The role of student's critical asking question in developing student's critical thinking skills

T Santoso¹), I Yuanita²), E Erman³)

¹) Chemistry Education Study Program, Universitas Tadulako
²) Chemistry Department, Universitas Negeri Surabaya
³) Science Education Department, Universitas Negeri Surabaya

*Corresponding author: trisantoso@untad.ac.id; trisantoso10@mhs.unesa.ac.id; lennyyuanita@unesa.ac.id; erman@unesa.ac.id

Abstract. Questioning means thinking, and thinking is manifested in the form of questions. Research that studies the relationship between questioning and students' critical thinking skills is little, if any. The aim of this study is to examine how student's questions skill correlates to student's critical thinking skills in learning of chemistry. The research design used was one group pretest-posttest design. The participants involved were 94 students, all of whom attended their last semesters, Chemistry Education of Tadulako University. A pre-test was administered to check participants' ability to ask critical questions and critical thinking skills in learning chemistry. Then, the students were taught by using questioning technique. After accomplishing the lesson, a post-test was given to evaluate their progress. Obtained data were analyzed by using Pair-Samples T.Test and correlation methods. The result shows that the level of the questions plays an important role in critical thinking skills is the question levels of predictive, analysis, evaluation and inference.

1. Introduction

Learning innovation, which suits the needs of the 21st-century skills of questioning and critical thinking, have to be done. The learning approach commonly used in chemistry is an inquiry. Based on the result of the literature study on chemistry learning using inquiry approach it was that there are potential and constraints. Inquiry learning activities are a reflection of scientific epistemic science that describes questionable activity in proposing, explaining, evaluating, justifying, and constructing knowledge [1,2]. These activities are components of critical thinking skills [3]. Nevertheless, In the practice of inquiry learning, it was found that students had difficulty asking questions [4,5], it is thought to contribute to low student's critical thinking skills [6,7].

Asking is a natural character possessed by everyone (learners). Learners can develop questioning skills but learners can not develop themselves to generate critical questions automatically. Therefore, it takes effort from educators to help students learn to ask critically. The form of assistance needs to be designed how to facilitate active learners asking questions, thereby generating critical questions that trigger a series of other questions. The series of questions will encourage learners to think critically [8]. Questioning means thinking, and thinking is manifested in the form of questions, therefore a learning model is needed that can facilitate learners to make questions that provoke other questions is important. The types of questions that trigger other questions are critical questions [9], that induce
high-level cognitive processes. These include idea analysis, comparison and contrast, inference, prediction, evaluation, and justification [10]. Helpful efforts to encourage skilled students to ask and think critically can be based on Vygotsky's notion of the zone of proximal development (ZPD) and scaffolding [11]. The ZPD theory, interconnectedness with others gives the role of self-regulation and the activity of constructing knowledge. Likewise in asking and critical thinking cannot be done alone but need to involve others [8]. Others are used as sources and partners to elaborate information, data, facts, and opinions through question and answer to reach conclusions. The ZPD and scaffolding theory can be interpreted that for learners to be motivated to think critically should be given complicated tasks, it is difficult and realistic then learners are given enough assistance in the form of guide scaffolding questions that lead to the completion of learning tasks. With guidance scaffolding of the question, then the learners can formulate the question and ask the question to himself or to others. According to Wiley & Voss (1982) in Chin & Osborne [12] that the effect of asking questions (ask) will lead to an active reasoning response or cognitive conflict. The emergence of cognitive conflicts can trigger critical questions [13].

One major problem lecturers usually face in the classroom is that students seem to be passive in interactive activities and once the lecturers ask a question, only one or two students raise their hands. Having lack of asking the question is believed as one reason that students are unwilling to participate in productive skills of critical thinking. This gives an indication that the lack of student participation in asking questions is due to blank mind, it should be examined in research.

Learners can develop critical questions and thinking skills, but cannot develop themselves automatically and quickly. Educators need to help students learn to ask questions and think critically. Aid effort to encourage students to ask and think critically can use the concept of zone proximal development, ZPD proposed by Vygotsky [11]. In this study, the form of assistance offered is to apply the inquiry learning model based on critical questions known as the BKBI model [14]. In the practice of learning, it is provided a student activity sheet that is accompanied by a guide list of critical questions based on the level. In other words, the present paper aims at using the questioning technique to encourage students to improve their critical thinking. The research questions are: (1) how is the improvement of students' critical thinking after following the learning using BKBI model? and (2) what level of questions can encourage students' critical thinking skills?

2. Methodology of Research
The design of this study was based on one group of pretest-posttest designs [15,16]. The sample used in this study was purposive sampling. The participants involved in this study were 94 students of Chemistry Education at Teacher Training and Education Faculty of Tadulako University, that were consisted three classes A, B, and C. The participants were taught by using BKBI model [14] in learning of chemical reaction rate and chemical reaction equilibrium. After accomplishing the lesson, a post-test was given in order to evaluate their progress.

The pre-tests and post-tests in this study are critical questionings and critical thinking tests that are integrated with understanding the concept of chemical reaction rate and chemical equilibrium [17,18]. The test was developed by researchers and validated by three chemistry education experts who stated validity with the reliability of 0.86. The scoring scores were based on the rubric adapted from Kaberman & Dori [19], whereas the scoring of critical thinking was based on a rubric developed by researchers.

The data obtained were analyzed by using paired samples T-test to find out the improvement of students' critical thinking ability after following the learning with BKBI model [14]. The improvement of students' critical thinking skills is derived from the difference in scores from the test results before and after the lesson. Data on preliminary and final test results of students' critical thinking skill are calculated to be expressed in terms of the normalized gain coefficient (<g>) according to Hake [20]. There are three categories of <g>: "high gain" if <g> > 0.7; "medium gain", if 0.7 > <g> ≥ 0.3; and "low gain", if <g> <0.3. The data obtained were also analyzed by using the bivariate test to know the correlation between student's questioning skill and critical thinking skill.
3. Results of Research

Before implementing of BKBI learning model, students' critical thinking skill is still low, then students after studying chemical reaction rate and chemical reaction equilibrium by using BKBI learning model, students' critical thinking skill increased significantly. Detailed data can be seen in Table 1.

Table 1. Student's score of critical thinking before and after attending lecturing by using BKBI model

| Class (N) | Activity | Mean results | Normality (Shapiro-Wilk) | Mean Gain | N-gain (<g>) | Pair-Samples T-Test 95% Confidence | Sig. (p-value) |
|----------|----------|--------------|--------------------------|-----------|-------------|------------------------------------|---------------|
| A (32)   | Pretest  | 27.50        | 0.106                    | 45.00     | 0.63        | 27.532                             | 0.000         |
|          | Posttest | 72.50        |                          |           |             |                                   |               |
| B (31)   | Pretest  | 28.87        | 0.084                    | 45.16     | 0.64        | 24.445                             | 0.000         |
|          | Posttest | 74.03        |                          |           |             |                                   |               |
| C (31)   | Pretest  | 28.39        | 0.063                    | 48.55     | 0.69        | 26.987                             | 0.000         |
|          | Posttest | 76.94        |                          |           |             |                                   |               |

The improvement of the average score of students' critical thinking skills for classes A, B, and C before and after learning with the BKBI learning model is 45.00; 45.16 and 48.55 with the normalized gain coefficient (N-gain) of 0.63; 0.64 and 0.69 respectively. The gain scale falls into the medium criterion [20]. These data say that the use of BKBI learning model can improve students' critical thinking skills with the degree of improvement in the medium category. Then, the correlation between student questioning and critical thinking is presented in Table 2.

Table 2. Correlation between student's Critical questioning and thinking skills

| Class (N) | Activity         | Mean results | Std. Deviation | Pearson Correlation is significant at the 0.05 level |
|-----------|------------------|--------------|----------------|-----------------------------------------------|
| A (32)    | Critical question| 72.03        | 9.23           | 0.666                                         | 0.000         |
|           | Critical thinking| 72.50        | 10.55          |                                               |               |
| B (31)    | Critical question| 72.90        | 10.47          | 0.768                                         | 0.000         |
|           | Critical thinking| 73.39        | 10.75          |                                               |               |
| C (31)    | Critical question| 75.97        | 11.43          | 0.798                                         | 0.000         |
|           | Critical thinking| 73.87        | 14.65          |                                               |               |

Table 2 shows the correlation coefficient (r) between questioning and critical thinking skills for classes A, B, and C is 0.666; 0.768 and 0.798 with the p-value of 0.000. These probability values are less than the critical limit of the study of 0.05; thus the relationship between asking of the question and critical thinking is strong. Based on the category of questioning skills according to Kabarmen [19] and Anderson & Krathwohl [22], the results of the asking question skills test can be grouped into three, i.e. understanding question (Q2), application question (Q3) and prediction, analysis/evaluation/inference question (Q4). In detail, the effect of students' asking skills on critical thinking skills is presented in Table 3.
Table 3 Question level and score of students' critical thinking skills

| Class | Number of students | Question level | Mean results of critical thinking |
|-------|-------------------|----------------|----------------------------------|
|       |                   |                | interpretation | prediction | analysis | evaluation | inference |
| A     | 14                | Q2             | 88.1          | 81.0       | 55.7     | 58.9       | 54.3       |
|       | 9                 | Q3             | 88.9          | 92.6       | 60       | 69.4       | 60         |
|       | 10                | Q4             | 96.7          | 100        | 74       | 80         | 76         |
|       | 11                | Q2             | 87.9          | 84.8       | 52.7     | 56.8       | 52.7       |
| B     | 11                | Q3             | 100.0         | 87.9       | 60.0     | 75.0       | 61.8       |
|       | 9                 | Q4             | 96.3          | 96.3       | 75.6     | 83.3       | 82.2       |
|       | 9                 | Q2             | 85.2          | 77.8       | 53.3     | 58.3       | 53.3       |
| C     | 11                | Q3             | 100.0         | 78.8       | 61.8     | 70.5       | 65.5       |
|       | 11                | Q4             | 100.0         | 100.0      | 80.0     | 95.5       | 81.8       |

Table 3 shows the tendency of a skilled student to ask critically at the level of understanding (Q2), so he or she will tend to think critically at a very good level of interpretation, good prediction level, while at the level of analysis, evaluation and inference are less skilled. Students who have the skills to ask application (Q3) will tend to be highly skilled at critical thinking at the level of interpretation and prediction, and skilled enough to think critically at the level of analysis, evaluation, and inference. Students who have critical questioning skills at predictive/analytical / evaluation/inference levels (Q4) will tend to be highly skilled at critical thinking at the level of interpretation and prediction, and good critical thinking at the level of analysis, evaluation, and inference.

4. Discussion

In general, after the implementation of the BKBI learning model on the subject of chemical reaction rates, students' critical thinking skills increase. The average score of critical thinking of grade A students increased from 27.5 to 71.5 with \( g = 0.63, t = 27.532, \) and \( p\text{-value} = 0.000 \), grade B increased from 28.87 to 74.03 with \( g = 0.64, t = 24.445, \) and \( p\text{-value} = 0.000 \), and class C increased from 28.39 to 76.94 with \( g = 0.69, t = 26.987, \) and \( p\text{-value} = 0.000 \). Based on the ANOVA test, the increase in students' critical thinking skill acquisition between class A, B, and C shows consistent improvement in the same gain that is middle scale \( F = 0.728; p\text{-value} = 0.486; \alpha = 0.05 \). These data indicate that learning by BKBI model can encourage students' critical thinking skills with increasing in the moderate category. The emphasis on critical thinking skills in chemistry learning, especially the chemical reaction rate and chemical reaction equilibrium, will change sense of chemistry lessons as the science of memorization into higher-order thinking.

The correlation between student's questioning and critical thinking skill in class A, B, and C is indicated by the correlation coefficient \( r \) respectively, that is 0.666; 0.768 and 0.798 with \( p \) of 0.000, the \( p \) values are less than the critical limit of 0.05. These data show significantly the relationship between questioning skills and critical thinking is very strong [22]. It can be interpreted if students have good questioning skills then critical thinking skills are also good, and vice versa. These findings are in line with research reports of Santoso & Yuanita [23], that student questions serve as critical thinking scaffolds in making possible or impossible explanations to support evidence, hypotheses, statements, and conclusions. The level of questions that contribute to critical thinking is the question of prediction, analysis, evaluation, and inference.

The findings on the impact of the application of the BKBI learning model mentioned above prove the questioning in every phase of learning. The questioning of the students in learning by applying the BKBI model are conducted through questioning activities on the formulation of questions, searching
for evidence of answers, explanatory analysis on the relation of evidence of answers, evaluation of explanatory evidence and inference (conclusions).

The steps of the BKBI model activities are in line with the National Research Council's statement, NRC [24], that critical thinking in inquiry learning is built by expressing curiosity by asking based on its knowledge, proposing a preliminary explanation or hypothesis, plotting and conducting a simple investigation, collecting evidence, explain based on evidence, consider other explanations, communicate explanations, and test explanations. Other concurrent views are statements from Carin [1] and Kelly & Finlayson [2], that critical thinking of learners can be achieved through questioning activities in proposing, explaining, evaluating, justifying, and constructing knowledge.

The results of the BKBI model implementation provide reinforcement to Paul & Elder's [25] assertion, that questions encourage students to make assumptions, distinguish between relevant opinions and irrelevant opinions, and enable students to control and test their thinking [26]. In addition, the BKBI model complements the findings of Dori & Herscovitz [26] who suggest questions can be used as effective learning strategies because student questions serve as critical thinking scaffolds about possible or impossible explanations to support evidence, hypotheses, statements, and conclusions [27]. As well as the findings of Eshach, Ziderman, & Yefroimsky suggests that students who ask divergent or evaluative questions will provoke a number of responses that promote critical thinking [7]. Another study in line with the findings of the development of this BKBI model is the influence of learners' questions on instructional strategies, that learners' questions are helpful in the development of critical thinking skills, particularly opportunities for dialogue in discussions emerge to improve the outcomes of critical thinking skills [27].

5. Conclusion
Implementation of learning questioned by using BKBI learning model gives a positive influence. Based on the calculation of paired t-test, students who have attended lectures with BKBI learning models have significantly improved critical thinking skills with the coefficient of $g$ on medium criteria. The ability to ask question skills of student has a strong correlation with the students' critical thinking skills, where the level of the questions that play an important role in critical thinking skills is the question levels of predictive, analysis, evaluation and inference.

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References
[1] Carin, A. A. (1993). Teaching Science Through Discovery. New York: Macmillan.
[2] Kelly, O., & Finlayson, O. (2007). Providing Solutions through Problem-based Learning for Undergraduates. Chemistry Laboratory. Chemistry Education Research and Practice, 347-361
[3] Facione, P. A. (2016, 11). Critical Thinking: What It Is and Why It Counts. INSIGHT ASSESSMENT, pp. 1-29
[4] Golding, C. (2011). Educating for critical thinking: thought-encouraging questions in a community of inquiry. Higher Education Research & Development, 357–370
[5] Katchevich, D., & Hofstein, A. (2013). Argumentation in the chemistry laboratory: Inquiry and confirmatory experiment. International Journal of Science Education, 317-345
[6] Passmore, C. M., & Svoboda, J. (2012). Exploring Opportunities for Argumentation in Modelling Classrooms. International Journal of Science Education, 1535-1554.
[7] Eshach, H., Ziderman, Y. D., & Yefroimsky, Y. (2014). Question Asking in the Science Classroom: Teacher Attitudes and Practices. Journal Science Education Technology, 67-81.
[8] Browne, M., & Keeley, S. M. (2012). Asking the Right Question: A Guide to Critical Thinking. New Jersey: Pearson Education, Inc
[9] Nussbaum, E., & Edwards, O. V. (2011). Critical Questions and Argument Stratagems: A Framework for Enhancing and Analyzing Students' Reasoning Practices. *The Journal of The Learning Science*, 443-488

[10] King, A. (1995). Designing the instructional process to enhance critical thinking across the curriculum. *Inquiring minds really do want to know: Using questioning to teach critical thinking*. *Teaching of Psychology*, 13-17

[11] Schunk, D. H. (2012). *Learning theories an educational perspective*. Singapura: Pearson Education, Inc.

[12] Chin, C., & Osborne, J. (2010). Supporting Argumentation Through Students’ Questions: Case Studies in Science Classrooms. *The Journal of The Learning Sciences*, 230–284.

[13] Choi, I., Land, S. M., & Turgeon, A. J. (2005). Scaffolding peer-questioning strategies to facilitate metacognition during online small group discussion. *Instructional Science*, 483–511

[14] Santoso, T., & Yuanita, L. (2016). Pengembangan bertanya kritis berbasis inkuiri (BKBI) untuk pembelajaran kimia. *Jurnal Pendidikan Sains*, 9-16.

[15] Creswell, J. W. (2012). *Educational Research Planning, Conducting, and Evaluating Quantitative and Qualitative Research*. Boston: Pearson.

[16] Fraenkel, J. R., & Wallen, N. E. (2009). *How to design and Evaluate Research in Education*. New York: Mc. Graw Hill Inc

[17] Abrami, P. C., Bernard, R. M., Borokhovski, E., Wade, A., Surkes., M. A., Tamin, R., & Zang, D. (2008). Instructional Interventions Affecting Critical Thinking Skills and Disposition: A Stage 1 Meta-Analysis. *Review of Educational Research*, 1102-1134.

[18] Liliasari. (2011). *Berpikir Kritis Dalam Pembelajaran Sains Kimia Menuju Profesionalitas Guru*. Bandung: Program Studi Pendidikan IPA, Sekolah Pascasarjana UPI.

[19] Kaberman, Z., & Dori, Y. J. (2009). Metacognition in chemical education: question posing in the case-based computerized learning environment. *Instructional Science*, 403-436.

[20] Hake, R. R. (2002). *Relationship of Individual Student Normalized Learning*. Idaho.: The Physics Education Research Conference

[21] Anderson, L. R., & Krtahwolhl, D. R. (2001). A Taxonomy for Learning Teaching, and Assessing: Revision of Bloom's Taxonomy of Educational Objectives. New York: Addison Wesley Longman, Inc.

[22] Hinton, P. R., McMurray, I., & Brownlow, C. (2014). *SPSS Explained Second edition*. London & New York: Routledge

[23] Santoso, T., & Yuanita, L. (2017). Metacognitive Analysis of Pre-Service Teachers of Chemistry in Posting Questions. *Journal of Physics: Conference Series*, 824, 012026.

[24] National Research Council. (2012). Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century. Committee on Defining Deeper Learning and 21st Century Skills, J.W. Pellegrino and M.L. Hilton, Editors. Washington, DC: The National Academies Press

[25] Paul, R., & Elder, L. (2008). *The miniatureguide to the art of asking essential questions*. Santa Rosa, CA: Foundation for Critical Thinking

[26] Dori,Y.J., & Herscovitz, O. (2005). "Case-based Long term professional development of science teachers". *International Journal of Science Education*, Vol.27 No.12, pp. 1413-1446

[27] Abrami, P. C., Bernard, R. M., Borokhovski, E., Waddington, D. I., Wade, C. A., & Persson, T. (2015). Strategies for Teaching Students to Think Critically: A Meta-Analysis. *Review of Educational Research*, 275-314