very much. Other non-sequential patterns were found on the surrounding of chemical representative figures and chemical equation. The quotation below showed the reason of a reader to read non-sequentially.

B: *I do not read sequentially. I jump from this sentence to another sentence. Because my memory was not too good. So, I cannot remember directly it. I forgot the discussion in this sentence. So, I read again at a glance to find some hints about it. So, my mind jumped to one spot to another spot.*

Some readers confessed that they did not check their reading because after finding the question, they were hesitant on their question but they did not know about the method to determine the propriety, even they did not think that they should check it. They did not reconsider their understanding of the task instruction and the text. The higher conditional-situational knowledge should reconsider their reading performance to make sure their reason to keep on reading. They would re-read again and check the goal.

This re-read activity observed in Figure 1 and Figure 2. The repeat spots were obtained on the long sentences, terms' explanation, numerical data, some representatives, and some equations. This re-read activity also contributed to the time consumed by the chemical reading activity. Maximum contributions ($\geq$ 15%) were given by S-1.5 (terms and numerical and chemical data), S-1.8 (terms), S-2.1 (terms), S-3.4 (numerical data), S-8.3 (terms), S-10.1 (terms), and S-9.5 (numerical data and explanation) [Note: Repeat contribution was ratio of delta to normally relative reading rate]. The data

implied that the more data about terms (and their explanation), chemical information, and numerical data on the chemical reading, the more time consumed as the contribution of repeat spots or re-read activities for more understanding towards the text. This case indicated to design the chemical reading activity, the repeat spots that were marked by chemical terms, numerical data, and important terms in the text that should be determined on time allocation given.

3.4. When do I master the reading?

Mastery reading was not only about the reading termination in the last sentences but also about the transition process from one idea to another in each sentence. The conditional-strategic knowledge acted in this domain, and not all participants had conditional-strategic knowledge of these chemical reading activities. Although they did not know, the conditional-strategic knowledge aspects were important and imperative to finalise their reading activity. As mentioned before, the nature of reader style had three types of strength empowerment, which were curious for inquisitive readers, eager for challenged readers, and merely obedient to obliged readers. These strengths were used by the readers to know when they mastered the whole reading or the partition of the reading.

There were five transitions found in these chemical reading activities. The first transition was from the preparation to the reading process. This transition occurred as the omen when the readers mastered the framework of the task (what the initial state was and what the final state was). This transition was important for the reader to design the strategic reading performance. The readers considered the task to the personal aspects (strength, weakness, motivation, and anxiety). All reader styles used curiousness to motivate them for chemical reading performance. The quotation below indicated the importance of motivation on chemical reading performance.

C: *if my motivation is too high, I would make the question rapidly. Although it could occur the misconception between the question required and the question posed. So, I decrease the anxiety and keep the motivation naturally.*

M: *if my motivation is too high in the beginning, I would have the full concentration to understand the idea of the text. If I had understood, so the curiousness will be appeared by itself. It means that my motivation should be wholehearted early*

The second transition was transition intra-to-inter-sentences. This transition occurred word-by-word from one sentence to another sentence. This transition was among the known things, the unknown things, and the important things. As discussed before, the things were chemical information, numerical data, terms and their explanation, and chemical representative figures. Figure 1 and Figure 2 showed that the things increased the concordant expression and the curiosity expression towards the text. Marked spots on the readings were understood as the important things emphasising the understanding of the unification of the idea discussed.

The third transition occurred from sentence-by-sentence in a paragraph to all paragraph in the text. This transition consisted of the iterative process of reading, capturing the idea in the text, and connecting the information with experiences and/or the preliminary knowledge. The iterative process in reading was observed in intra-sentence and inter-sentences. Figure 1 and Figure 2 had shown the intra-sentence iteration of these chemical reading performances as the function “repeat text”. Iterations of the inter-sentence in the first article were observed on T to S-1.4 (phenomenology figure), S-1.7 to S-3.1 (terms, chemical equations, numerical data, and process-micro of model representation), S-5.3 to S-6.1 (symbol chemical representative), and S-8.1 to S-9.1 (terms, model chemical representative, and chemical equation). Iterations of inter-sentence in the second article occurred on S-

3.1 to S-4.1 (explanation to the dependent chemical representative), S-4.4 to S-5.2 (explanation of the table of symbol and model representatives, the mathematical equation and the chemical equation), and S-9.1 to S-9.5 (explanation of the table of numerical data and mechanical equation). The spots implied that the iterations of inter-sentences were stimulated by the chemical representations.

A negative contribution of iterations (iteration contribution was the average of repeat contribution of all segments on iteration spot) was found in symbolic and model representatives, with or without chemical and mathematical equations. This case implied that all participants, as chemistry teacher candidates, had not enough think-aloud on dependent and/or independent chemical representatives of model and symbol levels, and had not enough interest to chemical and mathematical equations. The problems could be impacted by their chemical literacy towards the reading and their interest in the topic given**.**

The fourth transition was the diversion of reading process to the task climax, posing the question. The discussion of this transition was limited to reading performance of the readers. This transition consisted of making the question candidates, arranging the question, and examining. The reading activity on this transition was observed in Figure 1 and Figure 2 as "question stem". Some question stem spots were interesting to the readers. In the first article, these spots were on S-3.2 (detail information), S-3.3 (detail information), S-5.2 (terms and additional information), S-6.2 (terms), S-8.3 (terms and additional explanation), F-4.mo (model figure), S-9.3 (information), S-9.4 (explanation), S-9.5 (numerical data), and S-10.7 (include and suggestion). In the second article, these spots were on S-1.5 (terms ad explanation), S-4.4 (information), Tb-1.sy.mo (symbol-model data), S-5.2 (terms), S-5.3 (additional), S-5.4 (terms and explanation), S-6.1 (numerical data), S-8.1 (additional information), and Tb-3.sy (numerical-symbol data). Almost all spots had a similar tendency for their speed reading. The question spots which had the terms or related aspects of the chemical equilibrium, as the requirements of the question should be posed, were related to the reaction rate (S-3.2, S-3.3, S-4.4, Tb-1, S-$5.2_{\text{article-2}}$, S-5.3, S-5.4, S-8.1), contextual and daily life (S-$5.2_{\text{article-1}}$, S-9.3, S-9.4, S-9.5, S-10.7), chemical terms (S-6.2, S-1.5), chemical process (S-8.3, S-6.1), model representative (F-4). These spots indicated that the explanation about the task instruction was required, and the preliminary knowledge about the chemical topic was imperative for their chemical reading activity. These metacognitively chemical reading activities that conducted think-aloud protocol and question-posing had revealed the readers' conception of the gap between their old-item knowledge to the new-item knowledge from the text given. Thus, these reading activities could be the metacognitive stimulators for the assessors or teachers to know the problems in their learners' minds about the chemical topic.

The last transition occurred to the termination of the task. This was the last action of readers to claim that they had mastered or they had not mastered the chemical reading activity. The readers should regard that mastery the chemical reading activity was not only limited to the reading itself but also directed to the attainment of the reading purpose itself. The reason was that the reading activity was still on-going during the question posing. Some judgments to make sure the question posed were considered by the re-read-activity for a specific purpose. This re-read activity was skipped for reviewing the important information, searching the idea (when blanked in their mind or found no question candidate), and connecting some idea. By using their strengths to motivate themselves (when they were anxious, oppressed, puzzled, pessimistic, and frustration) the termination process of reading was controlled to finalise their chemical reading activity. Figure 1 and Figure 2 showed the motivation

depletion on chemical reading activity. For the article 1 was observed started from S-2.3 (237 words), S-3.4 (318 words), S-6.3 (635 words), S-6.4 (661 words, peak for the motivation depletion), S-7.3 (721 words), S-8.1 (785 words), S-8.4 (859 words), S-10.2 (992 words), and S-10.5 (1046 words). For the article 2 was observed from Tb-2.sy (608 words, peak for the motivation depletion) and S-9.5 (855 words). These patterns showed that the motivation depletion reached a high point on 608-661 words read. In-depth observation of these motivation depletion spots revealed the factors affected this depletion. They were passing more than one chemical equation; facing the very long coordinated sentences; facing the sentence containing many numerical data, symbols, equations, and terms; finding the cardinal number marked to more than one discussion about the topic (e.g. a think-aloud for S-7.2 [*First, the weakening of acid potential ...*] the word "*First"* gave the perception on the reader that there will be the second, the third, and so on till they did not know); and finding the difficult chemical representative for understanding such as a model figure (e.g. S-8.3).

Thus, each transition had a specific effect on conditional-strategic knowledge in the chemical reading activity. The readers thought that they had mastered the chemical reading when they confirmed themselves according to the omens in each transition state. Confirmation of their prediction about their understanding could be checked based on their posed questions. Their strategies used during the chemical reading performance would be an important determinant for the quality of their understanding of the chemical reading metacognitively. This proficiency in reading performance originated from the self-efficacy beliefs which were the sources used by the teacher candidates while studying, reviewing, and strategising chemistry learning (Uzuntiryaki, 2008) and were shaped by advanced personal epistemology (Bahcivan & Cobern, 2016).

CONCLUSION

Reading chemical articles by metacognitive tasks, like conducting a think-aloud for a question-posing, is a stimulator for metacognitive activity. Every step of this reading activity entails an interrelationship between metacognitive knowledge domains. Declarative knowledge is involved while preparing for the reading activity. Conducting the reading activity is executed by procedural knowledge. Staying to keep on the reading activity requires conditional-situational knowledge. Then, terminating the reading activity is decided from conditional-strategic knowledge. Each step needs the harmonic collaboration from the reader (person), task comprehension, strategy organisation and knowledge integration about the action to do.

In summary, the successful chemical reading activity requires the readers' personal aspect to maintain their interest, motivation, perception, and correct interpretation of the task required. This is the capital to have adventures in the chemical reading activity. The strategy is designed for understanding the reading as well as integrating the understanding of the knowledge they have. The chemical reading itself should fulfil some specific requirements for stimulating the metacognitive knowledge on all aspects.

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References

Atasoy, B., Akkus, H., & Kadayifci, H. (2009). The effect of conceptual change approach on understanding of students' chemical equilibrium concepts. *Research in Science & Technological Education, 27*(3), 267-282. https://doi.org/10.1080/02635140903162587

Bahcivan, E., & Cobern, W. W. (2016). Investigating coherence among Turkish elementary science teachers'

teaching belief systems, pedagogical content knowledge and practice. *Australian Journal of Teacher Education, 41*(10), 63-86. https://doi.org/10.14221/ajte.2016v41n10.5

Ben-Eliyahu, A., & Bernacki, M. L. (2015). Addressing complexities in self-regulated learning: A focus on contextual factors, contingencies, and dynamic relations. *Metacognition Learning, 10*, 1-13. https://doi.org/10.1007/s11409-015-9134-6

Binbarasan-Tüysüzoglu, B., & Greene, J. (2015). An investigation of the role of contingent metacognitive behavior in self-regulated learning. *Metacognition Learning, 10*, 77-98. https://doi.org/10.1007/s11409-014-9126-y

Charters, E. (2003). The use of think aloud method in qualitative research: An introduction to think aloud method. *Brock Education Journal, 12*(2), 68-82. https://brock.scholarsportal.info/journals/brocked/home/article/download/38/38

Chiu, J. L., & Linn, M. C. (2012). The role of self-monitoring in learning chemistry with dynamic visualizations. In A. Zohar dan Y. J. Dori (Eds.). *Metacognitive in science education: Trends in current research* (pp. 133-163). Springer. https://doi.org/10.1007/978-94-007-2132-6_7

Chopra, I., O'Connor, J., Pancho, R., Chrzanowski, M., & Sandi-Urena, S. (2017). Reform in a general chemistry laboratory: How do students experience change in the instructional approach? *Chemistry Education Research and Practice*, *18*, 113-126. https://doi.org/10.1039/C6RP00082G

Demirdogen, B., & Cakmakci, G. (2014). Investigating students' interest in chemistry through self-generated questions. *Chemistry Education Research and Practice*, *15*, 192-206. https://doi.org/10.1039/C4RP00037D

Dunlosky, J., & Metcalfe, J. (2009). *Metacognition*. Sage Publications, Inc.

Eitel, A., & Kuhl, T. (2016). Effects of disfluency and test expectancy of learning with text. *Metacognition Learning, 11*(1), 107-121. https://doi.org/10.1007/s11409-015-9145-3

Eldar, O., Eylon, B., & Ronen, M. (2012). A metacognitive teaching strategy for preservice teachers: Collaborative diagnosis of conceptual understanding in science. In A. Zohar dan Y. J. Dori (Eds.). *Metacognitive in science education: Trends in current research* (pp. 225-250). Springer. https://doi.org/10.1007/978-94-007-2132-6_10

Favieri, A. G. (2013). General metacognitive strategies inventory (GMSI) and the metacognitive integrals strategies inventory (MISI). *Electronic Journal of Research in Educational Psychology, 11*(3), 831-850. https://doi.org/10.14204/ejrep.31.13067

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive–developmental inquiry. *American Psychologist*, *34*(10), 906-911. https://doi.org/10.1037/0003-066X.34.10.906

Garcia-Rodicio, H., & Sanchez, E. (2014). Does the detection of misunderstanding lead to its revision? *Metacognition Learning, 9*(3), 265-286. https://doi.org/10.1007/s11409-014-9116-0

Ghasempour, Z., Bakar M. N., & Jahanshahloo, G. B. (2013). Innnovation in teaching and learning through problem posing tasks and metacognitive strategies. *International Journal of Pedagogical Innovations*, *1*(1), 53-62. https://journal.journals.uob.edu.bh//Article/ArticleFile/158

Green, S. R., & Redford, J. (2016). Metasearch accuracy for letters and symbols: Do our intuitions match empirical reality? *Metacognition Learning, 11*(2), 237-256. https://doi.org/10.1007/s11409-015-9143-5

Grotzer, T. & Mittlefehldt, S. (2012). The role of metacognition in students' understanding and transfer of explanatory structures in science. In A. Zohar dan Y. J. Dori (Eds.), *Metacognitive in science education: Trends in current research* (pp. 79-99). Springer. https://doi.org/10.1007/978-94-007-2132-6

Handel, M., Locki, K., Heydrich, J., Weinert, S., & Artelt, C. (2014). Assessment of metacognitive knowledge in students with special educational needs. *Metacogniton Learning, 9*, 333-352. https://doi.org/10.1007/s1409-014-9119-x

Herscovitz, O., Kaberman, Z., Saar, L., & Dori, Y. J. (2012). The relationship between metacognition and the ability to pose questions in chemical education. In A. Zohar & Y. J. Dori. (Eds.), *Metacognitive in science education: Trends in current research* (pp. 165-195). Springer. https://doi.org/10.1007/978-94-007-2132-6_8

Jacobse, A. E., & Harskamp, E. G. (2012). Towards efficient measurement of metacognition in mathematical problem solving. *Metacognition Learning, 7*(2):133-149. https://doi.org/10.1007/s11409-012-9088-x

Kaberman, Z & Dori, Y. J. (2009). Metacognition in chemical education: Question posing in the case-based computerized learning environment. *Instructional Science, 37*(5): 403-436. https://doi.org/10.1007/s11251-008-9054-9

Khezrlou, S. (2012). The relationship between cognitive and metacognitive strategies, age, and level of education. *The Reading Matrix, 12*(1), 50-61. http://www.readingmatrix.com/articles/april_2012/khezrlou.pdf

Korpershoek, H., Kuyper, H. & van der Werf, G. (2015). The relation between students' math and reading ability and their mathematics, physics, and chemistry examination grades in secondary education," *International Journal of Science and Mathematics Education, 13*, 1013-1037. https://doi.org/10.1007/s10763-014-9534-0

Leopold, C., & Leutner, D. (2015). Improving students' science text comprehension through metacognitve self-regulation when applying learning strategies. *Metacognition Learning, 10*(3), 313-346. https://doi.org/10.1007/s11409-014-9130-2

Marulis, L. M., Palincsar, A. S., Berhenke, A. L. & Whitebread, D. (2016). Assessing metacognitve knowledge in 3-5 years olds: The development of a metacognitve knowledge interview (McKI). *Metacognition Learning, 11*(3), 339-368. https://doi.org/10.1007/s11409-016-9157-7

Molenaar, I., Sleegers, P., & van Boxtel, C. (2014). Metacognitve scaffolding during collaborative learning: A promising combination. *Metacognition Learning, 9*, 309-332. https://doi.org/10.1007/s11409-014-9118-y

Norris, S. P., & Phillips, L. M. (2012). Reading Science: How a naive view of reading hiders so much else. In A. Zohar & Y. J. Dori. (Eds.), *Metacognitive in science education: Trends in current research* (pp. 37-56). Springer. https://doi.org/10.1007/978-94-007-2132-6_3

Overton, T., Potter, N., & Leng, C. (2013). A study of approaches to solving open-ended problems in chemistry. *Chemistry Education Research and*

Practice, 14, 468-475. https://doi.org/10.1039/C3RP00028A

Ozmen, H. (2008). Determination of students' alternative conceptions about chemical equilibrium: A review of research and the case of Turkey. *Chemistry Education Research and Practice, 9*, 225-233. https://doi.org/10.1039/b812411f

Pulmones, R. (2010). Linking students' epistemological beliefs with their metacognition in a chemistry classroom. *The Asia-Pacific Education Researcher*, *19*(1), 143-159. http://ejournals.ph/form/cite.php?id=3981

Sadowski, C., & McIntosh, J. E. (2015). A phenomenological analysis of the experience of security and contentment for latency aged children in shared-time parenting arrangements. *Journal of Phenomenological Psychology*, *46*, 69-104. https://doi.org/10.1163/15691624-12341285

Schraw, G., Olafson, L., Weibel, M., & Sewing, D. (2012). Metacognitive knowledge and field-based science learning in an outdoor environmental education program. In A. Zohar dan Y. J. Dori. (Eds.), *Metacognitive in science education: Trends in current research* (pp. 57-77). Springer. https://doi.org/10.1007/978-94-007-2132-6_4

Sperling, R. A, Howard, B. C., Staley, R., & duBois, N. (2004). Metacognition and self-regulated learning constructs. *Educational Research and Evaluation*, *10*(2), 117-139. https://doi.org/10.1076/edre.10.2.117.27905

Taber, K. S. (2014). Ethical considerations of chemistry education research involving 'human subjects'. *Chemistry Education Research and Practice, 14*, 109-113. https://doi.org/10.1039/C4RP90003K

Thomas, G. P., & McRobbie, C. J. (2013). Eliciting metacognitive experiences and reflection in a year 11 chemistry classroom: An activity theory perspective. *Journal of Science Education Technology, 22*, 300-313. https://doi.org/10.1007/s10956-012-9394-8.

Uzuntiryaki, E. (2008). Exploring the sources of Turkish pre-service chemistry teachers' chemistry self-efficacy beliefs. *Australian Journal of Teacher Education, 33*(6), 12-28. https://doi.org/10.14221/ajte.2008v33n6.2

Veenman, M. V. J. (2012). Metacognition in science education: Definitions, constituents, and their intricate relation with cognition. In A. Zohar & Y. J. Dori. (Eds.), *Metacognitive in science education: Trends in current research* (pp. 21-36). Springer. https://doi.org/10.1007/978-94-007-2132-6_2

Vierkant, T. (2017). Choice in a two system world: Picking & weighing or managing & metacognition. In T. Vierkant (Ed.), *Phenomenology and the cognitive science* (pp. 1-13). Springer. https://doi.org/10.1007/s11097-016-9493-8

Wilhelm, J. D. (2001). *Improving comprehension with think-aloud strategies.* Scholastic Professional Books.

Zohar, A., & Dori, Y. J. (2012). Introduction. In A. Zohar & Y. J. Dori (Eds.), *Metacognitive in science education: Trends in current research* (pp. 1-19). Springer. https://doi.org/10.1007/978-94-007-2132_1