The Effectiveness of Online Critical Thinking Cycle Learning Model on Pre-service Science Teachers' Critical Thinking Skills

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Abstract. The development of critical thinking through educational interventions is still needed to prepare competitive graduates. Pre-service teachers play an essential role in developing critical thinking as the primary goal of learning. This study aims to determine the effectiveness of the Critical Thinking Cycle (CTC) model to improve pre-service science teachers' critical thinking skills. This study is pre-experiment research with a one-group pre-test post-test design. During the Covid 19 pandemic, the learning processes were carried out online. The online CTC model was implemented with the Zoom Meeting platform and Google Classroom. The research subjects were 30 pre-service science teacher students at a university in Surabaya, Indonesia. The critical thinking skills test is used to measure critical thinking skills. The results showed that pre-service science teachers' critical thinking skills increased after the implementation of the online critical thinking cycle model with a normalized gain score (*N-gain*) of 0.719 in the high improvement category. Thus, the CTC model effectively improves pre-service science teachers' critical thinking skills.

Keywords: Critical thinking cycle · Learning model · Critical thinking skills

1 Introduction

Critical thinking is an essential issue in world education to face various challenges in the era of industrial revolution 4.0 [1][2][3]. Education, both higher education and schools are required to prepare competencies-qualified graduates who can think critically so that they can compete globally in the industry 4.0 era [4][5]. Education needs to be more optimal in making more efforts effective in preparing graduates to have critical thinking skills [6][7][8].

Development and training of critical thinking in learning is seen as one of the goals important in education to face the era of revolution Industry 4.0 in Indonesia [1][9]. Development of critical thinking through intervention education is still very much needed to prepare competitive graduates, in this case, educators play an essential role in planning the development of critical thinking as the primary goal of learning [7][10][11]. The educator plays a strategic role in developing thinking critically in their students [7].

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Therefore, critical thinking is also critical to be trained for educators, including student teacher candidates [11].

The study results indicate that pre-service teachers must develop strong critical thinking and examine the information from various digital sources. Teaching critical thinking to student teachers has attracted many researchers because pre-service teachers play an essential role in developing critical thinking through teaching and learning activities [12][13][14]. Pre-service teachers must have critical thinking competencies before they train their students in the classroom [12][13]. Several previous related studies have shown that the majority of students in Indonesia lack achievement in critical thinking because teachers have not been able to teach critical thinking to students in making the right decisions and solving problems effectively [15].

Several other researchers also reported the low critical thinking skills of students [16][17][18]. The low critical thinking skills of students are due to the fact that the science learning that has been carried out has not been optimal in facilitating skill development activities such as critical thinking, as has been found in graduate learning outcomes in the science education study program curriculum [18]. There has also not been much intervention in developing a model to improve disposition and critical thinking skills in science/science learning activities [11]. This certainly provides an opportunity for the academic community in Indonesia to innovate to facilitate critical thinking development in learning activities.

Universities for pre-service teacher students are the most appropriate intervention in promoting critical thinking skills [13]. Teaching critical thinking to pre-service teacher candidates has attracted the attention of several researchers, and the role of student teacher candidates seems to be more important than ever to overcome problems that occur in education related to increasing critical thinking through learning activities [13][14]. Higher education, especially science educators, should reconsider their instructional practices to improve students' critical thinking [7]. Therefore, studies on teaching interventions to train students' disposition of critical thinking and critical thinking skills, especially pre-service science teachers, are still needed. Interventions in the form of implementing learning models are needed in developing graduate competencies such as critical thinking dispositions and critical thinking skills [11].

Critical thinking is reflective thinking, careful thinking/diligent/persistent and thinking that has a specific purpose [19][20][21]. Critical thinking includes disposition and critical thinking skills [19][22]. Critical thinking skills are higher-order process skills that help students connect knowledge by using information from multiple sources and experiences to gain a broader perspective and deeper understanding [19][22]. Thinkers who use these cognitive skills will have skills in: identifying a problem and assumptions, recognizing essential relationships, making conclusions based on data and facts, and interpreting the conclusions from the information received [23]. Skilled individuals will be better at doing tasks with fewer mistakes when compared to less skilled individuals when given the same task [22]. Facione explained that critical thinking includes interpretation, analysis, evaluation, inferences, and explanation [24].

Critical thinking skills are highly recommended to be trained with a constructivism-based learning model. Previously, there have been reports on the results of development research on constructivism-based CTC models designed to train and improve critical

thinking dispositions and skills, namely the Critical Thinking Cycle (CTC) model [11]. Based on these results, the CTC model has proven relevant and consistent in developing pre-service science teachers' disposition and critical thinking skills. The CTC model has six phases/stages of the learning cycle: (1) thinking about issues/problems; (2) teaching critical thinking through modeling; (3) truth seeking & exploration; (4) thinking together: explaining & discussing with an expert; (5) trying implementation; and (6) evaluating critical thinking. Each cycle in this model always ends with evaluation and reflection to improve the development of critical thinking in the next lesson [11].

This study aims to examine the effectiveness of the CTC model in improving students' critical thinking skills. Implementing learning in universities was conducted online during the Covid 19 pandemic. Therefore, the implementation of the CTC model in this study was carried out online with the help of the Google Classroom and Zoom Meeting platforms.

2 Method

2.1 Design Research

This research is a pre-experimental study with one group pretest-posttest design [25]. The implementation of the CTC model was given for four meetings on the acid-base material and the colligative properties of the solution. Design research is shown in Table 1.

Experimental treatment using the CTC model was carried out online. Classes were given treatment in the form of learning using the online CTC model on acid-base materials and the colligative properties of solutions. Acid-base material was taught in two meetings covering the theory, properties, and strength of acid-base while the colligative properties of solutions were taught in two meetings covering colligative properties of electrolyte and non-electrolyte solutions.

Table 1 is the platform used at each online CTC model implementation stage. The first, second, third, and fourth phases are implemented synchronously with the help of the Zoom Meeting platform. The application of the fifth and sixth phases of the model is carried out asynchronously. CTS is given before and after learning activities using the CTC model.

2.2 Subjects and Data

The research subjects were 30 pre-service science teachers. This study was conducted in basic chemistry classes at universities in Surabaya, Indonesia. There were pre-service science teachers from Science Education Study Program, Universitas Negeri Surabaya (UNESA).

Table 1. Research Design

Pretest (01)	Experiment (x)	Posttest (02)
	CTC Model	CTST

Data were collected using the Critical Thinking Skills Test (CTST) instrument with 30 questions measuring five indicators of critical thinking skills. There were 15 questions for acid-base materials and 15 questions for the colligative properties of solutions. This instrument is in the form of true or false questions accompanied by reasons. The measurement of critical thinking skills indicators has been presented in Table 2.

2.3 Data Analysis

The obtained data were in the form of pre-test and post-test scores of pre-service science teachers' CTS. Analysis of critical thinking skills improvement by determining the

Table 2. The implementation of CTC model

Syntax CTC model	Platform
Thinking issue/problem	Zoom meeting
Teaching critical thinking through modeling	Zoom meeting
Seeking and exploring truth	Zoom meeting with breakout room
Thinking together by explaining and discussing with experts	Zoom meeting
Conducting implementation trial	Google classroom (assignment fitur)
Evaluating critical thinking	Google classroom with google form

Table 3. Instrument of CTST*

CTS	Indicators	Question
K1. Interpretation	K.1.1 Interpreting the facts of the problem and the data presented on the concept of acid-base base and colligative properties of solutions; K.1.2 Classifying the findings on the concept of acid-base and colligative properties of solutions using certain classifications	Six questions
K2. Analysis	K.2.1. Identifying problems related to acid-base and colligative properties of solutions	Six questions
K3. Evaluation	KD.3.1. Assessing the statements about acid-base phenomena and colligative properties of solutions	Six questions
K4. Inferences	K.4.1. Drawing conclusions based on experimental data on acid-base and colligative properties of solutions	Six questions
K5. Explanation	K.5.1. Explaining the reasons for agreeing or disagreeing with statements related to acid-base and colligative properties of solutions	Six questions

* adapted from Facione (2015)

normalized gain score [26]. *Normalized gain* (*N-gain*) is the ratio of the actual average gain to the maximum possible average gain.

$$N - gain = \frac{S_{postest} - S_{Pretest}}{S_{maximum} - S_{Pretest}} \quad (1)$$

N-gain states the CTC model's effectiveness in improving students' critical thinking skills. The criteria for increasing N-gain are presented in Table 3.

This normalized score gain is the level of treatment effect on the score acquisition, meaning that the CTC model is effective in improving students' critical thinking skills.

3 Data and Discussion

The results showed that the CTC model effectively improved students' critical thinking skills. The effectiveness of the CTC model in improving critical thinking skills was analyzed based on the increase in students' critical thinking skills scores (*N-gain*). Based on the results of the *N-gain*, the increase in students' critical thinking skills in the high *N-gain* category is presented in Table 4.

Table 4 shows an increase in students' critical thinking skills before and after learning with the CTC model with an average N-gain value of 0.719 (high category). CTC model effectively improves students' critical thinking skills on indicators of interpretation, analysis, evaluation, inference, and explanation. The results of this study prove that the CTC model significantly improves students' critical thinking skills. The CTC model has been designed to train critical thinking at every stage of the learning phase. The CTC model has been proven theoretically and empirically based on validation studies which show that this model has been designed to be relevant and consistent in training students' critical thinking dispositions and critical thinking skills [11] (Table 5).

The CTC model had designed to train critical thinking at every stage of the learning phase [11]. Based on Table 4 and Fig. 2, the KBK Indicator, which has the highest average score and an increase in N-gain, is interpretation, then the next is analysis, inference, evaluation, and explanation. So the critical thinking skills that are most developed and have increased in the high category are interpretation and analysis.

Table 4. The improvement of preservice science theacers' critical thinking skills

Syntax CTC model	Pretest	Posttets	N-gain
K1. Interpretation	35.65	88.58	0.823
K2. Analysis	24.85	81.64	0.755
K3. Evaluation	32.25	79.48	0.697
K4. Inferences	29.78	79.32	0.705
K5. Explanation	45.06	79.32	0.713
K1. Interpretation	35.65	88.58	0.823
Average score	**33.37**	**81.51**	**0.719**

Table 5. Criteria of *Normalized Gain*

Score N-gain	Criteria
N-gain > 0.70	High
0.30 ≤ N-gain ≤ 0.70	Moderate
N-gain < 0.30	Low

* adapted from Hake (1997)

The development of interpretation indicators is measured from six questions on the acid-base and colligative properties of the solution. In this study, students were tested with CTST questions by interpreting facts/finding data and classifying data or opinions using certain classifications. Interpretation skills include categorizing, deciphering meaning, and clarifying meaning. Interpretation is a person's ability to understand and state the meaning or intent of experiences in various situations, data, events, decisions, conventions, beliefs, rules, procedures, or criteria [24]. This skill is trained from the beginning (phase 01) of learning the CTC model, where learning begins with observing a phenomenon or issue/problem and then thinking about and interpreting the observations by conducting question and answer activities. Students have been able to interpret the data by categorizing.

Through thinking about issues/problems, students are expected to be able to interpret and share/communicate the results of their interpretations. Using issues/problems makes content more engaging, meaningful, challenging, and relevant to increase engagement among students, motivation, and skills [27]. In addition to phase 01, interpretation indicators are also developed in the second, fourth, and fifth phases. In the second phase, students reinterpret the phenomena in phase 01 after observing the modeling carried out by the model lecturer, then make decisions regarding the issues/problems to be investigated. Meanwhile, in the fourth phase, students will practice interpreting data after they have collected various information to seek the best knowledge in the third phase of the CTC model. In the fifth phase, students practice applying critical thinking skills questions.

The second KBK indicator that develops is analysis. The analysis is the ability to identify intentions and inferential relationships based on beliefs, decisions, experiences, reasons, information or opinions. Skills in analysis began to develop in the model's second phase. In the second phase, students will begin to practice analyzing the problem to be selected, deciding claims and hypotheses to be proven/tested, and planning alternative solutions to be used after observing the modeling of the lecturer. Indicators of analysis were measured from six CTST questions about acid-base and colligative properties of solutions. In this indicator, students are tested with questions to identify problems and inferential relationships on the concept of acid-base and the colligative properties of solutions.

Explanation, evaluation, and inference have almost identical average development and N-gain scores. The KBK indicators of explanation, evaluation, and inference have developed well, although the average value is lower than the other indicators. However, based on the record of obstacles during the implementation of the CTC model, it is known

that students still have difficulties formulating claims or hypotheses and in alternative solutions. During model implementation, students still need guidance from lecturers. Lecturers need to model and guide students in identifying and determining the elements needed to form hypotheses/claims on the issues to be studied. This causes the average inference value to be lower than other KBK indicators.

The inference is an individual's ability to make conclusions based on several statements [22][28]. The ability to conclude or make generalizations can be trained by applying the concepts, principles, and skills they have learned to solve their problems [29]. Inference is trained in the second, fourth, and fifth phases during the implementation of the CTC model. In phase two of the CTC model, students formulate claims or hypotheses, which are then proven true in the third phase, and the truth is decided in the fourth phase of the model. So during the implementation of the model, students practiced inference by forming hypotheses and or claims and formulating alternative solutions. In addition to the second phase, the inference is also trained in phase four of the CTC model. In the fourth phase of the CTC model, students practice drawing temporary conclusions before discussing them with experts, and in the fifth phase, practicing critical thinking skills. Furthermore, students discuss with experts to conclude by accepting or rejecting claims in the fourth phase. In this fourth phase, evaluation skills are also trained.

Evaluation is assessing the credibility of statements or other representations and being able to assess the logical strength of inferential relationships [22][24]. During the learning of the CTC model, after the truth-seeking and exploration activities, students are trained to assess the truth of statements about the concept of acid-base and colligative properties of solutions through a series of discussion, question, and answer activities with experts. Students practice developing critical thinking skills in evaluation starting in the fourth phase of the CTC model. In this fourth phase, students also practice much explanation. Explanation is a skill in explaining reasons/arguments that agree or disagree with an opinion or statement or explain concepts from various points of view [22][24]. Students practice explaining the reasons for agreeing or disagreeing with statements from various points of view related to information found and proven during the search for the truth of claims in the third phase of the CTC model. Through discussion activities with experts and other group members (in the fourth phase), students share opinions between groups, ask questions, offer suggestions to explain the findings, data analysis, and tentative conclusions, and draw final conclusions by accepting or rejecting the claims made has been proposed.

The CTC model is effective in improving students' critical thinking skills. Models that can facilitate students to think, explore, and find information/concepts in depth, explain, apply, and evaluate concepts that have been learned independently are very suitable for developing critical thinking [30][31][32]. The researcher found several learning activities that support implementing the CTC model to practice critical thinking skills: question and answer, discussion (groups and classes), truth-seeking, and exploration. These activities follow constructivism theory, where a person must actively construct knowledge through personal experience with others and the environment [33].

CTC learning facilitates students to experience assimilation and finally reach a state of imbalance (disequilibration). When students experience disequilibrium, students will collect data and look for trends or relationships in the data to develop new concepts.

Furthermore, educators can guide students to interpret, find data and construct concepts and accommodation of concepts, which results in equilibration [11]. Through this CTC model, participants are trained and allowed to organize concepts, and new skills learned with other concepts they already know. The CTC model was developed based on Piaget's theory of intellectual development, such as assimilation, accommodation, and organization, which goes through exploration, explanation, and elaboration. Previous researchers have also shown that elaboration can train students' intellectual systems to improve critical thinking skills [31].

The CTC model is designed as a cycle with the aim that students understand the importance of developing critical thinking and conceptual understanding by emphasizing the ability of students to use scientific investigations in seeking the best knowledge or meaningful learning experiences on the basis of constructivism. These findings also prove that a constructivist approach can train critical thinking skills. Previous researchers suggested improving teaching practices by adopting a constructivist approach to foster critical thinking skills [7][34].

4 Conclusion

The CTC model is effective in improving students' critical thinking skills. This can be seen from the increase in the N-gain score in the high category. Thus, this model can be used as an alternative learning model to train students' critical thinking skills. Based on the study's results, we propose that the CTC learning model can be applied as an alternative learning model that can be implemented both online and offline.

In addition, this model can also assist students in improving critical thinking skills, which are very much needed in implementing the Indonesian Education curriculum in the 21st century and the industrial revolution 4.0. However, further research is still needed to investigate the implementation of the CTC teaching model on a broader number of samples and levels of education other than tertiary institutions. It will evaluate the reliability of the CTC learning model.

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