2021

SciEd
SEAQIS Journal of Science Education

SEAQIS Journal of Science Education (SciEd)
P-ISSN: 2777-0397 | E-ISSN: 2798-7175
Vol: 1, No: 2, PP:49-59
www.journal.qitepinscience.org

Research Paper Open Accsess

Metacognitive Strategy of Chemistry Teacher Candidates in Chemistry Reading Activity

Benny Yodi Sawuwu [1]

[1] *SMA Katolik Santu Petrus Pontianak, West Kalimantan, Indonesia.*

Abstract

This qualitative study was conducted to explore the metacognitive strategy of chemistry teacher candidates in reading activities of a chemical article. There were 15 female chemistry teacher candidates voluntarily on this research from a public university. A chemical article that fulfilled some characteristics was used to stimulate the metacognitive activity, and 25 open-ended questions were posed for self-interviewing to reveal the metacognitive aspects. A think-aloud protocol was conducted during the reading activity. All reading activities were recorded and transcribed. Transcription of the think-aloud activity was considered to the reading rate to classify the think-aloud style into less think-aloud, formal think-aloud, and critical think-aloud. The reading pattern and data from self-interview showed that these three styles of think-aloud had different strategies on chemistry reading activity. The planning and evaluating activity determined the strategy chosen on reading. The monitoring activity was contributed by terms and chemical representatives used in the article.

Keywords: Chemistry reading activity, Metacognitive strategy, think-aloud

Introduction

When one reads an academic reading, like chemical information, will occur cognitive and metacognitive strategies concurrently in his/herself (Korpershoek, Kuyper, & van Der Werf, 2015; Leopold & Leutner, 2015). The question posed as the result of reading the chemical information could become an indicator to reveal one's metacognitive levels related to his/her understanding of the chemistry and context of the reading (Kaberman & Dori, 2009; Herscovitz, Kaberman, Saar, & Dori, 2012; Ghasempour, Bakar, & Jahanshahlolo, 2013). However, this metacognitive aspect is difficult to observe since the process occurs inside one's mind (Dunlosky & Metcalfe, 2009; Norris & Phillips, 2012; Grotzer & Mittlefehldt, 2012; Schraw, Olafson, Weibel, & Sewing, 2012). Divulging metacognition through problem posing in question-form could be handled by combining the question taxonomy with the think-aloud protocol (Kaberman & Dori, 2009; Herscovitz, et al., 2012) that is a technique to verbalize one's thought (Jacobse & Harskamp, 2012). The advantage of this technique is to give the sight of the process of memory and actual thinking when one is reading, understanding, strategizing, processing, and deciding (Wilhelm, 2001; Overton, Potter, & Leng, 2013) for revealing the metacognitive strategy (Binbarasan-Tüysüzoglu & Greene, 2015), metacognitive judgment (Ben-Eliyahu & Bernacki, 2015), and metacognitive knowledge in problem-posing (Herscovitz, et al., 2012).

The qualitative analysis could get a whole description of those metacognitive phenomena (Davidowitz & Rollnick, 2003; Pulmones, 2010; Siegel, 2012; Anderson, Nashon, & Thomas, 2009; Thomas &

McRobbie, 2013). One of the qualitative approaches that could be used is the phenomenological study (Vierkant, 2017). Nevertheless, this qualitative approach had a shortcoming because of its long time needed (Jacobse & Harskamp, 2012). Pulmones (2010) covered it by analysing in-depth the representative samples as found similar epistemological beliefs of students with the same metacognitive type.

Chemistry teacher candidates, as the agents to assess the students' metacognitive, should have the capacity to read the chemical reading and to pose the chemical problem before they would assess their students in the future. Particularly in the chemistry domain that has certain characteristics that evolve during the world development in this 21st century. This research was conducted to explore the metacognitive strategy of chemistry teacher candidates in the reading activity of a chemical article. This study would reveal the reading pattern and the reading strategy in chemistry teacher candidates.

Methods: Participant

This was a qualitative study of 15 chemistry teacher candidates in third years of a public state university in Yogyakarta, Indonesia. All of them were female and from 19 to 21 years old. They were in the international program that used a bilingual class in Indonesian Language and English during their courses. They participated voluntarily in this research outside the regular class activities. Ethical consideration was used to protect the data of participants (Taber, 2014; Sadowski & McIntosh, 2015) that was stamped in an agreement between each participant and the researchers. They were denoted by participants A to O.

Material

A chemical reading had been designed to stimulate metacognitive strategy in the reading activity.

The reading was an article about the application of chemical equilibrium in human teeth overlapping with other chemistry domains and other disciplines, that fulfilled some criteria about chemical reading as mentioned before, to stimulate the participants as readers to pose problems in question form at the metacognitive level. The title of the article is "Teeth Demineralization and Remineralization". It is an interdisciplinary topic with a total of 1095 words and uses multi representations. The article had been validated by two experts in related disciplines, and some suggestions from the experts had been used to consummate the reading. The phenomenology figures were placed in paragraphs 1 and 5, the model figure placed in paragraph 8, and the symbolic figure was placed in paragraph 5. Four chemical equations were placed in paragraphs 1, 2, and 8.

There were 25 questions of metacognitive strategy exploratory arranged to reveal another metacognitive activity that was not observed during the reading and posing question activities. The questions were made based on the indicators in Table. 1. The questions were open-ended and had been validated by two experts on chemistry education and psychological education. Some suggestions from experts had been used to complete the questions' visibility.

Table 1. Component of Dimension Metacognitive Strategy

Dimension	Aspect	Indicators
Planning	Recognition	recognize the category of task instruction
		read the information given
		think about what one own self knows about the task information
		think about what one own self does not know about the task information
	Identification	identify the relevant data
		identify the goal of the task

Dimension	Aspect	Indicators
	Comprehension	identify the relevant data that is not found from the information
		make your sketch about the information
		list the alternative methods that can be used to rich the goal
	Organization	list the sequence of procedure
		allocate the time in each sequence step
Monitoring	Firming up	re-read the information till getting the whole understanding
		try to understand the difficult, new, or unfamiliar data
	Thinking process	use a specific method to organize the data (e.g. graph, note, table, etc.)
		review the reference (the knowledge outside the information)
		solve the problem that appears subsequently
	Exactitude	review the solution
		re-analyse the examination conducted
	Congruence	check the progress
		ask for others' perspectives (friends or examples)
Evaluating	Examination	check the attainment
		check the success of the strategy used
	Reflection	assess the strategy based on the self-performance about the quality of the task given
	Appreciation	assess how to study the learning strategy in a different context
		appreciate own self after finishing the task

Procedure

The task was decided to be the purpose of the reading activity. Each participant should pose two problems in question-form after they read the article as the result of thinking and reflection of the article. The specific directions of the questions were (1) they should be the best complex problems consisting of the initial information and the final state, (2) they should be fetched us on the application of chemical equilibrium on the article's context, and (3) they could link another knowledge to pose the question but they should anchor to the chemical equilibrium and its application. After they made the questions, they should answer the open-ended questionnaire by themselves. The time was limited to 45 minutes to finish their activities.

A think-aloud protocol was used in this reading procedure to collect about metacognitive activities during reading the article. First, each participant was given the reading and had been simulated about the procedure of think-aloud for recording. Each participant had been requested to vocalize or verbalize their thoughts in front of the recorder during they were reading. There was no pause activity during reading, posing the question till answering the questionnaire. The participants were allowed to drink during the think-aloud activity if they felt husky. 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 the researcher's interruption, at the comfort place that participant selected before, and in their spare time.

Credibility

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

Analysing Data

The data collected from the recording were transcribed and validated by the participants. How they read the articles was transcribed and marked in specific coding consisting of reading patterns and reading parameters. The transcription was arranged embedding and sequentially between the textual word and think-aloud word. Every segment (sentences, equations, and figures/graphs) was measured to the reading rate. This measurement was just only for categorizing the data in the detailed segment of reading patterns. Next, seeking for the difference or delta (Δ) between the reading rate of think-aloud and textual word (relative to the time spent of each participant) was conducted to analyse the reading pattern and to find "what" the metacognitive activities during the reading process. The delta described the reading pattern. The positive value of delta showed that participants were more in think-aloud. The zero value of delta showed that participants were equal on think-aloud and normally textual words. The negative value of delta indicated that participants were less on think-aloud, did not read the words, and stayed silent several times.

The margin of error of the delta was determined as the multiplication product of standard error with critical value. Standard error was defined as the standard deviation of the delta divided by the square root of the participant number. The critical value was a z-score for one minus half of the significant level ($\alpha = 5$ %). For participants who had the delta above the positive margin of error were classified as critical-think-aloud. For participants who had the delta between the positive and negative margin of error were classified as formal-think-aloud. For participants who had the delta below the negative margin of error were classified as less-think-aloud.

A phenomenological reduction method was used to analyse the reading phenomena. All data were transcribed then were reduced (horizontalization of data).It was carried by deleting the statements of think-aloud expressions that were not relating 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 coded and categorized in the same theme that represented the specific expression and finding toward the metacognitive strategy in the reading activity of the chemical article. The coding from the reading pattern was used to find pneumatic themes (what the phenomenon is) and the coding from the think-aloud activity and self-interview was used to find noesis themes (how the phenomenon is).

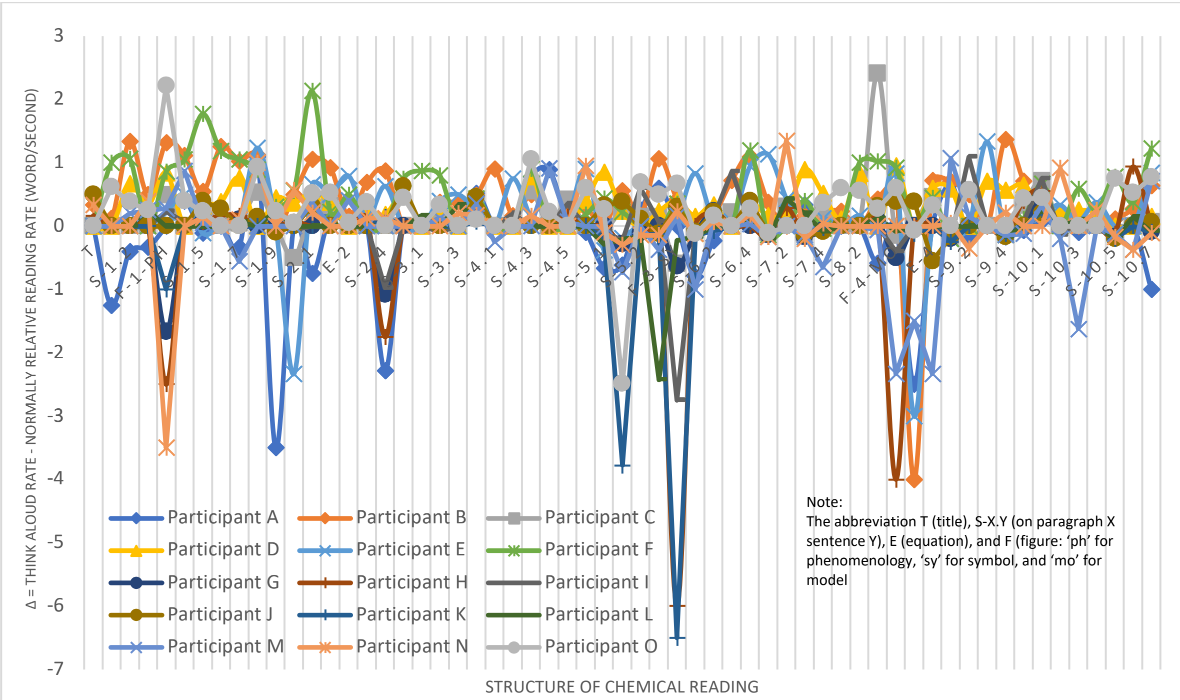
Then, data verification was conducted to clarify and reinforce the themes. The pneumatic themes were unified as formulation of the textural definition but the neosis themes were as the structural definition. By blending the textural and structural definitions and adding with data interpretation, the themes were merged to be the essential definition of metacognitive strategy in chemistry reading activity.

Result and Discussion

Chemistry Reading Pattern

The distribution of reading rate based on the structure of chemical reading was shown in Fig. 1. According to this delta (margin of error = 0,1258), we can classify the reading pattern on three types of chemical reading activities. Participants B, C, D, E, F, J, N and O were grouped on critical-think-aloud. Participants G, H, I, L and M were categorized on formal-think-aloud. The less-think-aloud group was occupied by participants A and K. These three chemical reading activities had a similar trend on reading the figure of chemical representatives (phenomenology, model, and symbolic) and the chemical equations. They would decelerate their reading rate when arrived at the figures and equations as the specific characteristic of chemical readings.

Figure 1. The pattern of Chemical Reading



The main differences between these three styles were the reflection about the content of the article during they read (the critical-think-aloud was the most reflective reading style) and the strategy of reading they used. The critical-think-aloud reading style was not always produced by one that had a metacognitive strategy, because some reflections made was only just expressions about agreement and familiarity. On contrary, few reflective or metacognitive expressions were elicited in a less-think-aloud style. There were some activities on critical think-aloud appearing on formal-think-aloud and less-think-aloud.

Planning activity on chemistry reading activity

Recognition of the task as the purpose to read was conducted by all think-aloud styles. It was an important thing to begin the chemistry reading activity. For critical-think-aloud style, the recognition about the task focused on the process that should be conducted about the task instruction, how the limitation is given like time allocation, how the requirement can or cannot be conducted, what the sources should be used (chemical equilibrium theory and application), and what the goal that should be reached after reading (to pose questions). For formal-think-aloud and less-think-aloud only focused on the process, limitation and the goal. The differences between them were on identification and comprehension of the task. The less-think-aloud decided to read rapidly and sequentially as the best strategy to manage the time given and to simplify effectively the think-aloud technique. Nevertheless, the formal-think-aloud tended to not consider the time given when reading, but just flowing naturally (relative in the range positive and negative of margin of error). The time was considered to be more left after reading to posing questions. This style arranged the strategy to have understanding during reading activity sequentially but in simple ways by reducing the think-aloud activity.

The critical-think-aloud considered the process, limitation, and the goal toward the requirements and the sources needed and used them to arrange the criteria to reach the goal. After they knew the topic of the passage, they expected some chemical aspects that may be found during reading.

They predicted some important things that should be searched by linking the preliminary knowledge related to being marked during reading. On less-think-aloud would read directly after this prediction making, but on formal-think-aloud, they initiated the reading activity by looking a moment the interesting part of the passage like figure, bold sentences, etc., before reading the title and memorizing the terms and related terms on the title.

After making the prediction, the critical-think-aloud style would count the pages to estimate the time by skimming. Scanning would be conducted to find the chemical aspect of the reading or to see a moment of the interesting part of the passage like figure, bold sentences, etc., before reading the title. Then read the terms and related terms on the title. In that, the critical-think-aloud had the more detailed on planning to read the chemical reading. The critical-think-aloud tended to be critical-based on reading planning not only process-oriented (through understanding the think-aloud protocol and estimating the strategy) but also result-oriented (through arranged the criteria of question should be made and predicted what the things should be found).

Monitoring activity on chemistry reading activity

When the reading process was ongoing, one was seeking for the familiarity or similarity about each word read. These were conducted by comparing the data and preliminary knowledge such as some terms. When the familiar data were found, the less-think-aloud would reduce them from his/her voice, but the formal-think-aloud would read them rapidly. The critical-think-aloud would find the new information from the familiar data for renewing the understanding and would criticize the gap between them. When the new, strange, and interesting terms were found, all think-aloud types would be slower on reading and would try to understand them. The monitoring in this chemical reading activity was carried on the understanding section of the chemical information, figures or graphs, and terms. This monitoring step would determine how to go forward or to have some iteration. During the efforts to seek familiarity and to find the understanding, they should mark the important information following the task instruction and the planning made before.

The critical-think-aloud would predict or make its definition (about the terms) and explanation (about the statement) through identifying the hint about them, before and/or after statements, as shown by this quotation of text S-1.8 below.

Text S-1.8	:	This process is called teeth mineralization
Less think-aloud (K)	:	This process is called teeth mineralization [3 seconds)
Formal think-aloud (G)	:	This process is called teeth mineralization [silent] (6 seconds)
Critical think-aloud (B)	:	This process is, this process is called teeth mineral, teeth mineralization. Matrix protein combines with water ... it means that contain mineral so why it is called teeth mineralization. (32 seconds)

The quotation above showed that the formal-think-aloud had tried to understand the sentence by decelerating the speed but she was trapped in puzzled and difficult to think-aloud. On another side, the less-think-aloud had judged that the term was not important because she thought that not all terms should be used to make a question.

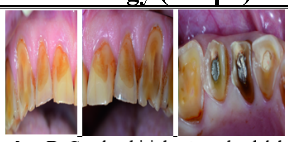
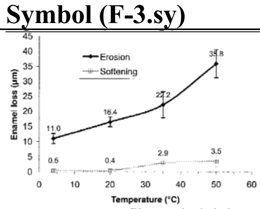
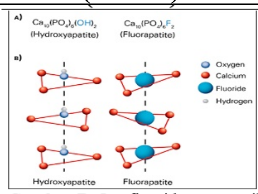
When they found the chemical equation the less-think-aloud tend to pass it, as shown by this quotation of text E-2 below.

Text E-2	:	$Ca_{10}(PO_4)_6(OH)_2(s)$ + $8H^+(aq)$ → $10Ca^{2+}(aq)$ + $6HPO_4^{2-}(aq)$ + $2H_2O(l)$
Less think-aloud (A)	:	-
Formal think-aloud (L)	:	$Ca_{10}(PO_4)_6(OH)_2$(solid) added by $8H^+$(aqueous) becomes $10Ca^{2+}$(aqueous) plus $6HPO_4^{2-}$ (aqueous) plus $2H_2O$(liquid) [11 second]
Critical think-aloud (F)	:	This is the demineralization reaction, $Ca_{10}(PO_4)_6(OH)_2$ added by $8H^+$, reacted with an acid, produce, oh, $10Ca^{2+}$ plus $6HPO_4^{2-}$ plus $2H_2O$, ha [what] HPO_4^{2-}? Oh it is acid, it means, with acids such as from bacteria, ehe [agree]. [36 seconds]

The formal-think-aloud just read the equation as a formal activity but the critical-think-aloud would identify the component on the chemical equation, find the connection of the sentences on the text and the equation, and criticize the new, strange, unfamiliar, and unreasonable partitions.

Figure 1 before showed that were negative delta values in each figure of chemical representative. For analysing the detail of each figure, Table 2 had showed the comparison.

Table 2. Think-aloud Activity for Chemical Representatives

	Phenomenology (F-2.ph)	Symbol (F-3.sy)	Model (F-4.mo)
Text (in Bahasa Indonesia)	 **Gambar B**: Gambar kiri dan tengah adalah erosi gigi akibat makanan asam dan trauma menyikat gigi pada seseorang berusia 70 tahun dengan pulp gigi yang sehat. Gambar kanan adalah erosi gigi yang terjadi pada penderita anoreksia dan bulimia berusia 35 tahun (Sumber: Colon & Lussi, 2014)	 **Gambar C**: Grafik erosi gigi dan pelunakan gigi selama 2 jam dalam asam sitrat (pH=3,2) dalam berbagai suhu cairan yang berbeda (Sumber: Eisenburger & Addy, 2003)	 **Gambar D:** Ion fluorida mengantikan posisi ion hidroksida dari hidroksiapatit menjadi fluorapatit (Sumber: (http://www.dentalcare.com)
Less think-aloud (A)	[read the text of figure explanation] there is something black, what is it? [21 seconds]	(0 seconds)	(0 seconds)
Formal think-aloud (I)	[read the text of figure explanation] [22 seconds]	[read the words on figure] [8 seconds]	[read text of figure explanation] (silent) [10 seconds]
Critical think-aloud (C)	How odious it is, yellow. [read the text of figure explanation] why could it be black? Anorexia, bulimia are diseases that spew the food out after eating, so scrawny. [50 seconds]	Eh [shock], oh the higher the temperature, the more it is? The more tooth enamels diminished [20 seconds]	Is it its geometry? Its geometry molecule? Apatite, Apatit…, forget it. [13 seconds]

According to Table 2, there was a trend of depletion of chemical comprehension from phenomenology to model representative for all think-aloud types. The think-aloud could be an indicator for revealing the understanding of the text. As mentioned by them that, "*I am understand, when I can re-tell what I read*", or "*if I do not understand, I will re-read again.*"

The less-think-aloud just saw the figure at a glance without determination because of the reason of sparing time. They thought that was becoming more advantageous when initiating mini questions to be options for the final question. The mini questions were the gap between the curiosity of the text written and preliminary knowledge. This mini question usually was on the new terms or important information marked by them.

Some cases were the gap between their experiences and the statements or new knowledge they found in the text.

For the less-think-aloud, iteration should be minimum (maximum two iterations) as a strategy. For the formal and critical think-aloud, iteration should be an alternative for more understanding about the text through considering the length of the passage left. By re-considering, the length of passage left and the time prediction, they would monitor and re-plan what they had to do to reach the goal of the task. The first depletion of motivation appeared on S-2.3 (230 words) and the peak of this depletion was on S-6.4 (690 words). It meant that the capacity of students to get more concentration in reading just 200-700 words. The range from S-2.3 to S-6.4 was the spots for mini-questions arranged and the spots for reflective expression appeared. After this range, the graph was flat to the minimum expression.

Looking for this monitoring activity on chemistry reading activity, seemed that by think-aloud activity during this reading activity all participants were carrying some metal actions. They elaborated the time for retention and performance (Eitel & Kuhl, 2016). During they were reading, they were detecting some errors toward their preliminary knowledge (Garcio-Rodicio & Sanchez, 2014) and were sorting the chemical alarms like symbols on terms, chemical formula and others figure (Green & Redford, 2015).

Evaluating activity on chemistry reading activity

As a strategic reason, the less-think-aloud said that they did not check their understanding of the text during the reading activity. On other hand, the formal and critical think-aloud tried to terminate the reading activity by making some reflection about the text through the link the data to personal experiences or preliminary knowledge on daily life. By retelling the information, they evaluate what they understand about the text and how they comprehend the whole text. After reading they checked again the goal that should be reached on the task. This was as reinforcement to the understanding and making sure they had known about the task.

Planning, monitoring, and evaluating activities could not be separated independently. After one planned and monitored the process, evaluation needed to re-design the planning. The reading rate would be fluctuating when the reflective reading had been conducted. Chemical reading, with all components of chemical characteristics, should be read by different strategies compared with other readings. As an unseparated part of chemical literacy, the attainments in these reading activities were affected by the lower multi-dimensional chemical literacy that impacted the insufficient reasoning and comprehension about the reading activity (Celik, 2014). So, the teacher candidate should improve themselves on chemical literacy.

Conclusion and Implication

Think-aloud in reading activity had trained the teacher candidate how to understand the task to get the more efficient strategy in metacognitive level. When they should voice the thought about the passage they read, they thought twice and moved to the metacognitive mode. Less-think-aloud, formal-think-aloud, or critical-think-aloud should be arranged by an effective strategy for planning, monitoring, and evaluating activities. As the teacher candidate, an obligation was to understand this reading strategy in chemical reading activities. The conformation of chemical representative in a chemical reading effect the chemical understanding of the readers.

Through the specific task given at the beginning of the reading activity, like posing questions, trained ones to know the goals of reading. It was not about selecting a type of reading way but it was about determining how to be effective on reading. The chemical reading, with its components, had characterized the multiple representatives for stimulating the metacognitive expression. It was important to help readers visualize what the chemical and its properties were spoken. By giving a limitation of the task, could stimulate readers to arrange the strategy when collecting the information during the reading activity. Think-aloud made the strategy be stimulated on the metacognitive reflective level and revealed the strategy used in the readers' minds.

Monitoring activities during reading determined the iteration, prediction, interpretation, and comprehension of the text. The new, unfamiliar chemical terms inserted on the text could be sensors or hints by the mind for marking the specific information for considering to list the important data. This monitoring was closer to the identification of familiarity and understanding of the chemical representative on the text. This identification caused the speed to be slower or faster. The more new related and important terms, the slower the speed. Chemical representative in phenomenology-contextual could be the important part to visualize the text but could be not too contributed if the readers judged it was not important for the task goal. The symbolic and model could be important to stimulate the readers to think on the level of chemical understanding. But the length of the passage should be determined to prevent the contribution of motivation depletion during reading. Interesting confirmation reading arrangement and limitation of words used could be the alternative solution to maintain the motivation and concentration of the reader during the chemistry reading activities.

Retelling and making a reflection about the text would convey the readers to evaluate the understanding about the chemical reading. The interlude section was more important to guide readers for reading comprehension. As teacher candidates, the critical-think-aloud style on chemical reading should be trained to firm the chemical understanding up about the written data. It helped chemistry teacher candidates to be the criticized and open-minded teachers.

Acknowledgement

Thank you to Indonesia Endowment Fund for Education (LPDP) for funding this research.

Reference

Anderson, D., Nashon, S. M., & Thomas, G. P. (2009). Evolution of research methods for probing and understanding metacognition. *Research in Science Education, 39*, 181-195. doi:10.1007/s11165-007-9078-1

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. doi:10.1007/s11409-015-9134-6

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

Celik, S. (2014). Chemical literacy levels of science and mathematics teacher candidates. *Australian Journal of Teacher Education, 39*(1), 1-15. doi:10.14221/ajte.2014v39n1.5

Davidowitz, B., & Rollnick, M. (2003). Enabling metacognition in the laboratory: A case study of four second-year university chemistry students. *Research in Science Education, 33*, 43-69. doi:10.1023/A:1023673122220

Dunlosky, J., & Metcalfe, J. (2009). *Metacognition*. Los Angeles, LA: Sage.

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

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

Ghasempour, Z., Bakar M. N., & Jahanshahloo, G. B. (2013). Innovation in teaching and learning through problem-posing tasks and metacognitive strategies. *International Journal of Pedagogical Innovations*, *1*(1), 53-62. Retrieved from 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. doi: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 & YJ. Dori. (Eds). *Metacognitive in Science Education: Trends in Current Research Series: Vol. 40 Contemporary Trends and Issues in Science Education* (pp. 79-99). Dordrecht: Springer.

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, Series: Vol. 40. Contemporary Trends and Issues in Science Education* (pp. 165-195). Dordrecht: Springer.

Jacobse, A. E., & Harskamp, E. G. (2012). Towards efficient measurement of metacognition in mathematical problem-solving. *Metacognition Learning,* *7*(2):133-149. doi: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. doi:10.1007/s11251-008-9054-9

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*(5), 1013-1037. doi:10.1007/s10763-014-9534-0

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

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 Series: Vol. 40 Contemporary Trends and Issues in Science Education* (pp. 37-56). Dordrecht: Springer.

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. doi:10.1039/c3rp00028a

Pulmones, R. (2010). Linking students' epistemological beliefs with their metacognition in a chemistry classroom. *Asia-Pacific Education Researcher*, *19*(1), 143-159. Retrieved from 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 sharedtime parenting arrangements. *Journal of Phenomenological Psychology*, *46 (1)*, 69-104. doi: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 & Y. J. Dori. (Eds.). *Metacognitive in Science Education: Trends in Current Research Series: Vol. 40 Contemporary Trends and Issues in Science Education* (pp. 57-77). Dordrecht: Springer.

Siegel, M. A. (2012). Filling in the distance between us: Group metacognition during problem solving in a secondary education course. *Journal of Science Education Technology, 21*, 325-341. doi:10.1007/s10956-011-9326-z

Taber, K. S. (2014). Ethical considerations of chemistry education research involving 'human subjects'. *Chemistry Education Research and Practice*, *14*, 109-113. doi: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. doi:10.1007/s10956-012-9394-8.

Vierkant, T. (2017). Choice in a two-system world: Picking & weighing or managing & metacognition. *Phenomenology and The Cognitive Science (*pp. 1-13). Dordrecht: Springer.

Wilhelm, J. D. (2001). *Improving comprehension with think-aloud strategies.* New York, NY: Scholastic Professional Books. Retrieved from http://gec.kmu.edu.tw/~lc/ecorner/eBook/Improving%20Comprehension%20With%20Think-Aloud%20Strategies.pdf