



The Profile of Students' Analytical Thinking Skills on Chemistry Systemic Learning Approach

Nur Fitriyana^{*a}, Marfuatun^a, Erfan Priyambodo^a

^aDepartment of Chemistry Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta, Indonesia

*Corresponding author: Colombo street No 1, Catur Tunggal, Depok, Sleman, Yogyakarta, 55281, Indonesia. E-mail addresses: nur.fitriyana@uny.ac.id

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abstract

The movement of educational systems on the 21st century need to be change from linearity to systemic form. The aims of this research is to determine the effect of Chemistry Systemic Learning Approach (CSLA) toward Students' Analytical Thinking Skills (SATS). A pre-experimental with pre-test and post-test design was adopted in this research. The population of this study were all of the students of public senior high school in Kulon Progo regency, Yogyakarta, Indonesia. Two classes from a public senior high school in those regency were cluster randomly selected as the research samples. A Systemic Test on Analytical Thinking (STAT) was used to collect the data of SATS, before and after the implementation of CSLA. The STAT covering four indicators of analytical thinking, they are differentiating, organizing, and attributing indicators. Meanwhile, the CSLA was integrated in the teaching-learning process and in the STAT, the CSLA was presented in the form of cyclic diagrams. The data of SATS on CSLA were analyse according to paired samples t-test and n-gain category analysis. The results of these analysis indicates that there was significant effect of CSLA on SATS. Moreover, the profile of SATS shows a satisfied improvement after the implementation of CSLA. Overall, a high n-gain category was reached that indicates the enhancement of students' understanding of the inter-related concept in chemistry. This study gives a significant contribution on the use of CSLA to improve SATS. Hence, the used of CSLA should be emphasized on chemistry learning to promote students' higher order thinking skills.

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1. Introduction

In the 21st century, the development of students' potential not only focus on the great emphasis on fostering students to become academic, knowledgeable, and independent. Promoting students become innovative, creative thinkers, effective doers, and skillful problem solvers were required in order to meet and deal with the 21st century learning skills. However, a student with skillful problem solvers need a skills of higher order thinking skill, that demands critical, analysis, and creativity thinking (Putri & Aznam, 2019).

Analytical, evaluation, and create skills are referred as the characteristics of higher order thinking skills (Petrovska & Veseliovska, 2013). Thus, one of higher order thinking skills is analytical thinking that belongs to the fourth level of thinking process of Bloom's Taxonomy (Anderson & Krathwohl, 2001). Therefore, an analytical thinking skill is considering as an elaboration of phenomenon remembering, understanding, and applying but as a basic of

evaluating or *creating*. These analytical thinking skills leads the students to compose the things (situations, practices, problems, statements, ideas, theory, arguments) into their parts and determine how each parts are correlate each other and yields an overall structure or objective (Anderson & Krathwohl, 2001; Thaneerananon, Triampo, & Nokkaew, 2016). Art-In and Sitthipon (2012) suggest that an analytical thinking skill is a competency that needed to identify and classify different aspects from an object, story, or the incident followed by finding a relationship from all these aspects. Thus, in the daily life, it is necessary to have analytical thinking skill since it is useful to classify which information would be useful to draw decision and even solve a problem. Unfortunately, the students' analytical thinking skills are rarely explored, hence many students found didn't exercise these skills that brings a difficulties in solving a problem in the daily life they meet.

Analytical thinking skills is necessary in order to develop a meaningful learning process; thus students are strongly suggested to have a good analytical thinking skills. This fact confirmed by Areesophonpichet (2013) that proposed about the trend on the recent studies which focuses on enhancing the development of students' analytical thinking skills which directly leads to the development of critical thinking skills and problem solving skills. Thus, an analytical reasoning is the basic way which used to solve a problem in the various field (Rutledge, 2006). According to Taleb and Chadwick (2016), enhancing students to analyse, criticize, assess, compare, and evaluate are the area should chemistry learning covered to enhance the analytical thinking skills. However, majority of chemistry teachers concerned on the transfer of knowledge instead of enhancing students' analytical thinking skill through constructing the knowledge by the students' selves (Sinlarat, 2000). Hence, the students have a lack of exercise to promote their analytical thinking skills that leads on the difficulties to solve a common problem in the chemistry lesson. It is necessary to the chemistry teachers in fostering of students' analytical thinking skill in chemistry.

On the other hand, chemistry is natural science subjects that has inter-related concepts on its nature (Sirhan, 2007). For example, in acid base concept that relates the stoichiometry and chemical equilibrium concepts. However, many students are forgot the concepts about stoichiometry and chemical equilibrium when they are deal with the acid-base concept. It shows that the students' understanding still such a pieces and concerned only for certain topics. They are not knowing that the concepts they got will be related to the next topic they will learn. Therefore, a learning environment that facilitates and depict chemistry with its

related concepts are needed in order to promote a meaningful learning for students that bring an increasing of students' thinking skills.

The systemic learning approach offers a learning environment that providing the concepts structure through an interaction with cyclic diagram that relates each concepts (Fahmy, 2017; Bashaireh, 2011). Systemic learning approach is an attractive and interactive methods to teach chemistry (Awad, 2017). Therefore, the inter-related concepts in chemistry are depicting clearer. The understanding of those inter-related concepts in chemistry are required the skills of analytical thinking. The systemic learning approach will open the students' thinking and increase students' interest rather being getting confused and wary of learning (Naqvi, Summer, Kanwal, & Hasnat, 2017). This systemic learning approach allow the development of thinking skills and different kinds of the thinking process (Golemi, 2017).

In order to improve students' skill in dealing with daily life problems, it is necessary to promote students' higher order thinking skills such as analytical thinking. The enhancement of students' analytical thinking skill could be enhancing since students enrolled in the school. Since chemistry has an abstract concept and has inter-related concepts on its nature, it is needed to exercise students' analytical thinking skill. The systemic learning approach that utilizing a cyclic diagram on its teaching-learning instruction and even in solving a chemistry problem could be used to promote students' analytical thinking skill in chemistry. Due to the systemic approach use a cyclic diagram, thus it will depict the chemistry's inter-related concept clearer. It will provide one concept to another in chemistry could be easily understood that bring a meaningful learning for students will be experienced. The research questions guided this study as follows:

- Is there any significant difference of students' analytical thinking skill before and after experiencing chemistry systemic learning approach?
- How was the profile of students' analytical thinking skills after perceiving chemistry systemic learning approach?

2. Methods

2.1 Research Design

The research conducted on the second semester of eleventh grader on acid-base topic of chemistry. The independent variable in this research was the implementation of Chemistry Systemic Learning Approach (CSLA). Meanwhile, the dependent variable that measured in

this research was the Students' Analytical Thinking Skills (SATS). A pre-experimental with one group pre-test and post-test design was adopted in this research. Hence, a Systemic Test on Analytical Thinking (STAT) was administrated before and after the CSLA implementation.

2.2 Research Samples

There was a group of students (N=54) applied the CSLA. These group of students came from the two classes of a public senior high school which were cluster randomly selected from the population. The population of this study were all of the students of public senior high school in Kulon Progo regency, Yogyakarta, Indonesia. Cluster random sampling was used to establish the group of students as the research sample. The cluster random sampling in this study was initiate by the analysis of students' characteristics and followed by the analysis of summative test data. The analysis of summative test aims to analyse the prior students' cognitive skills. After that, the samples were established by seeking the students' characteristics and summative test data analysis results. If there was no difference in all of the classes on the school used, thus the cluster random sampling conduct immediately. However, if there was found difference of the classes on the school used, the difference class should be discarded. Therefore, the cluster random sampling conducted with the remaining classes. According to the results of the students' characteristics and summative test data showed there were no difference. Hence, two classes from a total of five classes of the school were cluster randomly selected as the research samples.

2.3 Research Instrument

The SATS was measured before and after the implementation of CSLA. The data of SATS was collected by STAT which was constructed by the researcher. The STAT consisting of two open-ended questions on acid base concept. The construction of STAT was followed the CSLA and analytical thinking frameworks. The CSLA framework consisting the cyclic diagrams which shows the interrelationships among the concepts/ issues (Fahmy & Lagowski, 1999, 2011; Fahmy & Said, 2011; Fahmy, 2017). Meanwhile the analytical framework following Anderson and Krathwohl (2001); Mayer (2002); Ramirez and Ganaden (2008); and Areesophonpichet (2013) consisting of differentiating, organizing, and attributing indicators.

Prior to used, the validity and reliability of STAT were carried out. The validity of the STAT was conducted by two steps, the theoretical and empirical validity. The face and content validity as the parts of theoretical validity was conducted by asking the judgment of

the experts from chemistry education department. The experts were reviewed the STAT on each items according to some criteria; the suitability of the indicators of the problems to be achieved, the correctness of the acid-base concept, and the legibility on each item of the STAT. The comments of the experts were collected and necessary revision were made. As a result, the STAT instrument was ready for the empirical validation.

The empirical validation was conducted by a paper and pencil administration. A total of 82 students who had recently completed the acid-base course were participated as the subject of the empirical validation. The result of the paper and pencil administration on STAT were analysed. The final version of the STAT reached after the result on the paper and pencil test was analysed. In addition, the value of estimation reliability of the STAT was obtained with the Cronbach's Alpha value of 0.790. According to George and Mallery (2003) there were several category of reliability value consisting the excellent category if the reliability value > 0.90 ; good if > 0.80 ; acceptable if > 0.70 ; questionable if > 0.60 ; poor if > 0.50 ; and unacceptable if < 0.05 . Therefore, the STAT instrument in this research has acceptable category. Thus, the STAT instrument considered as the good instrument to collect the data of SATS.

2.4 Research Setting

The implementation of CSLA was fulfilled in 14 meetings. A number of 12 meetings concerned in lecture activities while the other 2 meetings were designed in laboratory activities. The chemistry learning material in this study was about acid-base concept. Before the CSLA implemented, a paper and pencil pre-test in the form of STAT in acid-base concept was administered to the samples. Due to the STAT that covered cyclic diagram and shows the inter-related concepts about acid-base in chemistry are unrecognized by the students. Majority of the students just answer the questions provided in STAT without paying attention toward the present and the function of cyclic diagrams.

In the next meeting, the teacher was introduced the CSLA to the students by giving a cyclic diagram about acid-base concept and giving directions to the students to understand the relationship of the concepts. The students' response toward the CSLA was not satisfied. They are not ready with the present of cyclic diagrams, because it was a new teaching environment they experienced. There are only a few students were asked about the function and the relationship of the concepts in cyclic diagram. In contrast, majority students were proposed that the chemistry concept they have been learned were not related with the other chemistry

concepts. They feel that the acid-base concepts were faster to learn when it was described by the teachers and without understanding the inter-related concepts. It means that the teaching-learning instruction paradigm still teacher-centred and need several times to change it into students centred that brings meaningful learning environment.

The teaching-learning instruction using CSLA were focused on students' centred learning with the discussion, laboratory work, demonstration, exercise, and also questions and answers methods. In the next five meetings, the students were given a chance to conduct a group discussion to understand a cyclic diagram in teaching-learning instruction. The passive students, step by step shows their active participation in CSLA. They tend to give argumentation and questions concerned on the cyclic diagrams. The students criticize the relationship among the concepts in the cyclic diagrams when they are trying to solve several problems in the students' worksheet.

Students' active response was showed in the 8th meeting, which was the experiment about the determination value of pH using several indicators. The students were discussing about the results of the laboratory work in a group and also describing the cyclic diagram provided. Each groups of student were giving an explanation with the prior knowledge they have. Slowly but surely, the students that in the beginning was proposed that the concepts of chemistry they have learned is not useful for the next concepts, they start to understand that it is necessary to know the relationship of the chemistry concepts after following CSLA.

Moreover, in the next four meetings, the teacher asked the students to arrange a cyclic diagram by their selves that shows the inter-relationship among the acid-base concepts. The students in arranging the cyclic diagrams were works in a group. The students were used to understand the relationship among the chemistry concepts in a cyclic diagrams form especially in acid-base concepts. They can easily explain the concepts relationship in their cyclic diagrams they arrange.

In the 13th meeting, the students actively involved in laboratory activity about acid-base titration. The students work in a group to discuss the results of the experiments and describe the cyclic diagrams. Each group giving a clear answers and shows a good skill in arranging a cyclic diagram.

Finally, in the last meeting, a post-test with a paper and pencil form of STAT in acid-base concept was administered to the samples. The results of the post-test will be compared with the results of pre-test in the beginning of the study.

2.5 Data Analysis

The paired samples t-test was used to determine the effects of CSLA on SATS. It explores the difference of SATS before and after CSLA has been implemented. Moreover, the profile of SATS data were further explored through normalized-gain formula (n-gain) in order to examine the SATS improvement after the implementation of CSLA and followed by categorising the n-gain of SATS as high ($n\text{-gain} > 0.7$), medium ($0.7 \geq n\text{-gain} \geq 0.3$) and low ($n\text{-gain} < 0.3$) following Hake (1998).

3. Results and Discussion

The measurement of SATS were conducted before and after the implementation of CSLA. The study concerned on the analysis of the SATS' profile in CSLA. The indicators of analytical thinking skill include cognitive process of differentiating, organizing, and attributing (Anderson & Krathwohl, 2001; Mayer, 2002; Ramirez & Ganaden, 2008). The differentiating is a process to distinguish the relevant from the irrelevant information presents. The organizing is a process to determine how an element suits its function within a structure. While the attributing is a process to determine a point of view, value, or intent of material presents. These kind of analytical thinking brings the students are able to differentiate between facts and opinions, similarities and differences, also causes and effects. After that, the students also have to compare and analyse the consistent and contrary or irrational information given. Finally, the students have to identify the key matters by summarize that relevant information into one concept. Therefore, a learning which promote analytical thinking skill is a learning to determine the relevant or important parts of information, the ways in which the parts of an information are configured, and the underlying the purpose of those information.

Table 1. Descriptive statistics of SATS

Aspect	Pre-test				Post-test			
	SAT S	Differentiating	Organizing	Attributing	SAT S	Differentiating	Organizing	Attributing
Number of Samples	54	54	54	54	54	54	54	54
Ideal Score	100	26,67	40,00	33,33	100	26,67	40,00	33,33
Mean	19,63	11,51	5,71	2,41	75,68	26,30	34,26	15,12
Std. Dev.	13,52	7,27	4,83	4,27	8,77	1,54	5,35	5,05

The descriptive statistics of SATS before (pre-test) and after (post-test) the implementation of CSLA seen in Table 1. It seen in Table 1 that the SATS were increasing with the specific aspects of analytical thinking skill consisting differentiating, organizing, and attributing were also improving. The data of SATS that were collected in this study, then analysed according to paired samples t-test technique. The results of this analysis was shown in Table 2.

Table 2. The results of Paired Samples T-test of SATS

Aspect	Paired Samples T-test	Conclusion*)
SATS	0,000	Significant difference
Differentiating	0,000	Significant difference
Organizing	0,000	Significant difference
Attributing	0,000	Significant difference

*) Computed using alpha of 0.05

According to Table 2, it shows that there were significant differences of overall SATS and each aspects of SATS among before and after the implementation of CSLA. The enhancement of SATS in this study was due to the effects of CSLA that contains cyclic diagrams which presents the inter-related concepts of chemistry. The results of Areesophonpichet (2013) shows that teaching-learning instruction with the concept maps lead the student to develop their thinking into analytical thinking with a higher level. The concept maps help to prevent the presence of misconception that might be found in the students' thinking. The role of concept maps was necessary in order to depict the desire concept relationship by the teacher that brings the students easily to understand those concepts.

The concept maps used in the CSLA was in the form of cyclic diagrams. This cyclic diagrams lead the students easier in understanding the chemistry inter-related concepts and it was the key element in the teaching-learning as the representation to teach chemistry globally (Fahmy & Lagowski, 2011). The cyclic diagrams emphasizing on the inter-relations among new concept with those previously acquired, hence it provides more information to the students compared the concept maps only (Hrin, Milenković, Segedinac, & Horvat, 2016). The prior concepts they have was needed in order to understand meaningfully the new concepts they will get. The meaningful learning, they experience brings a significant contributor to the students in solving a chemistry problem they faced. The CSLA was useful to promote meaningful learning in chemistry as proposed by Hrin, Milenković, and Segedinac (2015).

A research conducted by Suyanta, Marfuatun, and Widjajanti (2013) confirmed that the systemic learning approach can enhance a comprehensive thinking of students. Moreover,

Marfuatun, Fillaeli, and Yuanita (2014) that deal with the application of systemic learning approach with contextual learning that improve students' science process skills and concept understanding in chemistry. The results of this study also proven by the previous study conducted by Díaz-Vázquez (2012) that constructing the concepts relationship with the prior concepts brings the students to promote their analytical thinking skills. Rutledge (2006) also confirmed that the analytical thinking skills was necessary to the students when they are dealing to solve a problem in all fields, includes chemistry.

The students' needs to analyse a chemistry problem by three comprehensive aspects of analytical thinking, namely differentiating, organizing, and contributing that related to desire solution they proposed. In this study, these three aspects of analytical thinking were analysed according to n-gain analysis in order to determine the effects of CSLA toward SATS. The results of the n-gain category analysis on SATS were presented in Table 3.

Table 3. The results of n-gain category analysis on SATS

Aspect	Mean score (Before)	Mean score (After)	n-gain	Category n-gain
SATS	19,63	75,68	0,72	High
Differentiating	11,51	26,30	0,98	High
Organizing	5,71	34,26	0,82	High
Attributing	2,41	15,12	0,38	Medium

It can be concluded according to Table 3 that the n-gain category analysis of overall SATS, with the aspect of differentiating and organizing found to be high, while the aspect of attributing found to be medium category. The differentiating aspect cover analysing the importance information. In this case, the students should have the skills to classify the significant elements and necessary information that related and required to solve the problem (Art-In & Sitthipon, 2012; Areesophonpichet, 2013). Students are able not only to differentiate the facts and opinions, but also choose the information needed to deal with the problem. In this study, the students analyse the key elements on the STAT by classifying the necessary information with the help of the concepts on cyclic diagrams provided. The cyclic diagrams on CSLA was covered the multiple components that connected each other with mutual relationship (Priyambodo & Marfuatun, 2016). The presence of cyclic diagrams brings the students easily to perform differentiating aspect of analytical thinking skills. Thus, it makes the differentiating aspect of analytical thinking skills improving.

The organizing aspect of analytical thinking skills was concerned on analysing for finding and relate that information. The students were tried to analyse and relate the chemistry

concepts and its reasons (Art-In & Sitthipon, 2012; Areesophonpichet, 2013). They need to compare and analyse the consistent and contrary or irrational information given in the problems. In this study, the cyclic diagrams that shows the inter-related concepts among the prior concepts and the new concepts makes the students seems better in organizing the important information they need. The students also have a good ability in relating those concepts by giving a clear reason. Hence, it makes the students' of organizing aspect of analytical thinking skill in this study shows a good enhancement.

The last on the aspect of attributing of analytical thinking skills are focused on analysing the principle of information they have been analysed (Art-In & Sitthipon, 2012). This skill concerned with the skills to search for principles about the relationships among the elements of information (Areesophonpichet, 2013). Students have to identify the key matters of the problems by summarizing that necessary information into the main concept they need to solve a problem. The concluding remarks into one concept was found to be difficult to the students since it need several times of exercise. Therefore, the results of this study that shows the improvement of attributing aspect found in the medium category was due to the lack of students' exercise in solving a problem. It need a longitudinal study to maintain and improve this type of higher order thinking skills (Hrin, Milenković, & Segedinac, 2017). Future studies should be conducted with the presence of systemic learning materials in chemistry with the blended learning mode. The blended learning mode is proven to be effective to promote students' learning outcomes (Wiyarsi, Fitriyana, & Ikhsan, 2019; Fitriyana, Wiyarsi, & Sugiyarto, 2018; Fitriyana, Wiyarsi, Ikhsan, & Sugiyarto, 2018). The teaching materials in this blended learning mode can be designed according to systemic approach with website application as proposed by Marfuatun and Hardiningtyas (2018). Hence, the online phase of blended learning gives the students a chance to studying CSLA in an effective way.

4. Conclusion

The results of this study indicates that there was significant effect of systemic learning approach on students' analytical thinking skills. The profile of students' analytical thinking skills shows a satisfied improvement after the implementation of chemistry systemic learning approach. Overall, a high n-gain category was reached that indicates the enhancement of students' understanding of the inter-related concept in chemistry. This study gives a significant contribution on the use of systemic learning approach to enhance students'

analytical thinking skills. Therefore, the systemic learning approach should be widely used on chemistry learning to promote students' higher order thinking skills.

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