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Implementing Metacognitive based Guided Inquiry on Chemistry to Increase Student's Critical Thinking Skills

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Abstract--- *Critical thinking skills (CTS) are indispensable skills for dealing with the industrial revolution 4.0 era. Unfortunately, learning methods implemented by teacher in schools have not specifically focused on the development of these skills. This study aims to determine the effect of metacognitive based Guided Inquiry (GI) learning toward students' CTS and achievement on chemistry. The study applied pre-test post-test control group design method. The sample consists of 66 11th grade students of Madrasah Aliyah Negeri 1 (MAN 1) Banjarmasin, Indonesia. The data were collected using achievement test, critical thinking test, and attitude observation sheets. Then, the data was analyzed by using percentage and t-test. The results showed that; (1) through metacognitive-based GI learning, students' CTS in the experimental class develop better than in control class. The percentage of students who have the highest level of critical thinking in the experimental class is greater than those in the control class. (2) In the experimental class, all affective indicators measured namely: curiosity, cooperation, and responsibility achieved very good category. Meanwhile, in the control class, the cooperation indicator is the only indicator that is on good category. (3) The level of students' learning success in cognitive, affective, and psychomotor in the experimental class is higher than in the control class. It implies that integrating metacognitive into the stages of learning activities should be the solution of CTS development.*

Keywords--- *Critical Thinking Skill Guided Inquiry, Metacognitive.*

I. BACKGROUND

The world is currently at the time of the industrial revolution 4.0, where in order to be successful everyone must have special skills, one of which is Critical Thinking Skills [1]. Critical Thinking Skill is a thinking process that requires a person to be able to understand something in more depth, can convey a variety of questions, and can find a variety of accurate and relevant information [2].

Ironically, according to Zivkovic [3] the teaching and learning process in its practice does not encourage the achievement of critical thinking. The low critical thinking skills is due to the emphasis on understanding the concepts, and the learning is not oriented towards empowering higher order thinking skills [4]. Learning Chemistry itself still does not help students develop higher-order thinking skills. Chemistry learning in schools is still largely done through activities such as teachers conveying information and students memorizing formulas and concepts, as well as doing exercises that require mathematical calculations [5,6]. Most of the evaluation questions given to assess

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student learning success still focus on the ability to solve difficult math problems and require memorizing algorithm formulas and calculating skills. However, according to Tolebo and Dubas [5], in developing higher-order thinking skills of students, the most important thing is not how difficult the problem is given. However, it is how much the thought process involved when a person solves a problem on the question. Through learning activities that empower students' thinking abilities, in addition to helping students to be able to find concepts independently, they can also develop critical thinking skills.

Besides critical thinking, another skill that students need to have to facilitate them in understanding and managing their learning process independently is metacognitive skill. Metacognitive skill can help students manage their learning process independently then be able to think critically so that they can determine the right decision in overcoming various problems in learning [7]. The Malaysian Curriculum development center revealed that metacognitive skill would be better if it is integrated in other learning models. In other word, it is not specifically taught. One learning model that can be integrated with metacognitive is the Guided Inquiry (GI) model. It is because according to Nasikhah [8] the syntax of the GI learning model reflects the metacognitive aspects of planning, monitoring and evaluation.

The application of GI learning model is expected to make students freely develop learning concepts that are learned. They do not just record and memorize the material. Through the application of metacognitive skill, they get an opportunity to be able to solve a problem by doing it in groups and exchanging information [9]. The integration of the metacognitive-based GI learning model makes both effective when it is combined. Based on previous studies reported by Nasikhah [8] and Rachmawati [10], the results show that the application of metacognitive with Guided Inquiry model in Physics and Biology subjects can improve students' critical thinking abilities in the medium category. Therefore, based on this background, this study aims to examine the effectiveness of the metacognitive-based Guided Inquiry learning model on Colloidal Chemistry in terms of its effect on increasing critical thinking skills and student learning outcomes in cognitive, affective, and psychomotor aspects.

II. METHOD

The study employed a quasi-experimental method with a pre-test post test control group research design. This study was carried out in the eleventh grade of Madrasah Aliyah Negeri 1 Banjarmasin. It involved 66 students, each consisting of 32 high school students in the experimental class and 34 control class students. The experimental class students was taught by using the GI model based on metacognitive while the control class was taught by using the cooperative model that is commonly applied at the school. The selection of the research sample was based on the characteristics of the school that is in accordance with Guided Inquiry learning.

The Guided Inquiry learning in the experimental class was done with the steps of Orientation, Formulate Problems, Formulate hypotheses, Collect data, Test hypotheses, and Conclude. Metacognitive activities were carried out at the planning, monitoring and evaluation stages through fill in the daily metacognitive sheet activity containing the problem solving plan, questions about what concepts need to be learned to solve the problem, reviewing the steps of problem solving that have been done, the need to repeat the work if something is felt wrong, reviewing what has been learned, what is not yet understood, obstacles experienced, and what efforts will be made to overcome

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them. Meanwhile, the learning in the control class was done through the following steps such as Orientation, Presentation/ Demonstration, Guided Exercise, Checking understanding and giving feedback, as well as independent training.

The learning itself was carried out on the subject of Colloidal Chemistry. Data was collected by using test techniques, namely in the form of tests of critical thinking skills and cognitive learning outcome test, and non-test techniques using attitudes and skills observation sheets. The data were analyzed by using descriptive analysis techniques and independent sample t-test statistical analysis.

III. RESULTS AND DISCUSSION

3.1 Analysis of Critical Thinking Skills (CTS) Improvement

The findings of critical thinking skills on the six indicators measured [1] can be seen in Figure 1.

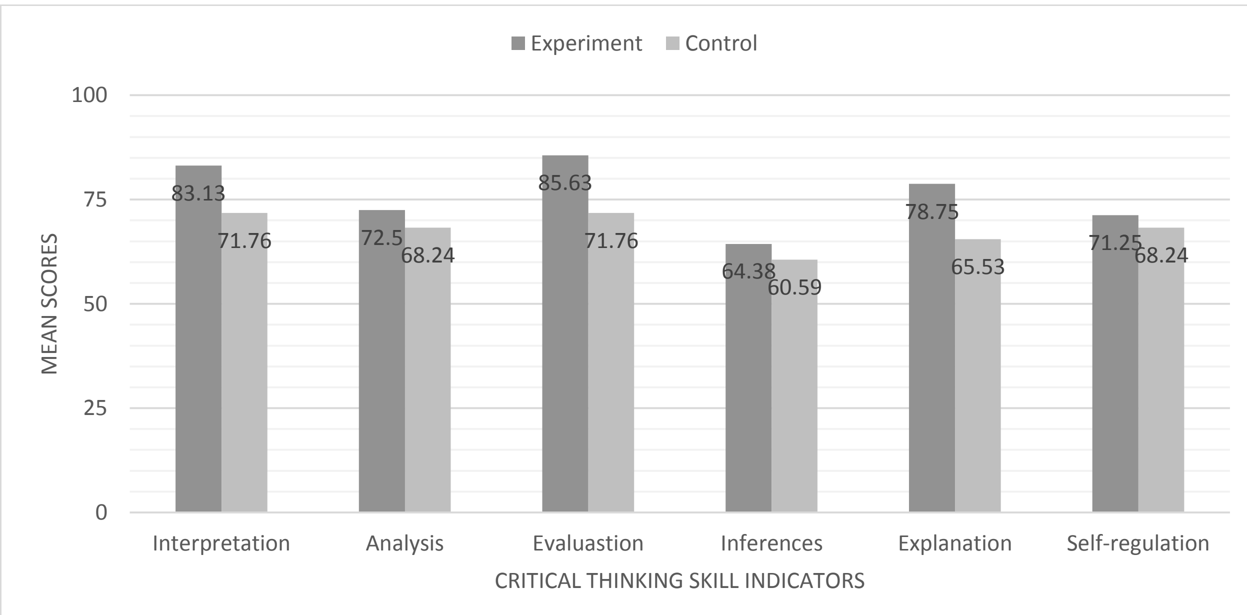

Figure 1: Average Level of Each Indicator Achievement

Figure 1 shows that critical thinking skills in the class that was learning with the metacognitive-based GI model reached higher level of development than the control class. The evaluation and interpretation indicators developed best compared to the other four indicators. Referring to the qualifications of critical thinking skills according to Sudjana [12], after learning 40.62% of the experimental class students reached the very critical category, and only 8.82% of the control class students reached this category.

This result is also supported by the results of the t-test on the average score of critical thinking skills and N-Gain of both classes as in Table 1.

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Table 1: T-Test Result of the Critical Thinking Skills

Result	**Class**	**dB**	**Average**	**SD^2**	**t_{count}**	**t_{table} ($\alpha = 0{,}05$)**	**Conclusion**
Pre-test	Experimental	31	16,25	65,78	1,29	2,00	There is not any difference
	Control	33	13,24	109,42			
Post-test	Experimental	31	75,94	124,54	3,42	2,00	There is difference
	Control	33	67,35	75,95			

From the calculation of N-gain, it is known that the average N-gain of the experimental class is 0.71 (high), while the average N-gain of the control class is 0.62 (moderate). From the difference in the value of N-gain it can be said that the implementation of different learning models in the two classes seems to produce significant critical thinking skills (CTS) differences in the two classes. The increase in CTS shows that the metacognitive-based GI model gives a better effect on CTS than the conventional cooperative learning model used by teachers. This is relevant to research conducted by Duran & Dokme ([13] which reveals that learning using Guided Inquiry has a significant influence in increasing students' critical thinking. As according to Lalang, Ibnu, & Sutrisno [7], Guided Inquiry combined with metacognitive is more effective in increasing critical thinking skills compared to students in the class who learn by applying conventional models.

This is due to the learning using GI metacognitive-based model in the experimental class guide students to find concepts independently. The metacognitive ability was integrated in learning through questions that were given directly by the teacher and guiding questions in the worksheet that has been adapted to the components in the GI model. While working on the worksheet, students were given a metacognitive daily sheet with three aspects, namely planning, monitoring and evaluation that were adjusted to the stages through which the students passed. The questions given at the planning stage include:

What do I have to do first to answer the questions in this worksheet?

Is this material related to the previous learning?

What knowledge do I need to answer the questions in this worksheet?

The first aspect is that planning was together with the GI stages. It was from the orientation phase, formulating problems to writing hypotheses. At this stage, the students were given the opportunity to observe and understand the text presented in students' worksheet in groups, then formulate problems based on the text. The second aspect is monitoring. It was together with the stages of testing hypotheses in the GI model. The final aspect is that the evaluation was carried out together with the drawing conclusion stage on GI.

The use of metacognitive learning with this discovery seems to make students easier when passing each stage of GI, starting from the orientation stage, formulating problems, formulating hypotheses, collecting data, testing hypotheses or analyzing data, concluding lessons using questions contained in every aspect or metacognitive stages.

Of the six CTS indicators, the ability of interpretation and evaluation are two indicators of critical thinking skills that experienced the highest development in the experimental class. The development of interpretation indicators in the experimental class was influenced by the activities of students practicing formulating problems in students' worksheet based on the text given previously. The text itselt presented daily events that were close to students' lives and could cause curiosity. The following is one of the examples.

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> *"When the lights go out, a child uses a flashlight to illuminate the room. When the flashlight light on a glass of milk and tea water which is located next to each other, it can be seen that the flashlight cannot penetrate the glass of milk, but in the glass of tea water the flashlight can penetrate the glass. Make a statement of the problem of this situation."*

Through the practice of understanding the context and formulating problems based on these simple contexts, students become accustomed to applying their interpretation skills. The ability of interpretation is then applied in all GI steps such as analysis, inference, and conclusion.

The second indicator of critical thinking skills that developed best is evaluation. At one of the stages of GI-based metacognitive learning, the students were asked to analyze data in groups. The analysis phase began by examining the data, identifying opinions, and supporting reasons. The activity of analyzing data could be done by building and using ideas by the students themselves, then comparing the experimental data obtained with the theory. At this stage, they must provide opinions with supporting explanations by citing evidence that points to whether the group accepts or rejects the idea of solving the problem.

The activity was carried out through group discussions in order to determine the opinion that is considered the most appropriate by considering evaluating various data obtained, determining the credibility of an information source and assessing the quality of various opinions that have been submitted by considering the logical advantages of the argument based on the location of the hypothesis and relevancy [14]. Arfianawati, Sudarmin, and Sumarni [15] explained that discussion is one of the effective ways in training and developing critical thinking skills. Through this activity, students' evaluation skills become more developed.

3.2 Analysis of Student Learning Outcomes

Research data on student learning outcomes in Colloidal Chemistry material can be seen in Table 2.

Table 2: Student Learning Outcomes on Colloid Material

No	Learning Outcome Indicator on Knowledge Aspect	Score			
		Experimental Class		Control Class	
		Pre-test	*Post-test*	*Pre-test*	*Post-test*
1	Determine the solution, colloid, and suspension based on observation data	62,50	100.00	58,82	70.59
2	Classify colloid types based on dispersion phase and dispersed phase	78,13	93.75	64,71	82.35
3	Analyze the solution, colloid and suspension	43,75	81.25	41,18	79.41
4	Analyze colloid types based on the dispersing and the dispersed phase	56,25	87.50	41,18	50.00
5	Describe the properties of colloid	34,38	81.25	26,47	88.24
6	Connects the colloidal system with its properties	31,25	84.38	11,76	52.94
7	Differentiate lyophobic colloid and hydrophobic colloid	59,38	75.00	35,29	73.53
8	Analyze the nature of colloid in daily life	25,00	90.63	20,59	70.59
	Mean	48,83	86,61	37,50	70,95

Table 2 shows that the mean understanding of students of the experimental class on all indicators of the Colloidal Chemistry concept was higher than the control group. The best understanding of students in the experimental class is found in indicators determining the solution, colloid and suspension based on observation data (100%), classifying colloid types based on the dispersion phase and dispersed phase (93.75%) and analyzing the nature of colloid in daily life (90.63%). This results corresponds to the increase in critical thinking skills that occur in aspects of analysis and evaluation. The exercise conducted in the Guided Inquiry learning stages and filling in the

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metacognitive sheet asking students to plan well how to solve problems and review the steps that have been done, is one of the causes of the high learning outcomes in this indicator.

From these findings it can be concluded that an increase in critical thinking skills can contribute to improving students' understanding of concepts. This finding is similar to the results of the study of Taghva, et al [16]; Abbasi & Izadpanah [17] which state that there is a correlation between critical thinking skills and student achievement. That is why Karbalaei [18] suggests the need for learning that can encourage the development of critical thinking knowledge and skills to improve student learning success while encouraging the development of other competencies needed in the world of work.

Furthermore, the mean learning outcomes of the two groups of students were tested using the t-test with the results as in Table 3.

Table 3: T-test Result of Learning Outcome

Result	**Class**	**dB**	**Average**	**SD^2**	**t_{count}**	**t_{table} (α = 0,05)**	**Conclusion**
Pre-test	Experimental	31	41,88	235,08	1,79	2,00	There is not any difference
	Control	33	34,41	322,37			
Post-test	Experimental	31	82,19	198,29	2,92	2,00	There is difference
	Control	33	71,18	259,18			

From Table 3, it was found that there were significant differences in learning outcomes between the experimental class and the control class. N-gain data in both classes shows that the GI metacognitive-based model gives a higher increase (N-gain = 0.69) than conventional model (N-gain = 0.55). In the class with a metacognitive-based GI model, during learning the metacognition ability (monitoring) that is done helps students understand the concepts or examples of colloidal system material. In the North Central regional educational laboratory [19], it is stated that through monitoring activities, students will look for or find information and then record the important things they get. Students can monitor the success they have achieved and control their own cognitive activities by monitoring their own time and learning strategies.

The findings of this study are relevant to studies conducted by Graham et. Al. [20] and Adadan [21] which state that the implementation of metacognitive learning has contributed to the improvement of student learning achievement. The differences are that in study implemented by Graham et al. [20] treatment is not carried out to train metacognition awareness, while in research conducted by Adadan [21] metacognition students are trained using direct instruction. As for this this study, students' metacognition is trained through planning, monitoring and evaluation steps by filling the daily metacognitive sheet activity. Students' activities in this study were more varied than in the previous studies.

3.3 Analysis of Student Skills Observation Results

There are six aspects of psychomotor skills observed, namely (1) folding filter paper, (2) filtering solution, (3) using a measuring cup, (4) directing light to the solution, (5) using a dropper pipette, (6) designing and using a tool in making colloids. The average observations of students' psychomotor skills can be seen in Figure 2.

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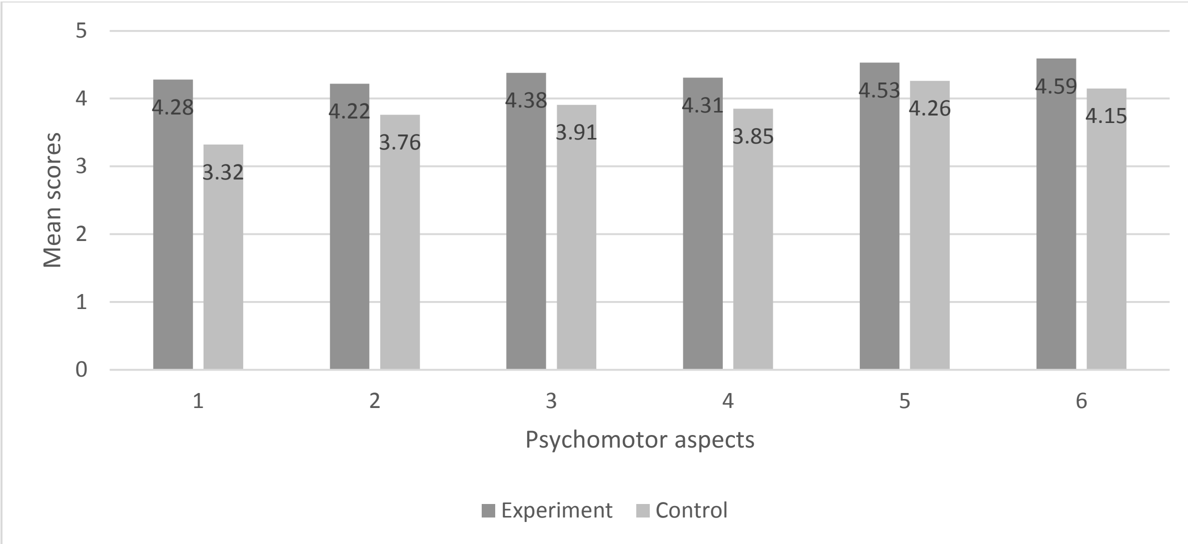

Figure 2: Average Psychomotor Skills of Students after Learning

Figure 2 shows that the experimental class had a higher psychomotor skill score in each aspect of the observations. In metacognitive-based GI learning, students are not only asked to plan, monitor and evaluate what has been done when solving problems or answering questions, but also when doing practical work. That's why practicum activities become more controlled and students become more careful in doing practicum activities. This is consistent with the results of research by Wulansari, Iskandar, & Suryadharma [22] that learning that implements Guided Inquiry models with the application of metacognitive gives a good influence on student learning outcomes, especially in the aspect of skills. In the experimental class, the students are accustomed to filling in the metacogitive daily sheet containing planning, where students in the experimental class are guided to prepare their initial knowledge by planning so that the time given to carry out the practicum can be more efficient.

3.4 Attitude Observation Results

Comparison of the results of attitude observation in the two classes is shown in Figure 3.

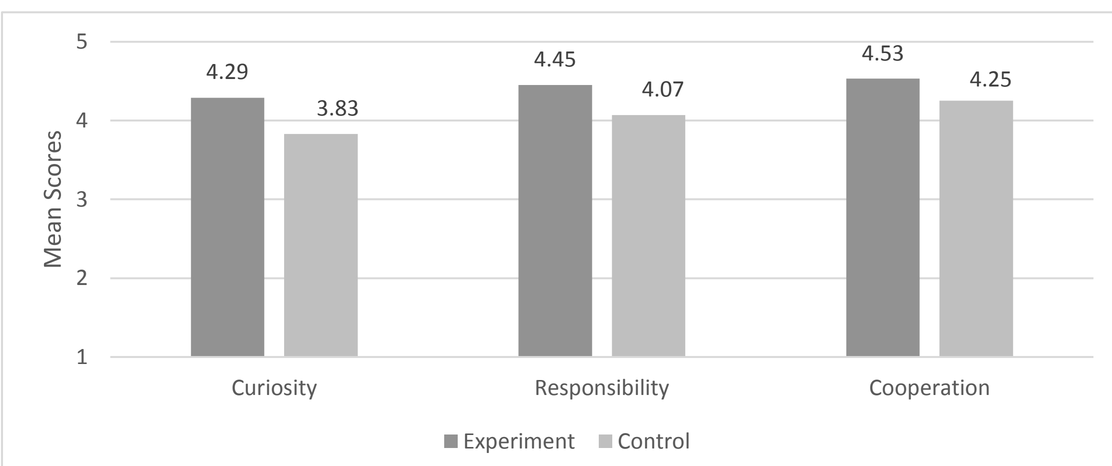

Figure 3: Average Results of Attitude Observation

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Figure 3 shows that the experimental class got a higher average score in every aspect of the attitude observation results than the control class. If it is qualified according to Widoyoko's reference [23], the average value of the three aspects of attitude in the experimental class is very high. Meanwhile, in the control class that is classified as very high only in the aspect of cooperation.

In terms of attitude formation, the application of metacognitive helps students develop self-concepts and self-regulation, so that students' curiosity, responsibility, and cooperation increase. Meanwhile, in the control class that did not apply metacognitive, what develops only cooperation as the impact of the application of cooperative learning. This finding is in line with the previous study by Noghabaee [24] and Nageswara Rao [25] that the application of metacognitive strategies has an impact on the formation of students' self-concept, self-esteem, and self-efficacy. Improved self-concept is what makes students' attitudes more positive than before. This is in accordance with what was found by Namira, Kusumo, & Prasetya [26] that the increase in students' attitudes is directly proportional to the increase in student activity because the application of metacognitive strategies during learning has good affective learning outcomes.

IV. CONCLUSION

Based on the results of this study, it can be concluded that the implementation of metacognitive based Guided Inquiry model on Colloidal Chemistry learning has proven to be effective in increasing students' critical thinking skills, especially in the indicators of interpretation and evaluation. The application of Guided Inquiry learning based on metacognitive also has a positive effect on students' understanding of Chemistry concepts, the formation of positive attitudes on aspects of curiosity, responsibility, and cooperation, and students' psychomotor skills. From the results of the study and the data analysis, it is evident that the integration of metacognitive into the GI learning model by filling in the metacognitive daily sheet everytime the students will start and finish doing the learning stages contributes quite significantly in helping to improve students' thinking skills and learning outcomes in cognitive, affective, and psychomotor aspects. The results of this study can be a reference to the importance of integrating metacognitive into the stages of learning activities. Further research needs to be done that integrate metacognitive into other learning models with different activities that are more interesting and challenge students to develop their thinking skills.

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