Pegem Journal of Education and Instruction, Vol. 13, No. 2, 2023 (pp. 173-181)

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RESEARCH ARTICLE **WWW.PEGEGOG.NET**

Online Critical Thinking Cycle Model to Improve Pre-service Science Teacher's Critical Thinking Dispositions and Critical Thinking Skills

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Abstract

Currently critical thinking skills is becoming an important education issue to overcome the challanges of industrial revolution 4.0. Previous studies reported that the pre-service teachers' critical thinking dispositions and skills were still low, therefore, both aspects of critical thinking should be improved through learning activities in higher education. This study aimed to determine the effectiveness of the online critical thinking cycle learning model to improve pre-service science teachers' critical thinking disposition and critical thinking skills. This study used pre-experimental research with one group pretest-posttest design. The online critical thinking cycle learning model was implemented in two classes without a control group. A total of 58 pre-service science teachers from two different universities participated in this study. Each pre-service teacher's critical thinking dispositions and skills were measured using the critical thinking disposition inventory and critical thinking skills test. The results showed that the pre-service science teachers' critical thinking disposition and critical thinking skills increased after the implementation of the online critical thinking cycle learning model with a g score of 0.697 and 0.712, respectively. There was no significant difference in the pretest and post-test scores, and there was a consistent increase in g score between the two classes studied. Thus, the online critical thinking cycle learning model is effective and consistent to improve pre-service science teachers' critical thinking dispositions and skills.

Keywords: Critical thinking dispositions, critical thinking skills, online critical thinking cycle model.

Introduction

Practicing critical thinking through learning interventions has been a neglected area in most educational institutions (Ali & Awan, 2021). The development of critical thinking is important for educational institutions to ably produce competitive graduates (Ridho et al., 2020). Both higher education and secondary schools need to prepare qualified and competent graduates who conceive critical thinking skills so that they can compete in Industrial Revolution 4.0 (Hafni et al., 2020). Many education experts have made their consensus on the fact that critical thinking is currently becoming an important education issue to cope with the challenges of Industrial Revolution 4.0 (Adnan et al., 2021; Ridho et al., 2021; Ulger, 2018; Hafni et al., 2020).

Education must be conducted more optimal and effective in preparing graduates to perceive critical thinking skills (Ulger, 2018; Ali & Awan, 2021). In Indonesia, critical thinking becomes one of the important learning aspects in shaping people's cognition so that they might solve any confronting life obstacles precisely (Hafni et al., 2020). Educators, including but not limited to pre-service teachers, are the strategic role models and facilitators in forming and developing students' critical thinking skills (Fikriyatii et al., 2022).

Teaching critical thinking to pre-service teachers has been widely a concern by many researchers since it is presumed to be the best way in creating brighter future generations who own the skills to disseminate and analyze information. Moreover, the existence of pre-service teachers could be the education capital in succeeding the actualization of permeating critical thinking in the teaching and learning activities (Palavan, 2020; Prayogi et al., 2018; Sendag et al., 2015). Indeed, pre-service teachers must have critical thinking competencies before they train the skills in their students (Palavan, 2020; Prayogi et al., 2018). Several previous studies depicted that the majority of Indonesian students had poor achievement in critical thinking because their teachers had not been able to properly teach critical thinking skills, such as creating justifiable decisions and solving problems effectively (Suarniati et al., 2018).

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How to cite this article: Sutoyo S, Agustini R, Fikriyati A (2023). Online Critical Thinking Cycle Model to Improve Pre-service Science Teacher's Critical Thinking Dispositions and Critical Thinking Skills. Pegem Journal of Education and Instruction, Vol. 13, No. 2, 2023, 173-181

Source of support: Nil

Conflict of interest: None.

DOI: 10.47750/pegegog.13.02.21

Received : 07.08.2022

Accepted :25.11.2022 **Published:** 01.03.2023

Previous studies also found that the pre-service teachers' critical thinking dispositions and critical thinking skills were still low, therefore, both aspects of critical thinking should be improved through learning activities in higher education. The other studies reported that the pre-service teachers' critical thinking dispositions and skills were still in the weak category and underdevelopment (Fitriyani et al., 2018; Fitriyani et al., 2019). The results of the preliminary study also found that the pre-service teachers' critical thinking dispositions and critical thinking skills were still low (Fikriyati, et al., 2022). Previous studies suggested that training pre-service teachers' critical thinking dispositions and skills should be undertaken. Henceforth, serious handling through learning interventions is required to improve the pre-service science teachers' critical thinking dispositions and critical thinking skills (Fitriyani et al., 2018; Fitriyani et al., 2019, Fikriyati et al., 2022).

In addition, some studies showed that people might not perform their critical thinking skills better except appropriating critical thinking dispositions (Sendag et al., 2015). There is a positive relationship between critical thinking disposition and critical thinking skills (Kirmizia, et al., 2015; Bell & Loon, 2015). Ali & Awan (2021) suggested that critical thinking dispositions and critical thinking skills should be trained through the learning process using a constructivist approach to make students master the two aspects of critical thinking (Ali & Awan, 2021). Unfortunately, there are still few studies that implemented the development of critical thinking dispositions and critical thinking skills simultaneously through learning (Rauscher & Badenhorst, 2020). Instructional interventions based on active and collaborative learning strategies have been proven to be more effective in promoting critical thinking skills among higher education students (Ali & Awan, 2021). One of the constructivist-based learning models is the Critical Thinking Cycle (CTC) learning model (Fikriyatii, et al., 2022).

Critical Thinking Cycle Learning Model

Critical Thinking Cycle (CTC) is a constructivist-based learning model designed to train and improve students' critical thinking dispositions (CTD) and critical thinking skills (CTS). This model is composed of six phases, namely 1) thinking about issues/problems, 2) teaching critical thinking through modeling, 3) seeking and exploring truth, 4) thinking as well as explaining and discussing the issues with experts, 5) conducting implementation trials, and 6) evaluating critical thinking (Fikriyatii et al., 2022) (Figure 1).

Figure 1 are syntax of the CTC learning model adapted from Fikriyatii et al. (2022). Each cycle is ended with evaluation and reflection to improve the development of CTD and CTS in the next lesson.

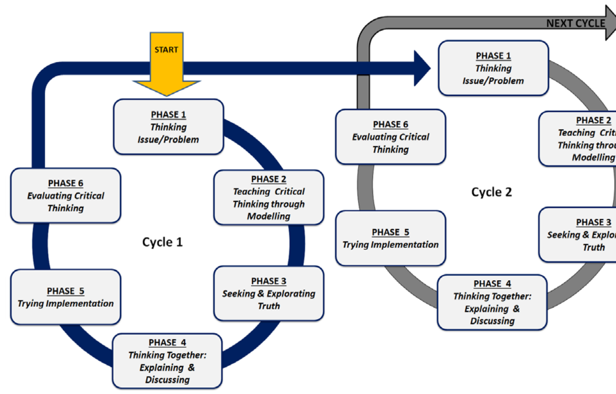

Fig 1. CTC Learning Model

Critical Thinking Dispositions and Critical Thinking Skills

Critical thinking is a reflective and rational thought process (Ennis, 2011). It is one of the high-level thinking that should be the center of learning development as it makes humans have life skills, creativity, and innovation to confront complex real-life problems (Prayogi et al., 2018). Someone who perceives critical thinking skills will have a careful consideration to collect various evidence/information before making a decision or setting a position (Saputro et al, 2022). Nonetheless, critical thinking requires not only the skills to properly assess reasons, but also the willingness, desire, and disposition to base one's actions and beliefs on the reasons (Ennis, 2011; Facione, 2015).

Critical thinking includes critical thinking dispositions (CTD) and critical thinking skills (CTS) (Ennis, 2011; Facione, 2015). Critical thinking skills (CTS) are a detailed description of several characteristics that include the process of interpretation, analysis, evaluation, inferences, explanation, and self-regulation. Whereas, critical thinking dispositions (CTD) are the tendency to behave toward critical thinking. It is also understood as an attitude that can form one's certain behavior. This attitude becomes an identity for a person in dealing with various life problems. CTD includes truth-seeking, open-mindedness, analysis, systematicity, confidence in reasoning, inquisitiveness, and maturity of judgment (Facione 2015). This study developed seven CTD indicators and five CTS indicators adapted from Facione (2015).

Research Question

This study aimed to determine the effectiveness of the online critical thinking cycle (CTC) learning model to increase the pre-service science teachers' critical thinking dispositions (CTD) and critical thinking skills (CTS). Moreover, the present study specifically aimed to explain pre-service science teachers' CTD and CTS before and after the implementation of the online CTC learning model and to report the effectiveness and consistency of test results of the online CTC learning model. A detailed description of this research's purpose is investigated by making questions. 1) How is the average class's improved CTD and CTS? 2). How is the improvement profile of each indicator of CTD and CTS? 3) How the effectiveness of the CTC model to improved the pre-service science teachers' critical thinking dispositions and critical thinking skills?

Previously, the researchers have reported the results of developing a CTC model that was designed to train and improve critical thinking dispositions and critical thinking skills. Based on the results of content and construct validation of the CTC model, the model was relevant and consistent in facilitating the development of the pre-service science teachers' critical thinking dispositions and critical thinking skills. However, further research is necessary to be conducted to determine the implementation and the effectiveness of the model (Fikriyatii et al., 2022). The present study is a continuation of the previous study on the CTC model development. The implementation of the learning processes held in universities was carried out online due to the limited physical gathering and interaction during the Covid 19 pandemic. The present study used the Google Meeting platform and Google Classroom to conduct a class.

Method

Research Design

This study was pre-experimental research with one group pretest-posttest design (Fraenkel & Wallen, 2012). Experiments were carried out by implementing the CTL learning model. This study was conducted in two classes without using a control class (Figure 2).

Both 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. During the Covid 19 pandemic, the learning processes were carried out online. This study used the Zoom Meeting platform and Google Classroom. Table 1 conveys the platform used at each online CTC model implementation.

Name of Class	*Pretest (CTST&CTDI)*	*Treatment group*	*Posttest (CTST & CTDI)*	*N*
1A UINSA	O1	CTC Model	O4	31
1C UNESA	O3	CTC Model	O5	27

Fig 2: Research Design

Zoom meetings were used for the first, second, third, and fourth phases of the model that were carried out synchronously. Practical activities were carried out in groups using a virtual laboratory in the third phase of the model that was carried out by utilizing the breakout room feature in the zoom meeting. The application of the fifth and sixth phases of the model was carried out asynchronously. Pretest and posttest about CTD and CTS were given before and after learning activities using the CTC learning model, respectively.

Participants

This study was conducted in basic chemistry classes at two different universities in Surabaya, Indonesia. From three basic chemistry classes at the Undergraduate Program of Science Education, Universitas Negeri Surabaya (UNESA), and two basic chemistry classes at the Undergraduate Program of Science Education, Universitas Islam Negeri Sunan Ampel Surabaya (UINSA), one class was randomly selected for research, respectively. There were 27 pre-service science teachers from the Undergraduate Program of Science Education at UNESA and 31 pre-service science teachers from the Undergraduate Program of Science Education at UINSA.

Data Collection

Critical Thinking Disposition Inventory (CTDI)

CTDI was used to measure pre-service science teachers' critical thinking dispositions (CTD). This assessment sheet was in the form of a questionnaire containing 27 statements on a six-point graded scale from 1 (strongly disagree) to 6 (strongly agree) if the statement was positive, and from 1 (strongly agree) and 6 (strongly disagree) if the statement was negative. Table 2 shows the components and indicators of CTDI.

Table 1: *Online implementation of the CTC learning model.*

Syntax CTC model	*Platform*	*Description*
Thinking about issue/problem	Zoom meeting	Synchronous
Teaching critical thinking through modelling	Zoom meeting	Synchronous
Seeking and exploring truth	Zoom meeting with breakout room	Synchronous
Thinking as well as explaining and discussing the issue with experts	Zoom meeting	Synchronous
Conducting implementation trial	Google classroom (assignment fitur)	Asynchronous
Evaluating critical thinking	Google classroom with Google form	Asyncronous

Critical Thinking Skills Test (CTST)

CTST was used to measure pre-service science teachers' critical thinking skills. It was compiled on acid-base material and the colligative properties of the solution in the form of 30 true-false written test questions with reasons. There were 15 questions for acid-base materials and 15 questions for the colligative properties of solutions. Table 3 shows the components and indicators of CTST (Table 3).

Data Analysis

The obtained data were in the form of pretest and posttest scores of pre-service science teachers' CTD and CTS. The total CTD score was calculated by adding up the scores of 27 answers on each aspect of the CTDI. Meanwhile, the CTS score was calculated by determining the scores obtained compared to the maximum score for 30 CTST questions. The analysis of increasing CTD and CTS was carried out by determining the normalized gain score (Hake, 1998). Normalized gain (*g*) was defined as the ratio of the actual average gain to the maximum possible average gain.

$$g=\frac{S_{post}-S_{pre}}{S_{max}-S_{pre}} \qquad \text{equation (1)}$$

The *g* score was the normalized gain score, $S_{postest}$ was the post-test score, S_{pre} was the pre-test score, and S_{max} was the maximum score. The *g* score showed the effectiveness of the CTC learning model to improve the pre-service science teachers' CTD and CTS. Table 4 shows the criteria for the increasing *g* score (Table 4).

The effectiveness of the CTC learning model was analyzed statistically using the differential tests in the average pretest and posttest scores, namely using the Paired Sample t-Test from each class. The hypothesis to be tested is that there is a significant difference in the average CTD and CTS scores of students between the pretest and posttest. It is essential to find out how significant is the impact of the CTC model implementation. The consistency of the CTC learning model was determined by testing the difference in the mean *N-gain* for the 2 classes using the Independent Sample t-Test. The hypothesis to be tested is that there is no significant difference in the students' CTD and CTS n-gain scores between the two classes studied (A and C).

The data analysis technique was carried out using SPSS 26. Assumption tests, namely normality and homogeneity tests, had to be carried out before the t-test was used. The researcher had tested the normality using the Shapiro-Wilk test and

Table 2: CTDI Components and Indicators*

Components	*Indicators*
D1. Truth Seeking	Having the courage and honesty to find and prove the truth of information/knowledge by looking for various reasons or relevant evidence
D2. Open-mindedness	Demonstrating tolerance for different views/opinions/beliefs/ideas
D3. Analyticity	Being able to give reasons and think about the consequences of every situation, choice, or plan to be carried out
D4. Systematicity	Demonstrating regularity, focus, and persistence in researching information, building knowledge, dealing with questions, and solving problems
D5. Inquisitiveness	Demonstrating intellectual curiosity and desire to learn even though the application of the knowledge was limited
D6. Confidence in Reasoning	Demonstrating self-confidence, respecting the power of thinking skills, and being able to guide others to solve problems rationally
D7. Maturity of Judgment	Being able to measure one's wisdom in making decisions

*adapted from Facione (2015)

Table 3: CTST Components and Indicators*

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

*adapted from Facione (2015)

Table 4: Criteria of Normalized Gain (Hake, 1998)

g	*Criteria*
g > 0.70	High
0.30 ≤ g ≤ 0.70	Moderate
g < 0.30	Low

the homogeneity test was carried out with the Lavene Test for all pretest, posttest, and *g* data. The results showed that the data were normally distributed and homogeneous with a significance value > 0.05. The results indicated that the pre-test, post-test, and *g* data came from a population that was normally distributed and homogeneous. So, a t-test could be performed.

Findings

Pre-Service Science Teacher's Critical Thinking Dispositions

Table 5 shows the results of the analysis of the disposition score and the increase in *g* of pre-service science teachers' critical thinking dispositions (Table 5).

Table 5 shows an increase in the pre-service science teachers' CTD with the implementation of the CTC learning model for each class with an average of *g* score in the medium (0.687) and high (0.709) categories. The development of CTD could also be seen from the analysis results of the increase in the average *g* score on each aspect of CTD indicators (Table 6).

Every aspect of CTD indicators had developed in the high and medium *g* categories after the implementation of the online CTC learning model.

Pre-Service Science Teacher's Critical Thinking Skills

Table 7 depicts the *g* scores and improvements in students' critical thinking skills (CTS) before and after the implementation of the CTC learning model.

Table 7 shows the increase in the pre-service science teachers' critical thinking skills with a *g* score in the high category for the two classes. Table 8 depicts the development results data for the five CTS indicators (Table 8).

The five indicators of critical thinking skills (CTS) had increased in with the g scores classified in the high category after the implementation of the online CTC learning model.

The Effect of Online Critical Thinking Cycle Learning Model on Pre-Service Science Teachers' CTD and CTS

Table 9 portrays the test results of the effectiveness and consistency of the online CTC model in improving the critical thinking dispositions (CTD) and critical thinking skills (CTS).

Table 5: Recapitulation and Improvements of CTD Scores

	Class 1A			*Class 1C*		
Description	*Pretest*	*Posttest*	*g*	*Pretest*	*Posttest*	*g*
Maximum (27)	106	160	0.687	114	161	0.709
Minimum (162)	66	122		66	120	
M	86.16	137.96		86.67	140.11	
N	31			27		
High *g* categories	14 (45.16%)			11 (40.74%)		
Moderate *g* categories	17 (54.48%)			16 (59.26%)		
Low *g* categories	0			0		
Average *g*	0.698 (Moderate)					

Table 6: Development of Each Aspect of CTD Indicators

	Class 1A score				*Class 1C score*			
CTD	*Pretest*	*Posttest*	*g*	*Category*	*Pretest*	*Posttest*	*g*	*Category*
D1	14.29	20.84	0.684	Moderate	12.81	20.48	0.721	High
D2	11.00	20.90	0.762	High	13.81	21.67	0.772	High
D3	11.71	20.13	0.664	Moderate	12.48	20.70	0.713	High
D4	12.32	20.03	0.656	Moderate	13.00	20.93	0.695	Moderate
D5	10.60	15.71	0.691	Moderate	10.94w	16.11	0.753	High
D6	12.65	20.13	0.643	Moderate	11.22	19.48	0.647	Moderate
D7	14.26	20.23	0.609	Moderate	14.08	18.72	0.433	Moderate

Table 7: Recapitulation and Improvement of CTS Scores

	Class 1A			*Class 1C*		
Description	*Pretest*	*Posttest*	*g*	*Pretest*	*Posttest*	*g*
Maximum Score	59.17	96.67	0.706	43.33	93.33	0.719
Minimum Score	24.17	69.17		20.83	68.33	
M	41.24	82.63		33.37	81.51	
N	31			27		
High g categories	16 (51.61%)			17(54.83%)		
Moderate g categories	15 (48.38%)			10 (32.25%)		
Low g categories	0			0		
Average g	0.712 (High categories)					

Table 8: Development of Each Aspect of CTS Indicators

CTS	*Class 1A*		*g*	*Category*	*Class 1C*		*g*	*Category*
	Pretest	*Posttest*			*Pretest*	*Posttest*		
K1	48.52	87.23	0.764	High	35.65	88.58	0.823	High
K2	42.34	84.27	0.733	High	24.85	81.64	0.755	High
K3	40.59	80.24	0.667	Moderate	32.25	79.48	0.697	Moderate
K4	39.78	80.11	0.670	Moderate	29.78	79.32	0.705	High
K5	34.95	81.32	0.719	High	45.06	79.32	0.713	High

Table 9: Results of the Effectiveness and Consistency of the Online CTC Learning Model

Parametric Test	*Data*	*N*	*Df*	*T*	*Sig. (2-tailed)*	
Paired Sample t-Test	CTD 1A	31	30	-16.477	0.000	Sig. 0.00 < 0.05 H0 rejected
	CTD 1C	27	26	-19.187	0.000	
	CTS 1A	31	30	-24.504	0.000	
	CTS 1C	27	26	-26.526	0.000	
Independent Samples t-Test	N-gain CTD	31	30	-0.557	0.580	Sig. > 0.05, H0 accepted
	N-gain CTS	27	26	-0.752	0.455	

*$p = 0.005$

Table 9 shows the results of the Paired Sample t-Test, which obtained $p < 0.05$ so H_o was rejected. The results of this study proved that there were significant differences between the pretest and posttest scores of the pre-service science teachers' CTD and CTS for each class. Therefore, the online CTC learning model was effective in improving the pre-service science teachers' CTD and CTS. Based on the results of the Independent Samples t-Test, $p > 0.05$ so H_0 was accepted. In other words, there was no significant difference in the average normalized gain (g) of CTD and CTS between class 1A and class 1C. The results of this study indicated that there was a consistent increase in the CTD in the implementation of learning with the online CTC learning model.

Discussion

The online CTC learning model was proven to be effective in improving the pre-service science teachers' Critical Thinking Disposition (CTD) and Critical Thinking Skills (CTS). The effectiveness had been seen from the gain score of CTD and CTS, and the results of hypothesis testing that have been carried out using paired samples and independent sample t-tests. Based on this research there is a significant difference between the pretest and posttest scores of CTD and CTS, and the consistency of the CTC model on the increase in CTD and CTS between the two classes. This research also showed that the increasing g score of the development of the pre-service teachers' CTS was higher than their CTD. This occurred because the development of CTD took longer than pre-service teachers' CTS. Critical thinking dispositions were attitudes or characteristics that could be developed although the development of CTD might take longer than developing CTS (Facione et al., 2011).

The results of this study indicated that four CTD indicators were in the g development criteria namely truth-seeking, open-mindedness, analyticity, and inquisitiveness. The other three indicators, namely systematicity, confidence in reasoning, and maturity of judgment were in the medium g category. Open-mindedness, truth-seeking, analyticity, and inquisitiveness were important parts of developing CTD. During the implementation of the online CTC learning model, these four indicators had been trained since the first phase of the model. The ideal critical thinker began with inquisitiveness and open-mindedness. Inquisitiveness, truth-seeking, and open-mindedness were motivational components of critical thinking dispositions and were significantly correlated with learning motivation (Dwyer et al., 2014). Truth-seeking was considered an important attitude in critical thinking that significantly affected one's performance and critical thinking skills (Yu, et al., 2013). This meant that the CTC model supported the development of four important disposition indicators that played a significant role in the development of dispositions and were closely related to critical thinking skills.

The two CTS indicators that had the highest g increasing score were interpretation and analysis, then inference, and explanation. The CTS indicator with the medium g category was the evaluation. The four critical thinking skills had been widely trained since the beginning of the online CTC learning model. Through thinking about issues/problems and truth-seeking, the pre-service teachers were expected to be able to interpret, plan problem-solving, analyze results, and share or communicate the results. The use of issues/problems and trust-seeking made the contents more interesting and challenging to prove the truth of information so that the pre-service teachers' involvement, motivation, and skills increased (Anshori et al., 2016).

There was a relationship between the pre-service teachers' CTD and CTS. Based on the CTD and CTS scores, pre-service teachers who had CTD scores in the high category also had high CTS scores. This confirmed that the previous research's thinking disposition was strongly related to the thinking skills. The study showed that individuals without a thinking disposition could be disabled in using their thinking skills (Sendag et al., 2015). CTD and CTS were mutually reinforcing each other and significantly correlated (Palavan, 2020; Ali & Awan, 2021). Individuals needed a critical thinking disposition to use their critical thinking skills. Critical thinking required not only the skills to properly assess reason, but the disposition to base one's actions and beliefs on reason (Ennis, 2011; Facione, 2015).

This model had a constructivist approach that consisted of six learning steps. The present study's findings also proved that critical thinking skills could be trained through a constructivist approach. Previous researchers suggested improving teaching practice by adapting a constructivist approach to foster critical thinking skills (Ali & Awan, 2021; Saputro et al, 2022). In the first phase, pre-service teachers started by interpreting the phenomenon of acid-base and colligative properties of solutions related to daily life, for example, the process of making traditional ice cream that utilized the concept of freezing point depression of solutions. Questions and answers and discussions took place in the first phase of the CTC learning model. Furthermore, pre-service teachers observed the modelling and motivation carried out by the model lecturer and made decisions by formulating problems, claims, and/or hypotheses as well as alternative problem-solving solutions plans related to the issues/problems investigated. For example, how to prove that there was a freezing point depression in the traditional ice cream making process. The activities of the third phase of the model were finding out the truth and exploring through experimentation and information seeking to find the best knowledge. The results of the third phase of the model were discussed and presented in the fourth phase, then decided whether to reject or accept the claims that had been investigated. The fifth and the sixth phases of critical thinking evaluation were carried out independently with guidance and feedback from lecturers. So, during the implementation of the CTC learning model, lecturers acted as mentors, motivators, models, facilitators, consultants/experts, and mediators in the learning process to train CTD and CTS.

Researchers found that several online learning activities of the CTC model that supported the development of critical thinking were question and answer, discussion (groups and classes), truth-seeking, exploration, elaboration, and evaluation. These activities were by constructivism theory where a person must actively construct his knowledge through personal experience with other people and the environment (Moreno, 2010). Models that could facilitate students to think, explore, and find concepts, explain, apply, and evaluate independently the learned concepts were very suitable for developing critical thinking (Palavan, 2020; Rauscher & Badenhorst, 2020; Budprom et al., 2010). Previous researchers had shown that elaboration was able to train students' thinking processes so that they could improve their critical thinking skills (Budprom et al., 2010).

The present study's findings supported the results of the previous studies that suggested that to develop critical thinking, lecturers must train it through discussion activities (Živkoviüa, 2016; Kalelioğlu & Gülbahar, 2014), persistent, thorough, and continuous reflection (Alotaibi, 2013; Akyuz & Samsa, 2009), seeking the best knowledge (truth-seeking) (Anshori et al., 2016) and exploration (Haghparast et al., 2013). Information-sharing activities through discussions and questions and answers were highly recommended in developing critical thinking because pre-service teachers could share, combine, and synthesize credible information (Kalelioğlu & Gülbahar, 2014; Hajhosseini, et al., 2016).

Another finding from the implementation of the CTC learning model was the importance of mentoring from lecturers so that the pre-service teachers were actively involved and more confident in developing critical thinking during the learning activities. During the development of critical thinking skills, modelling and motivation were essential aspects to be considered. Moreover, the present study's findings supported the results of previous studies that recommended the importance of modelling in learning by observing the motivation and mentoring or behaviour of others (Alotaibi, 2013; ivkoviüa, 2016; Temel, 2014). To teach critical thinking, lecturers must be able to demonstrate their thinking processes to their students. Students must be guided to develop critical thinking skills otherwise they would not be able to work to develop the skills properly (Palavan, 2020).

Overall, the CTC learning model was effective and consistent in improving pre-service teachers' critical thinking dispositions and critical thinking skills. This effectiveness could be referred to as the increasing results of the normalized gain scores (Hake, 1998) and the significance of the test results conveyed in the paired sample t-test mean (Lestari et al, 2021). The model was consistent based on the test results of the difference in the mean of the two unpaired samples that showed a consistent increase in the disposition of the critical scores of the two classes. In this online CTC learning model, the ways that lecturers did to develop the pre-service teachers' CTD and CTS were by (1) attracting pre-service teachers' curiosity by asking lots of questions, (2) modelling, motivating, and convincing pre-service teachers to be confident in critical thinking, (3) guiding the pre-service teachers to explore and seek the truth of the issues/problems discussed, (4) facilitating and mediating group discussion activities by involving experts, (5) strengthening pre-service teachers' concepts, dispositions, and critical thinking skills by integrating them into new problems, and (6) evaluating the development of CTD and CTS (Fikriyatii, et al., 2022).

Conclusion

The CTC model is effective and consistent in improving the pre-service science teachers' critical thinking dispositions (CTD) and critical thinking skills (CTS). This can be seen from (1) the increase in CTD for each class that is in the medium (0.687) and high (0.709) categories; (2) the increase in CTS in both classes that are in the high category (0.706 and 0.712, respectively); (3) improvement of seven CTD indicators that are in the high and medium *g* categories; (4) the increase in five CTS indicators that are in the high and medium *g* categories; (5) a significant difference between the pretest and posttest scores of CTD and CTS ($p < 0.05$) for the two classes; and (6) the consistency of the CTC model ($p > 0.05$) on the increase in CTD and CTS between the two classes. Thus, this model can be used as an alternative learning model to train critical thinking dispositions and critical thinking skills

Suggestion

Based on the results of the study, the present study proposes that the CTC learning model can be applied as an alternative teaching-learning model that can be implemented online or offline. In addition, this model can also help students improve their critical thinking dispositions and critical thinking skills that are relevant to the 21st century and the Industrial Revolution 4.0. However, further research is still needed to investigate the implementation of the CTC learning model in a wider number of samples and education levels, therefore, the CTC learning model can be more reliable.

Limitation

There are some limitations, i.e., this research has only been tested on pre--service science teachers from two universities in Surabaya, Indonesia, with a subject of 58 students, and the implementation of the online CTC learning model has used zoom meeting and a google classroom, the material learning limited to acid-base and colligative properties of solutions.

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