Effect of scientific critical thinking model to train critical thinking skills and student self efficacy

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Abstract. The Scientific Critical Thinking (SCT) model is a learning model developed to train critical thinking skills and student self-efficacy. This study aims to analyze the effect of the SCT model in improving critical thinking skills and the self-efficacy of Primary School Teacher Study Program students. This study used quasi-experimental research with the design of one group pre-test and post-test. The research subjects were one hundred and eight students of the Primary School Teacher Study Program from three classes of the Lambung Mangkurat University. Data was collected through tests of Critical Thinking Skills, questionnaires about student self-efficacy, and in-depth interviews. The collected data was analyzed using paired t-test / Wilcoxon test and n-gain. The results of the research on class D, class E, and class F indicate that the sig value is obtained. (2-tailed) critical thinking skills are 0.00 (p = <0.05) and n-gain is class D 0.77, class E 0.77 and class F 0.77 show that it is important in high criteria. In addition, sig is obtained. (2-tailed) student’s self-efficacy is 0.00 (p = <0.05) and n-gain is class D 0.77, class E 0.81 and class F 0.79; shows significant results in high criteria. It was concluded that the SCT model was effective. This study implies that the SCT model can be used as an alternative to training students’ critical thinking skills and self-efficacy.

1. Introduction
The chemistry provides a contribution to helping people resolve complex life. In fact, many students found studying chemistry was not interested and did not have a good understanding after studying chemistry [1, 2, 3]. Educators are required to present meaningful chemistry learning so that learners interested to learn in preparation to face the global competition era. Chemistry teachers must have special competence in the competitive era of globalization with a range of skills of the 21st century, one of the critical thinking skills. Life skill critical thinking if it is not well developed in the chemistry student teachers, it will be difficult for them to face tough competition in the 21st century.

According to [4], critical thinking is reflective thinking that is reasonable or based on the reasoning that is focused on deciding what to do. Critical thinking is a thinking skill that is useful in any situation. According to [5], there are eight pieces of descriptions that can be associated with critical thinking, i.e testing, connecting, and evaluate all aspects of a situation or problem, focusing on the part of a situation
or problem, collect and organize information, validate and analyze information, remember and analyze the information, determining the reasonableness of an answer, draw valid conclusions, are analytic and reflective.

The same thing also expressed by [6] that there are some abilities to separate relating to the ability of a thorough critical thinking, namely: determine analogies and kinds of other relationships between pieces of information, determining the relevance, and validity of the information can be used for the formation and problem resolution, as well as find and evaluate the settlement or ways to solve problems. The general criteria for a person to think critically are FRISCO (focus, reason, inference, situation, clarity, and overview) [4]. According to [7], the main critical thinking skills involved in critical thinking process. These skills are the interpretation, analysis, evaluation, and inference.

One aspect that is measured in PISA and TIMSS is a problem-solving ability to correlate very closely with critical thinking skills. TIMSS and PISA study results Indonesian students belonging to the lower level [8, 9, 10, 11]. Indonesia had a lower level does not mean that students do not have the intelligence to compete with other countries, but the learning process is not in accordance with the standard test used by the PISA and TIMSS. It needs to be a joint evaluation material in the process of improvement in education in a comprehensive manner. One alternative solution is to equip the critical thinking skills to students of chemistry teacher candidates who will become educators for students in Indonesia.

Initial studies by [12] on 70 students of Chemistry Education, Faculty of Teacher Training and Education, Lambung Mangkurat University, who follows the course of Chemistry School 1 known that chemistry student critical thinking skills are still low (25.57%). In general, 72 students still quite incapable of critical thinking. The ability to analyze arguments (31.83%), identifying assumptions (60.35%), asking and answering questions (19.48%), decide on the action (15.91%) and induced (1.04%). It shows critical thinking chemistry students still low.

Interviews and observations on some of the students and lecturers disclose 1) the limited time lecturers develop learning models and tools that emphasize critical thinking skills, especially for prospective teachers of chemistry, 2) students have difficulty using science process skills in investigation activities, and 3) students have difficulty completing tasks continued as a form of deepening and application of the material obtained from the learning activities. Preliminary results indicate the necessary chemistry learning model that emphasizes critical thinking and science process skills appropriate character chemistry student teachers in Indonesia.

Models of learning that can improve students' critical thinking skills among others are a model of Problem Based Learning (PBL) and model of inquiry. It is explained by some experts [13,14,15,16,17,18,19,20,21] that the PBL model has a common objective to improve the skills of inquiry and problem-solving skills, behavior, and social skills appropriate adult roles, skills to learn independently. The research result of [22] which aims to teach analytical chemistry and usefulness through PBL suggesting that students in PBL groups are far more successful in using laboratory equipment, resulting in problem-solving, self-efficacy, and production theory. Findings of [23] note the achievements of prospective science teacher ratio in the elementary classroom problem-based learning (PBL) with conventional class indicates that the class-based issues more effective in improving knowledge, positive attitudes toward chemistry, the development of independent learning and critical thinking.

PBL models still have some weaknesses that must be overcome if we want to use more widely. PBL model's shortcomings are less appropriate for the scope of adequate information or knowledge base and some teachers do not encourage its use [14]. [15] research results found that the model PBL can improve critical thinking skills of learners with problem-solving procedural activities. These results suggest further research by providing more systematic activities so that students can remember the steps for resolving the issue to improve their critical thinking. Results of a meta-analysis of research by [24] on the results of the study, 2006 to 2013 showed that PBL learning effective in learning to improve student attitudes.

The results of the study [25] showed that the model PBL can improve the critical thinking skills of students in chemistry experiments. PBL model is able to provide a real problem for learners to improve
their thinking skills and communication. Some recommendation for further research include: 1) research is still needed on models and more varied methods to support the model of PBL in improving critical thinking skills of learners, 2) providing time laboratory experiments are still needed to support the implementation of PBL models. Research result of [26] found that the structure of the PBL is not a significant factor related to science teaching self-efficacy. This is reinforced by the findings of [27] which states that PBL is a learning strategy centered learning, in which students are given a large role in their own learning, therefore, transfer this role may need more time for adjustment to the student's learning style. The results of the study on the model PBL above indicates the importance of innovation to the model of PBL to improve critical thinking skills and self-efficacy in learning chemistry.

[28] found that the inquiry learning model can improve critical thinking skills, especially on indicators of recognition and judgment learners, but it can not improve thinking skills indicators deduction owned learners. [1] developed a model of experimental learning (learning experimental model) based inquiry (inquiry) with the main objective to improve learning outcomes and skills of the scientific process chemistry student teachers. The samples in the study were 40 chemistry student teachers in Chemistry Education, Hacettepe University. Research results show that there are increase learning outcomes and significant scientific process skills. But in the implementation of activity-based learning model experimental investigation (inquiry) developed by Alkan still requires improvements in investigation activities with more varied material content so that students have enough stock when they become a chemistry teacher.

The research result [1] and [3] indicate the need for continued research effort to improve the learning model based inquiry to develop a model of learning that can improve critical thinking skills and self-efficacy of student teachers chemistry through investigations in the laboratory, so that students have the provision in chemistry in the classroom learning process according to the demands of the 21st century skills and to compete in the world of work in the era of globalization. The results of the above studies show that the model PBL and inquiry model still requires modification and developed for improving critical thinking skills and self-efficacy chemistry student teachers.

Self-efficacy science learner entered in the PISA assessment in 2015. It is considered important to measure as a positive self-efficacy is closely related to motivation, learning behavior, the general expectation in the future and the performance of students [29]. Self-efficacy is a predictor for entering higher education in their respective domains. Teacher professional confidence is also measured in the PISA 2015 in this case is the self-efficacy of teachers in classroom management, giving instructions and maintain positive relationships with students. Science teachers will also be required to report their self-efficacy with respect to content and teaching science [29]. Self-efficacy has a direct positive influence on students' scientific attitudes towards chemistry [30].

Initial studies by [12] in chemistry students who follow courses of Chemistry School 1 show that in general self-efficacy of students is still low. Most students feel less confident to do well on exams, less confident to complete the task difficult, less certain that the lecturer of the course will tell the student is superb in following the course, it is not sure that students have the talent and good at following the lecture. It is strengthened by the initial study results [31] study that the importance of self-efficacy influences academic achievement in the field of science and can’t be underestimated. The study results indicate the importance of self-efficacy of students who need to improve by using chemical learning model designed specifically for increasing self-efficacy.

Self-efficacy can affect cognition, motivation, affective processes and in the end that person's behavior [32, 33]. Bandura explains how ideas about their successes affect teacher-selected activities for student work, classroom management style, and presentation effective lessons. These findings led to the conclusion that teachers' self-efficacy enhancement will lead to improvements in student learning. According to Bandura, self-efficacy can be obtained, modified, upgraded, or downgraded by one or a combination of four sources of experiences of success (mastery experiences); the experience of others (vicarious experiences); verbal persuasion (verbal persuasion); and physiological and affective state (physiological and affective state) [34].
Problems arising from the results of the study TIMSS, PISA, and the study of literature for the model Problem Based Learning (PBL) and model of Inquiry, and the results of initial studies in Education Program Chemistry, University of Lambung Mangkurat and some high schools showed that in general the critical thinking skills and self-efficacy is low student in the learning process chemistry. Researchers proposed the development of a chemistry learning model that integrates critical thinking skills and self-efficacy. This innovation is expected to be an alternative solution to train critical thinking skills and student self-efficacy. Therefore in this study will be developed model of Scientific Critical Thinking (SCT) for train critical thinking skills and student self-efficacy.

2. Method
Research conducted at the Lambung Mangkurat University, primary school teacher study program, the months of August to October 2018. The research subjects were students who took Natural Sciences 3 courses totaling 108 students, consisting of extensive test subjects in class D 33 students, class E 40 students and class F 35 students at the Lambung Mangkurat University, primary school teacher study program. Each class has the same initial capability, i.e critical thinking skills and self-efficacy are still low. Research is emphasized on the analysis of the effectiveness of SCT models by analyzing the increase in critical thinking skills and self-efficacy of students before and after the teaching process with the model SCT.

This study uses one group pretest-posttest design (O1 X O2). Learning begins by giving a pretest (O1). Each student is asked to do critical thinking skills pretest and then fill out a questionnaire self-efficacy students. Critical thinking skills test instrument consists of four items referring to indicators of critical thinking skills adapted from [7], include skills to interpret, analyze, evaluate, and inference. Each indicator is measured using critical thinking skills 1 point test on the material reaction rate. Instrument self-efficacy questionnaire consisted of 20 statements were developed by adapting to the Sources of Middle School Mathematics Self efficacy Scale. There are six items for appraisal aspect of mastery experiences, six items for aspects of vicarious experiences, the six items on the social aspect persuasions and six aspects to assess aspects of physiological and affective state. Completed pretest, a lecturer in applying the model SCT and its peripheral devices for 6 meetings in each class (X). Lecturer orient start the lesson with students on issues, scientific activities, presentation of the results of scientific activity, task completion critical thinking and ends with evaluation.

The learning process ends with a posttest (O2). Each student was asked to do the posttest SCT, then after that, students are asked to complete a questionnaire on student self-efficacy. In addition, in-depth interviews conducted for some students to clarify the problems found during the study. Six items for the social aspect persuasions and six aspects to assess aspects of physiological and affective state. Completed pre-test, a lecturer in applying the model SCT and its peripheral devices for 6 meetings in each class (X). Lecturer orient start the lesson with students on issues, scientific activities, presentation of the results of scientific activity, task completion critical thinking and ends with evaluation.

Pretest and posttest results data for each indicator critical thinking skills then calculated using an assessment rubric in Table 1.

Based on Table 1; critical thinking skills indicator score is given based on the suitability of the results of pretest and posttest students with aspects of the ratings assigned. If the three aspects of the assessment are met, the student is given a score of 4; if the two aspects of assessment are met, given a score of 3; if one aspect of the assessment are met, given the score of 4; and when all aspects of the assessment are not met, given a score of 0. In addition, to calculate the score of student self-efficacy is the total score obtained is divided by the maximum score multiplied by 4. Selection of test methods depends on the fulfillment of the assumptions of normality to score pretest and posttest and student self-efficacy. Test statistically by paired t-test (parametric) or Wilcoxon test (non-parametric). This test is performed with the help of IBM SPSS 22.0 software.
Table 1. Rubric assessment of critical thinking skills

| Indicator   | Aspects Rating                                                                 |
|-------------|--------------------------------------------------------------------------------|
| Interpretation | • The students explain the situation/ incident corresponding answer keys.     |
|             | • The students make the appropriate interpretation of the answer key.         |
|             | • The students make interpretation using scientific language and logical.      |
| Analysis    | • The students identify the relationship of some of the statements (e.g. questions, concepts, descriptions, and various models) corresponding answer keys. |
|             | • The students reflect on the thought / view / belief / decision / reason / information and opinions corresponding answer keys. |
|             | • The student makes analysis using scientific language and the appropriate logical answer keys. |
| Evaluation  | • The students make decisions based on the relationship of some of the statements (e.g. questions, concepts, descriptions, and various models) corresponding answer keys. |
|             | • The Student test the truth of the statement that is used to convey the thought/ perception/ view/ decision, reasons/ opinions corresponding answer key. |
|             | • The students make an evaluation by using scientific language and the appropriate logical answer key. |
| Inference   | • The students make conclusions based on facts based on data / information / statements / events / principles / opinions / concepts corresponding answer keys. |
|             | • The students identify and select elements needed to make a conclusion that has reason / to suspect and diagnosis / to consider the information corresponding answer keys. |
|             | • The students make inferences using scientific language and the appropriate logical answer key. |

3. Result and Discussion

Third-class learning outcomes associated with critical thinking skills and self-efficacy are presented in Figure 1.
Based on Figure 1, before being applied to the model SCT, the mean score of students' critical thinking skills of analysis indicators, evaluation, interpretation, and inference are the criteria Low Score \(<\) With a score of 1.33 and Medium \(>\) 1.33. Vice versa, once implemented the model SCT, mastery of critical thinking skills of students indicator analysis, evaluation, interpretation, and inference are the criteria for being with Score \(<\) 2.67 and high score \(>\) 2.67. This indicates that there is the impact of SCT models to increase students' critical thinking skills.

Figure 1 also illustrates aspects of self-efficacy student mastery experiences, vicarious experiences, social persuasions and physiological and affective state before applying the model SCT, self-efficacy of students are still in fairly certain criteria with score\(>\)0.67. Conversely, once implemented SCT models, the role of student self-efficacy aspects of student mastery experiences, vicarious experiences, social persuasions and physiological and affective state for the better, which is located on the criteria are very confident with the score\(>\)3.33. This indicates that the impact of the application of the SCT to the increase in self-efficacy of students in learning. Increase critical thinking skills and self-efficacy of students before and after applying the model SCT is calculated through the N-gain. The mean value of the N-gain SCT and self-efficacy for all three classes are presented in Figure 2.

**Figure 2.** N-gain average of critical thinking skills and self-efficacy in third grade

Figure 2 shows that the average value of the N-gain for class D, class E and class F respectively is 0.77; 0.77; and 0.77; This means an increase in critical thinking skills in high criterion. On the other hand, the average value of the N-gain self-efficacy of students to class D, class E and class F respectively is 0.77; 0.81; and 0.79; This means an increase in self-efficacy of students in the high criteria. Furthermore, to determine the significance of the impact of SCT models can be seen from the results of inferential statistical test that begins with normality test pretest and posttest scores for the third grade. Normality test results with one-sample Kolmogorov-Smirnov Z test are presented in Table 2.

**Table 2.** The normalized pre-test and post-test of critical thinking skills and self-efficacy for all classes

| Class | Test   | N  | Critical Thinking Skills | Self Efficacy |
|-------|--------|----|--------------------------|---------------|
|       |        |    | Mean (SD)                | Mean (SD)     |
| D     | Pre-test| 33 | 0.7530 (0.14023)         | 0.2994 (0.00933) |
|       | Post-test| 33 | 3.4621 (0.27330)         | 0.8442 (0.06750) |
| E     | Pre-test| 40 | 2.0902 (0.13448)         | 0.2998 (0.00862) |
|       | Post-test| 40 | 2.4058 (0.12756)         | 0.8530 (0.06136) |
| F     | Pre-test| 35 | 2.0946 (0.15277)         | 0.2994 (0.00906) |
|       | Post-test| 35 | 2.4203 (0.13826)         | 0.8566 (0.5866) |
Table 2 shows that the pretest and posttest scores of critical thinking skills and self-efficacy in the third grade are not normally distributed because between both scores (pretest and posttest) or one of the scores not normally distributed. Therefore, the impact of applying SCT to improve critical thinking skills and self-efficacy was analyzed by the Wilcoxon test. The Wilcoxon test results are presented in Table 3.

| Learning outcomes | Class  | Wilcoxon test |  |
|-------------------|--------|---------------|---|
| Critical Thinking Skills | D      | -5.018        | 0.000 |
|                    | E      | -5.535        | 0.000 |
|                    | F      | -5.179        | 0.000 |
| Self efficacy      | D      | -5.016        | 0.000 |
|                    | E      | -5.515        | 0.000 |
|                    | F      | -5.165        | 0.000 |

Table 3 shows that the mean score of critical thinking skills to class D, class E and class F that the Z value of each; -5.018; -5.535; and -5.179 with a significance level of P < 0.05; This means significant. On the other hand, the mean score of self-efficacy on class D, class E and class F that the Z value of each -5.016; -5.515 and -5.165 with a significance level of P < 0.05; This is also significant.

Figure 2 and Table 3 show the impact of SCT models to increase students' critical thinking skills is significant in high criteria. The success of the model SCT is because critical thinking skills is a major concern in every phase of the model, ie starting from the motivation and orientation problems (phase 1), scientific activity (phase 2) and the presentation of the results of scientific activity (phase 3), the completion of the task of critical thinking (phase 4), and evaluation (phase 5). This is according to the theory of social constructivism by Vygotsky [36] includes social learning theory (students learn by interacting with adults and peers who are more capable); Zone of Proximal Development (students learn best when the concept of development in the zone closest to them); and the theory of scaffolding (students are given assignments complex, difficult, and realistic, and then given enough assistance to complete tasks).

Reinforced by the results of research [25] regarding the model PBL gives recommendations for further research is still needed research on models and more varied methods to support the model of PBL in improving critical thinking skills of learners. Improved critical thinking skills that students can Practice SCT models indicate the critical thinking skills of students in limited testing and extensive trials.

Application of SCT models also has a significant impact on the increase in self-efficacy of students in the high criteria. In line with the theory that self-efficacy, a person's belief that he or she can succeed in performing a given task [35] which is reinforced by the results of research by [3] which provides recommendations on research on inquiry learning model need to increase self-efficacy possessed by students in learning science, especially the science-based activities in the investigation process in the laboratory. Increased student self-efficacy indicates SCT models can train student self-efficacy on limited testing and extensive trials. SCT models novelty, when compared with the inquiry model, namely 1) the phase of scientific activity, students conduct scientific activities in chemical experiments to train critical thinking skills and student self-efficacy. 2) Their Critical Thinking Task Completion phase which is specifically designed as Practice critical thinking skills and student self-efficacy, this phase does not exist in phase inquiry model.

Based on the findings above, can be synthesized that the effectiveness of the model SCT to increase critical thinking skills and self-efficacy is caused by (1) the existence of problems in everyday life; (2) the phase of scientific activity, students conduct scientific activities in chemical experiments to practice critical thinking skills and student self-efficacy. SCT models novelty PBL model than in practice critical thinking skills lies in the completion phase of critical thinking tasks. This phase is designed specifically to enable students to think critically chemical tasks to be solved independently as a stage practice critical thinking skills he already has as well as self-efficacy practice students. SCT models novelty, when
compared with the inquiry model, namely 1) the phase of scientific activity, students conduct scientific activities in chemical experiments to train practice critical thinking skills and student self-efficacy. In line with the results of [3] provides recommendations on research on inquiry learning model, namely a) the lack of optimization of activity in laboratory experiments that vary and need to be improved survey activities in the laboratory in each semester, b) acquisition of knowledge about material science noteworthy in learning when using the inquiry model, and c) the need to improve self-efficacy which is owned by student teachers in science teaching, especially with science-based activities in the investigation process in the laboratory. 2) The completion phase of critical thinking tasks that are specifically designed as practice critical thinking skills and student self-efficacy, this phase does not exist in phase inquiry model. Research results [15] suggested for further research by providing more systematic activities, so that students can remember the steps for resolving the issue to improve their critical thinking.

4. Conclusion
The application of SCT includes effective models for improving critical thinking skills and self-efficacy of students in learning, because of the findings showed that there was significant improvements in the critical thinking skills of students in the high category and self-efficacy in the high category for all three classes. This effectiveness is due to 1) the phase of task completion critical thinking specifically designed to make students think critically chemical tasks to be solved independently as a stage to train critical thinking skills he already has as well as self-efficacy to train students. 2) phase of scientific activity, students conduct scientific activities in chemical experiments to train critical thinking skills and student self-efficacy.

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