Guided inquiry assisted by metacognitive questions to improve metacognitive skills and students conceptual understanding of chemistry

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Abstract. Metacognition is an aspect to build students' understanding of chemistry. A preliminary study conducted at SMAN 4 Banjarmasin showed that students' metacognitive skills in the learning process is still low. The Guided Inquiry Assisted by Metacognitive Questions (GIAMQ) is an alternative to improve students' metacognition skills in the learning process. A research on the application of guided inquiry assisted by metacognitive questions on buffer solution learning material has been conducted to: (1) the implementation of teacher activity, (2) increased students activity, (3) enhancement of metacognitive skills and students conceptual understanding; (4) students response to learning. This study implemented an action research model, consisted of several stages: planning, action, observation, and reflection. The subjects of the research were students in class XI MIA 4 SMA Negeri 4 Banjarmasin with a total of 35 students. Research instruments in the form of test instruments and questionnaires. Data were analyzed using quantitative analysis techniques and qualitative analysis. The results showed that (1) teachers ability to implement GIAMQ were improved, from good enough to good category, (2) students activity during GIAMQ were improved, from active enough category to active, (3) students metacognitive skills were improved from began to developed category in cycle I to already well-developed category in cycle II, (4) conceptual understanding increased from 74.69% to 79.80%, (5) students response during in learning were categorized as good. Researchers concluded that implementation of GIAMQ can improve metacognition skills, conceptual understanding, activity, and students.

1. Introduction
Metacognition is one aspect of building students' understanding of chemistry. In fact, students have difficulty solving problems and understanding buffer chemistry [1,2]. The initial test data for metacognition abilities and conceptual understanding of class XI-MIA 4 SMA Negeri 4 Banjarmasin in 2018/2019 were very low. Students who understand the concept of buffer solution material are 33.33%. This is in line with the achievement of students' initial metacognition. Only 20.48% of students planned while learning, 8.57% of students monitored learning, and 2.86% of students had evaluated their learning. Because the learning process has not developed students' metacognition and conceptual understanding in problem-solving [3].

The method that can improve students' understanding of the concepts and metacognition skills of students is by applying a learning model that is in accordance with the 2013 Curriculum, namely the guided inquiry learning model. Inquiry-based learning [4] has been proven to be effective in
addressing student misconceptions. The guided inquiry learning model places students as learning subjects, wherein this model students play a role in finding and finding the essence of the subject matter itself and the answer to a question in question [5]. The application of the guided inquiry learning model assisted by metacognitive questioning is inspired by Teaching Science as Inquiry (TSI) [6-7]. TSI encompasses cycles of both learning and instruction. These cycles are reflected in phases, which represent different aspects of the inquiry process. The five phases of the TSI model are initiation, invention, investigation, interpretation, and instruction.

Seraphin, & Baumgartner [6] said the pedagogical framework of TSI, which is centered on learning through the authentic application of knowledge and skills, in which students learn science by doing science as authentically as possible. We have found that metacognition plays a key role in learning science through inquiry. Inquiry-based learning and problem-based learning has also been associated with increased self-regulation [8-10], and student metacognition [11-15]. The TSI framework balances content, context, inquiry, and pedagogy, and creates classroom settings that promote self-regulation and deliberate learning for effective learners. Students can actively integrate new information with their own awareness of how they make sense of this information; they are motivated to learn: and, most importantly, they understand that knowledge of a topic is constantly evolving and that mastery requires time, great effort, and persistence [16]. Self-regulated, intentional learners are in charge of, and responsible for, much of their learning, using elements of inquiry and metacognition to help guide their thinking.

The GIAMQ implementation by teachers requires scaffolding in the form of metacognitive questions to help students systematically solve problems [17] and create awareness of the problem and improve students' ability to solve them [2]. This study aims to the application of GIAMQ model on buffer solution learning material conduct to: (1) the implementation of teacher activity, (2) increased students activity, (3) enhancement of metacognitive skills and students' conceptual understanding; (4) students response to learning.

2. Method
The study was conducted by using the classroom action research design developed by Stephen Kemmis and Robin McTaggart. The experiment was conducted in two cycles and each cycle consisted of four phases: planning (plan), execution (act), observation (observe), reflection (reflect) [18]. Cycle I was held in 2 meetings and cycle II in 2 meetings, add 1 meeting for the cycle test. The action was given in the grade XI of MIPA 4 SMA Negeri 4 Banjarmasin in even semester with the number of research subjects as many as 35 people and on the material of Buffer Solution. The GIAMQ was carried out in five stages in Table 1. Learning activities in cycle 1 below.

| Syntax                    | Metacognitive Questioning                  | Conceptual Understanding Aspect |
|---------------------------|--------------------------------------------|---------------------------------|
| **Initiation.**           | Comprehension question (planning skills)   | Exemplifying                    |
| Formulate a well-formed,  | What is the problem about?                 |                                 |
| investigatable research    |                                             |                                 |
| question                   |                                             |                                 |
| **Invention**             | Connection and strategic question (planning| Explaining                      |
| Generate competing        | What is the data or hypothesis regarding    |                                 |
| alternative hypotheses    | the problem?                               |                                 |
| and predictions           | What strategy can be used in order to solve |                                 |
|                           | the problem?                               |                                 |
|                           | Why is this the appropriate strategy?       |                                 |
| **Investigation.**        | Monitoring question (monitoring skills)    | Applying,                      |
| Design and carry out      | How were those strategies implemented?      | Classification                  |
| experiments for data      |                                             | Interpreting,                   |
| collecting                | How were the strategies monitored?         | Explaining,                     |
|                           |                                             | Comparing                       |
| **Interpretation.**       |                                            |                                 |
| Analyze their data        |                                            |                                 |
Syntax  

Metacognitive Questioning  

Conceptual Understanding Aspect

*Instruction.* Conclude, evaluate, and reflection  

Reflection questions (terkait keterampilan evaluasi)  

Does the solution make sense?  

Is there another way to solve problem?

The test technique was done by using conceptual understanding and metacognition skill test instruments. The metacognition skill instrument used was in the form of problems and in the form of essays. The non-test technique was carried out by observing the implementation of the learning plan by the researcher’s colleague and the researcher’s field note, and metacognitive skill questionnaire with 20 statements adapted from Metacognitive Awareness Inventory (MAI) [19-20]. The test instrument validation referred to the Aiken’s V with 5 panelists.

The indicator of success in the implementation of the action was the students’ metacognitive skills in solving the problem at least 61 and cognition learning outcome at least 75 as the minimum score. The result of the metacognitive skill was determined by development category were shown in Table 2 below.

**Table 2** Development category of metacognitive skills [15]

| Criteria | Category       |
|----------|----------------|
| 0 – 20   | Undeveloped    |
| 21 – 40  | Still very risky |
| 41 – 60  | Starting to develop |
| 61 – 80  | Well-developed |
| 81 – 100 | Very well-developed |

The implementation of learning by the teacher at least in the good category and students in the active category refers to Table 3.

**Table 3** Category learning implementatian and student activity [15]

| Criteria | Category       | Criteria | Category       |
|----------|----------------|----------|----------------|
| Learning implementation | Category | Students’ activity | Category |
| 0 – 20   | very not good  | 0 – 20   | very not active |
| 21 – 40  | less good      | 21 – 40  | less active    |
| 41 – 60  | quite good     | 41 – 60  | quite active   |
| 61 – 80  | good           | 61 – 80  | active         |
| 81 – 100 | very good      | 81 – 100 | very active    |

Data of students’ conceptual understanding was analyzed by using the guidelines on Three-tier diagnostic test imposed on the pretest and posttest. Based on the analysis of the three-tier diagnostic test, the level of students’ understanding is divided into three categories i.e. misconceptions, lack of knowledge, and knowledge of the correct concept.

3. **Results and Discussion**

This research was conducted in two cycles with the aim to improve the implementation of learning and empowering educators in order to get optimal results [21]. Based on the data obtained through the learning process, an analysis is then carried out. The GIAMQ model was carried out in five stages, namely the initiation, invention, investigation, interpretation, and instruction stages. The implementation of the GIAMQ model has been applied by teachers in the classroom to experience an increase from cycle I to cycle II in learning. This increase can be seen in Table 4.
Table 4. Learning Implementation

| No | Rated aspect     | Cycle I | Cycle II |
|----|------------------|---------|----------|
|    |                  | P1      | P2       | P1      | P2       |
| 1  | Preliminary      | 3.33    | 3.65     | 3.78    | 4.39     |
| 2  | Core activities  |         |          |         |          |
|    | Initiation       | 3.00    | 3.00     | 3.00    | 4.33     |
|    | Invention        | 2.33    | 3.00     | 3.67    | 4.33     |
|    | Investigation    | 2.80    | 2.80     | 3.17    | 3.80     |
|    | Interpretation   | 3.00    | 3.00     | 3.00    | 4.00     |
|    | Instruction      | 3.00    | 3.00     | 3.67    | 4.33     |
| 3  | Closing Activity | 3.50    | 3.50     | 3.80    | 4.50     |
|    | The average observer's overall rating | 2.99 | 3.14 | 3.44 | 4.18 |
|    | Average percentage | 59.80% | 62.80% | 68.80% | 83.60% |
|    | Average percentage of cycle | 61.30% | 76.20% |
|    | Category         | Quite good | Good    |

Table 4 shows that the teacher's ability to imitate the GIAMQ model in the classroom has increased from cycle I to cycle II, because the teacher has made corrective actions in learning, efficient time, and actions such as being more assertive in responding to deviant student behavior and improvements to guide students. In formulating problems, formulating hypotheses, collecting data, testing hypotheses, concluding, and doing individual tests.

Learning activities in cycle I below(1) 

1. **Phase Initiation**: Formulate a well-structured and investigable research question whose pursuit will advance their understanding of the topic they want to know.

2. **Phase Invention**: Generates competing for alternative hypotheses and predictions about what might happen in relation to the question and why it might happen.

3. **Phase Investigation**: Design and carry out experiments using real-world simulations and computers to determine what really happened.

4. **Phase Interpretation**: Analyze their data to build an explicit conceptual model that includes scientific laws that will predict and explain what they find.

5. **Phase Instructions**: Teachers help students conclude, evaluate, and decide which inquiry techniques to use during their investigations through a process of self-regulation with metacognition, awareness, and control of their thought processes. The encompassing instruction phase can occur throughout the other phases, as a teacher prompts students to consider alternative conceptions or methods, as students communicate and share information with each other, or when students present their findings outside the classroom.

Students to learn how to generalize the inquiry and reflection processes so that they can apply them to new learning situations.

The activity of students is not separated from the influence of the teacher. The activities of students increase when learning is carried out by the teacher effectively and efficiently. This shows that the two of them influence each other and are related. The results of observations of student activity have increased in each cycle. The obstacles that students get in cycle I are: students are still not able to connect their previous knowledge and new knowledge. Students are still not active, so they need teacher guidance in organizing or building the knowledge they have acquired, and during discussions, the collaboration between students is needed. Students also still have difficulty understanding the questions contained in the worksheet. This is due to the application of this model for the first time and it seems that students are still not used to it so that the activities of students are still not optimal.

The increase occurred in cycle II. Learners are more active in carrying out every syntax in guided inquiry. Students can move smoothly through the stages as individuals, pairs, or groups, while the entire classroom community develops through the larger learning cycle, moving towards a clearer understanding of scientific concepts. Instructional GIAMQ model to enable students to achieve this expertise, we developed a constructivist approach that can be characterized as learning metacognitive knowledge and skills through a complex process of inquiry, reflection, and generalization. This approach is centered on the cycle of inquiry, which is used to guide student research. Curricular
activities are focused on enabling students to develop the skills necessary to carry out the steps in the cycle of inquiry as they conduct research, as well as to monitor and reflect on their progress. This is in line with the research of Ariani, Hamid, & Leny [22] that there was an increase in student activity from good criteria in cycle I to very good criteria in cycle II. The comparison of the results of the average total score per cycle can be seen in Figure 1.

![Figure 1 Students’ activity](image)

The activities of students in the teaching and learning process using the guided inquiry learning model assisted by metacognitive questioning in each cycle have increased in each syntax. This is due to the improvement of the teacher in teaching and providing other actions in each guided inquiry action which affects the activities of students so that it increases in cycle II.

### 3.1. Metacognitive skills

Metacognitive training needs to apply effective metacognitive instruction (eg, [23,24]). First of all, metacognitive instructions must be integrated in domain-specific instructions. Second, the application and usefulness of the metacognitive strategy instructed must be explained, otherwise, the student will not use it spontaneously. Finally, metacognitive instruction should include metacognitive questions about what, when, why and how students choose specific self-regulation strategies, approaches or responses to the learning process, and how to monitor and adapt their learning accordingly to achieve understanding (eg, [23]). Metacognitive questions encourage students to be actively involved in the self-regulation of their learning through the use of four types of questions: understanding, connection, strategy, and reflection.

The learning process in the first cycle by applying the guided inquiry learning model assisted by metacognitive questioning, the average value of the overall metacognitive skills test results of students in cycle I was in the category of starting to develop. Overall, the average metacognition skills test in the first cycle was 48.57, which is in the developing category. The unsuccessful learning in cycle I was due to the fact that the teacher was not evenly distributed in conducting effective scaffolding and modeling metacognition skills to students at the stages of the learning process.

Learning improvements were carried out in cycle II which had an impact on increasing the results of students’ metacognition skills. In cycle II, the teacher has been able to manage the best possible time in the learning process. Metacognition skills can be well-formed if they are practiced and trained continuously when answering metacognitive questions in the worksheet. Where in the learning process the teacher always provides direction to students and the application of guided inquiry learning models assisted by metacognitive questioning is of great importance for the improvement of students' metacognition skills. The complete details regarding the results of the metacognition skills test in cycle I and cycle II can be seen in Table 5.

| Indicators  | Metacognitive Questions | Percentage   |
|-------------|-------------------------|--------------|
|             | Baseline                | Cycle 1      | Cycle 2      |
| Planning    | a, b, c,d               | 20.48        | 65.71        | 75.27        |
| Monitoring  | e, f                    | 8.57         | 47.14        | 52.86        |
| Evaluating  | g, h                    | 2.86         | 32.86        | 61.43        |
| Average Total| 10.64                   | 48.57        | 63.18        |
| Category    | Undeveloped             | Starting to develop | Well-developed |
| n-gain      | -                       | 0.42         | 0.59         |

Table 5 Results of tests on students' metacognition skills
Remarks: (a) What is the problem about? (b) What are the data? (c) What strategy can be used in order to solve the problem? (d) Why is this the appropriate strategy? (e) How were those strategies implemented? (f) How were the strategies monitored? (g) Does the solution make sense? (h) Is there another way to solve the problem?

Based on Table 5, the overall average metacognition skills test for each planning, monitoring, and evaluation indicator has increased from cycle I to cycle II. Planning indicators percentage of students are included in the well-developed category. Planning skills can be well-formed if they are practiced and trained continuously when answering metacognitive questions in the worksheet. Students become accustomed to answering metacognition questions, besides that in the learning process, the teacher always provides direction to students. Developmental improvement can occur because every metacognitive skill can be improved with practice [25].

Monitoring activities include monitoring every step that has been taken, checking answers to the results of the investigation, and considering the accuracy of the results of the investigation [26]. The percentage of students' scores at the monitoring stage has increased from cycle I to cycle II, but is lower than planning is still in the category of starting to develop in line with the research of Ref. [27-31]. This is due to inaccurate examination and monitoring of students at every stage of the process regarding a process and achievement, revealing reasons inappropriately. Lack of student answers to monitoring causes students to score less than the maximum score.

The aspect of evaluation skills has the lowest average score which is in the very risky category (not yet complete), this result is in line with the research of Ref. [32]. This is because students are still unable to provide reasons for strategies that have been implemented with strategies that are planned to solve problems and provide other strategies for solving problems. Some students tend to skip the evaluation step and forget to conclude the results of solving problems and linking with problems.

Measuring the level of metacognition skills, in addition to using questions, students were also given the MAI questionnaire. The results of the students' MAI questionnaire also increased from cycle I, although still in the well-developed category.

The difference in the achievement of students' metacognition skills is that there are test questions and questionnaires because when filling out the questionnaire students are less able to assess themselves. Students have difficulty in carrying out self-assessments of what they have done in solving the problems contained in the questions so that not all questionnaires match what they have experienced when answering test questions. This resulted in the achievement of indicators for metacognition skills based on the results of the questionnaire which was not in line with the results of the written test.

### 3.2. Students’ conceptual understanding

The increase in the implementation of teacher activities, student activities, and students 'metacognition skills also has an impact on increasing students' conceptual understanding. Metacognitive engagement is key to developing deeper conceptual understanding [33-39]. The percentage of students' completeness in understanding the concepts of each cycle can be seen in Figure 2.

[Figure 2 Level of students’ understanding concept]

Remarks:
- **S**: Scientific Knowledge
- **K**: knowledge of correct concept (TK)
- **L**: Lack of Knowledge (TTK)
- **M**: Misconception
- **L**: Lucky Guess (TTK)
These facts indicate that the implemented learning cycle I to cycle II can change student conception, which is from MC and TTK into TK. N-Gain result of increasing students conception shown in Table 6.

Table 6 The results of tests on students' conceptual understanding

| Indicators              | SK (%) Baseline | SK (%) Cycle I | SK (%) Baseline to CI | SK (%) Cycle II | SK (%) Baseline to CII | Category |
|-------------------------|-----------------|----------------|-----------------------|-----------------|------------------------|----------|
| Understanding the concept (TK or SK) | 33.33           | 74.69          | 0.62                  | 79.80           | 0.66                   | moderate |
| Not understanding the concept (TTK i.e LK, LG, and LC) | 28.52           | 7.98           | (0.29)                | 4.70            | (0.33)                 | moderate |
| Misconception (MC)     | 38.15           | 17.33          | (0.34)                | 15.50           | (0.37)                 | moderate |

( ): reduction TTK and MC

The percentage of students' conceptual understanding in the first cycle as a whole was 74.69%. These results indicate that the mastery of students has not reached the indicators of success because students who completed ≤75%. Blonder et al [40] found that the quality of the questions posed by students (posed questions) was directly proportional to academic achievement. In some categories, the problem still shows that the level of understanding of the concept of students has not yet reached completeness in line with the research of Ref. [41-42] which stated that students' understanding was still lacking so that they had difficulty solving the buffer solution questions.

Based on Table 6 the level of understanding of the concepts of students in cycle II increased when compared to cycle I with a percentage of 79.80%. From the results of the evaluation, it is known that the percentage of students 'completeness has exceeded 75% which states that in cycle II students' understanding has reached indicators of success. There are increasing students conception baseline, cycle I and cycle II using GIAMQ model. Overall N-gain score obtained is 0.66, which means the category is "moderate." This indicates that GIAMQ model capable to reducing students’ student misconceptions (MC) and students’ not understanding concepts (TTK). GIAMQ model capable to change students’ MC and TTK into a knowledge of correct concept (TK). This is because the teacher makes improvements in learning so that students understand better when the concept understanding knowledge test is carried out and has reached the indicators of success, but there are still indicators of understanding the concept of students in the low category, namely the indicators of classifying and concluding.

Many students are wrong in giving reasons. The errors that occur in this study are in line with the research conducted by Nurhujaimah, Kartika, & Nurjaydi [43] that on average students answer the correct answer choices, but choose the wrong reasons. Marsita, Priatmoko, & Kusuma [44] also stated that the difficulty of students with this concept occurs because students only rely on the memorization aspect, so they are fooled by the available choices. Errors can occur because students do not read all the available answer choices, so the answers they choose are not correct.

Students respond positively to learning. This indicates that students can receive a guided inquiry learning model assisted by metacognitive questioning as a learning model that is fun and provides valuable experiences, which are strengthened research findings from [45-46] that students respond well to guided inquiry learning.

GIAMQ model activities can be in the form of laboratory activities, simulations, and problem-solving. This learning activity involves metacognition in orientation the problem, planning, monitoring, and evaluation/reflection stages. By reflecting on the attributes of each activity and its function in building scientific theory, students grow to understand the nature of inquiry and the habit of thinking to understand concepts and practice metacognitive skills. So, GIAMQ learning model is reinforced by the data of learning implementation result that is well implemented and impactful in to the improvement of students’ metacognitive skill and conceptual change. This result is consistent to
research conducted by Ref. [47-52], that the learning using tools, simulation, and computer multimedia could improve students interaction, learning concentration, problem-solving skill, understanding concepts, learning achievement, academic goals, promoting students’ metacognition and conceptual change.

4. Conclusion
Based on the research that has been done, it can be concluded that the application of the guided inquiry learning model assisted by metacognitive questioning can improve (1) the implementation of teacher activities from good enough to good (2) student activities from quite active to active categories (3) students' metacognition skills. developed in cycle I into a well-developed category in cycle II (4) metacognition skills and students' conceptual understanding of the concept had reached completeness in cycle II (5) student responses in learning showed a positive response.

Implications. The GIAMQ model is designed using problem-solving to train students' metacognitive skills and conceptual change can be applied in schools to support the successful achievement of metacognitive competencies and conceptual understanding of chemistry. One thing to note from these findings is that the use of problem-solving in developing metacognitive and conceptual skills changes daily activities as future skills, be it learning activities in class or other activities outside the classroom. In the daily life of the scientific community, that is, one person who is an expert in any academic field, when faced with a demanding problem and an important decision, they will decide based on metacognitive skills and metacognitive questions. Based on this, the GIAMQ model is suitable as an alternative learning model to support student competencies. The learning process in the GIAMQ model is student-centered and involves students using metacognitive questions. The application of this model can shift the paradigm of 1) students from being told to learn to people who are looking for knowledge, and 2) aspects of chemistry learning identified as low-level thinking to high-level thinking. The further conduct empirical research to evaluate the effects of the metacognitive skills-oriented learning, and the Tetrahedral-ZPD Metaphor on student conceptual change.

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