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Critical thinking cycle model to promote critical thinking disposition and critical thinking skills of pre-service science teacher

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Abstract

Developing critical thinking in teaching-learning activity is a major issue for educational institutions, and giving appropriate learning model intervention certainly provides an assurance to successfully develop competitive graduates for Industrial Revolution 4.0 challenges. This research aims to validate the development of Critical Thinking Cycle (CTC) model as an intervention. It employs educational development research through validation study design by examining two criteria, content validity (relevance) and constructs validity (consistency). The validation involved five experts through Focus Group Discussion (FGD). The results show that CTC model was valid and reliable (proved by 75% of experts' agreement) which means that CTC model is possibly implemented to promote critical thinking disposition and critical thinking skills from pre-service teachers. Yet, for future study, there is a need to conduct other research to determine the effectiveness and practicality of the model to increase critical thinking disposition and critical thinking skills.

Keywords: content validity (relevance), construct validity (consistency), Critical Thinking Cycle Learning Model.

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I. Introduction

Industrial Revolution 4.0 brings many changes. These rapid changes force individuals to make appropriate preparations and one of them is critical thinking skill. This skill is an important competency which allows individuals to face challenges and changes of the Industrial Revolution 4.0 preparedly (Ridho et al., 2021) (Ulger, 2018); (Hafni et al., 2020). However, in Indonesia, critical thinking is often neglected, especially in learning (Ali & Awan, 2021).

In education world, preparing to face a full of 'disruption' era is hard and complicated. However, despite these hardness and complications, each individual is forced to do it so as not to be left during the competition (Adnan et al., 2021) (ŽivkoviĿ, 2016). Critical thinking is very important and increasingly needed, especially to deal with the complexity of problems caused by the rapid development of technology and social movements in this era (Ulger, 2018). Therefore, more optimal and effective actions should be carried out by all education institutions to prepare graduates skilled in critical thinking (Alotaibi, 2013) (Ulger, 2018) (Ali & Awan, 2021). Considering these demands, teachers put at crucial role because they need to own ability to develop students' critical thinking. Hence, every pre-service teacher should be armed by ability to develop critical thinking skill for their students, including pre-service science teachers.

Ennis (1985) defines critical thinking as reflective and reasonable thinking especially during deciding to do something or solving problems. Critical thinking is needed for deciding on receiving information, forming opinions based on appropriate, logical, and non-subjective reasons, as well as ensuring the correct conclusion (Bassham et al., 2011)(Morales-Obod et al., 2020). The essence of critical thinking is careful goal-directed thinking (Lloyd & Bahr, 2010), meaning that one who thinks critically carefully collects references/evidence before making decisions or believing certain information.

Critical thinking includes critical thinking disposition and critical thinking skills (Ennis, 1985) (Peter A. Facione, 1990). It requires not only the skill to properly assess reasons, but also willingness and disposition to base one's actions and trust on reasons. Critical thinking dispositions are tendencies or habits of mind that make individuals motivated to respond reflectively (P. A Facione, 2015) (Ennis, 1985). Disposition is a way of how one tends to behave towards critical thinking. Moreover, critical thinking skills also known as high-level process skills help people to relate knowledge, information from various sources, and experiences to gain broader perspective and deeper understanding.

Critical thinking disposition highly influences one's character and thinking skills. Many research also agrees on the importance of critical thinking dispositions as distinct entities to distinguish critical thinkers from uncritical thinkers in addition to their actual level of critical thinking ability (Ennis, 1985). High dispositions greatly affect students' learning performance (Pu et al., 2019). Another research also proves the positive and significant relationship between disposition and critical thinking skills (Kirmizi et al., 2015) (Ali & Awan, 2021). Hence, critical thinking disposition existence is as important as practicing critical thinking skills (P. A Facione, 2015).

Teaching critical thinking to pre-service teachers has attracted many researchers because pre-service teachers will play an important role in their teaching activity especially on how to develop critical thinking skills in teaching-learning activities (Prayogi et al., 2018). According to Prayogi & Yuanita (2018), developing critical thinking through learning interventions during pre-service teacher's training in universities is the most appropriate way to intervene and promote critical thinking skills. Higher education for pre-service science teachers should reconsider its instructional practices improving students' critical thinking (Ali & Awan, 2021) (Fikriyati et al., 2022). These situations encourage research and studies on teaching interventions to develop this skill, including developing critical thinking disposition and critical thinking skills for pre-service science teachers.

Prior research suggests improving teaching practice by adopting a constructivist approach to foster critical thinking dispositions and skills (Ali & Awan, 2021). Problem Based Learning (PBL) and Learning Cycle (LC) are two constructivist approach-based learning models that are often employed to train

critical thinking skills or critical thinking dispositions. Many studies proved that PBL(Pu et al., 2019) (Ulger, 2018) and Learning Cycle (Budprom et al., 2010) (Cahyarini et al., 2016) is effective in improving and developing critical thinking. Nevertheless, there are other studies on PBL that found the less significant effects of this method in increasing critical thinking disposition (Pu et al., 2019) (Ulger, 2018) (Temel, 2014).

This research aims to design a Critical Thinking Cycle (CTC) model and validate the CTC model development referring to criteria of relevance and consistency in formatting the learning model. The researcher developed the CTC model based on theoretical studies and empirical evidence from the PBL and LC learning models. Based on the results of the synthesis of previous research on the implementation of PBL and LC learning models to train and improve critical thinking, researchers believe that to develop the disposition and skills of critical thinking several activities need to be carried out, including 1) engagement activities to attract students' curiosity by presenting various questions that encourage their critical thinking; 2) information provision, motivation, and self-confidence of critical thinking through modeling; 3) truth-seeking for issue/problem that is discussed through exploration; 4) group activities such as information sharing and discussions involving experts; 5) concepts-strengthening by allowing students to integrate with new problems; and 6) evaluation and reflection on the critical thinking development for future improvement. These activities serve as a reference in designing a CTC learning model. This research is purposely developed a new learning model that can train, facilitate, and improve pre-service science teachers' critical thinking dispositions and critical thinking skills.

2. Method

2.1 Research Design

As educational development research, this research aims to validate the newly developed Critical Thinking Cycle (CTC) model as a learning intervention. In development research, the intervention is developed as a prototype. This prototype is a CTC model that becomes a supporting learning device to train students' dispositions and skills in critical thinking. The educational development research employed in this research is a validation research design. Validation research is research of educational interventions (such as instructional design/models) aiming to design, develop, and validate theories that underlie the development of the instructional design (Plomp, 2013). This research design develops research-based solutions in solving complex problems in education.

A prototype developed in this research considers good quality if it meets four criteria, namely relevance, consistency, practicality, and effectiveness (Plomp, 2013) (Nivieen & Folmer, 2013). This research focuses on two criteria, namely content validity (known as relevance) and constructs validity (known as consistency) on the prototype of the developed learning model. Content validity assesses the need for model interventions based on the latest scientific developments, while construct validity assesses the constructiveness and logic of the developed model intervention (Nivieen & Folmer, 2013).

The stages of developing the CTC model are presented in Figure 2.1.

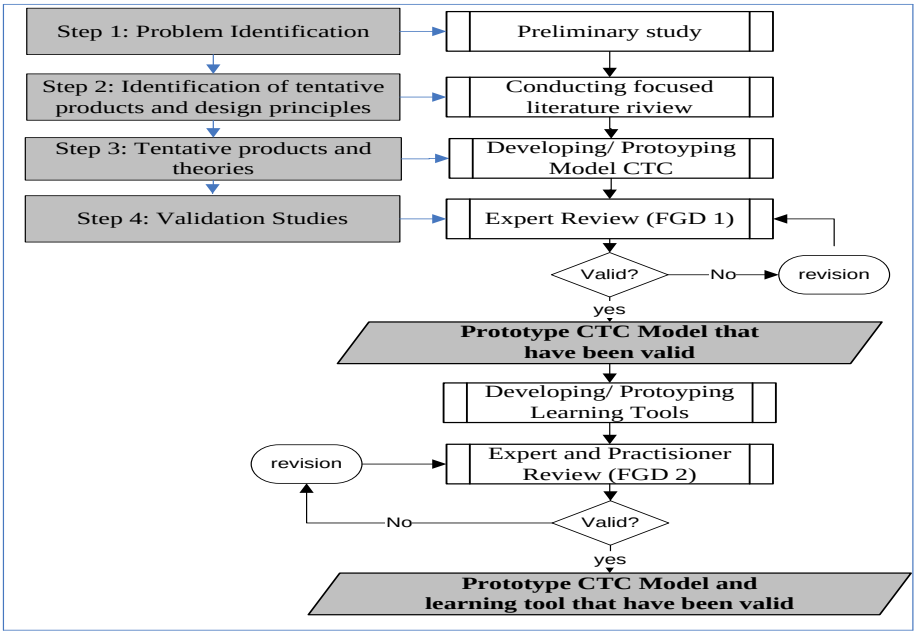

Figure 2.1. Development Stage of CTC Learning Model

This research was conducted through 4 stages (Figure 2.1). Stages 1 and 2 are designing stages that were started with problem identification and conducting a focused literature review. In stage 3 the researchers developed a prototype of the learning model product and supporting learning tools. The product prototype that has been developed is then validated in stage 4.

2.2 Instrument and Data Collection

Data were collected using validation format for the CTC model and learning tools. There are three types of instruments used in validity testing, namely content validity of CTC model, construct validity of CTC model, as well as construct validity of learning tools that support the CTC model. This validation involves five experts who reviewed and provided input through online discussion of Focus Group Discussion (FGD) activities on the CTC model and online assessment by filling out a validation form. Focus Group Discussion (FGD) was conducted twice online through zoom meeting (see Figure 2.1). FGD 1 is aimed to collect the validity of the content and construct of the CTC model that has been developed. Researchers have provided a prototype CTC model and learning tools two weeks before the scheduled FGD implementation. FGD 1 involved five experts. They are three professors and two doctors as experts in chemistry and science education from Universitas Negeri Surabaya. They conducted an assessment by filling out a validity sheet using a validation format for the CTC model. Three experts and two practitioners (chemistry education lecturers) are participated in FGD 2 to assess the construct validity of learning tools that support the developed model. Researchers used three types of validity sheet instruments as presented in Table 2.1.

Table 2.1. Instruments and the Component Assessment of Aspect of Validation

Instrument	**Aspect of Validation**
The Content Validity of CTC Learning Model	(1) The need for CTC model development, (2) CTC model design based on state-of-the-art scientific knowledge, (3) Description of CTC model development
The Construct Validity of CTC Learning Model	(1) Rationality of the development of the CTC model, (2) theoretical and empirical support of the CTC model, (3) planning of the CTC model, (4) implementation and components of the CTC model, and (5) learning environment, and assessment and evaluation of the CTC model
The Construct Validity of CTC Model's Learning Tools	1) Semester learning plans: completeness of content and suitability of content components with the purpose of developing the CTC learning model 2) Lecture program units: completeness of content and suitability of content components facilitate the development of critical thinking dispositions and critical thinking skills 3) Student worksheet: (1) systematics, (2) format and presentation, (3) material, (4) language, and (5) innovation and quality improvement of learning activities 4) Student Book: (1) systematics, (2) format and presentation, (3) material, (4) language, (5) innovation and quality improvement of learning activities 5) Critical thinking disposition inventory: consistency with critical thinking disposition indicators (*trurh-seeking*, *open-mindedness*, *analyticity*, *systematicity*, *self-confidence*, *inquisitiveness*, and *maturity of judgement.* 6) Critical thinking skill tests: consistency with critical thinking skills indicators (*interpretation*, *analysis*, *evaluation*, *inference*, and *explanation*.

(Adapted from Plomp, 2013; Nieveen & Folmer, 2013)

The content validity of the model measures three aspects, namely 1) the need for developing a CTC model, 2) the design of the CTC model that is developed based on scientific knowledge, and 3) a description of the CTC model. The construct validity of the model measures six aspects, namely 1) the rationale in developing a CTC model, 2) theoretical and empirical support of the CTC model, 3) CTC model planning, 4) CTC model implementation and components, 5) learning environment, and 6) CTC model assessment and evaluation (Plomp, 2013) (Nivieen & Folmer, 2013). Meanwhile, the construct validity of the CTC model's learning tools measures consistency and logic of the developed CTC model learning tools (in form of semestrial lesson plans, lecturing units, student activity sheets, student textbooks, as well as critical thinking disposition and critical thinking skills evaluation sheets).

Data Analysis

Data content validity (relevance) and construct validity (consistency) were analyzed descriptively using qualitative statistical approaches to conclude the good quality of the model developed. The CTC model and learning tools validity were assessed using a scale-based validation sheet. This assessment sheet consists of a 4-scale rating, from very invalid (1) to very valid (4) for each aspect of the assessment. Data analysis was carried out by determining the modes and average value of the validation scores

from five experts. The score shows opinion (evaluation) from all validators (Handayani et al., 2020). The score obtained is then converted into qualitative data using 4-scale criteria (see Table 1).

Table 2.2. The criteria of learning model validity

Score Interval	Criteria	Description
3.25< P ≤ 4.00	Very valid	Can be used without revision
2.50< P ≤ 3.25	Valid	Usable with minor revisions
1.75< P ≤ 2.50	Enough	Can be used with major revisions
1.00≤ P ≤ 1.75	Invalid	Cannot be used and need further consultation

Source: adapted from Tukiran, Suyatno & Hidayati (2017) *and Handayani, Rahayu, & Agustini* (2020)

The developed CTC model and learning tools consider valid if the results of components testing scored higher than 2.51 (> 2.15) (Tukiran et al., 2017). Meanwhile, the reliability of model validation and CTC model's learning tools is based on the interobserver agreement obtained from the statistical analysis of the percentage of agreement (PA) (Borich, 1994). The model validation and CTS model's learning tools consider reliable if its percentage is similar or higher than 75% (≥ 75%).

$$PA = \left[1 - \frac{A - B}{A + B}\right] \times 100\%$$

Note:

A = The frequency of the aspect observed by the observer giving a high frequency

B = The frequency of the aspect observed by the observer givin a low frequency

Observer in this research is validator. The results of the validation of the CTC learning model and learning tools are reliable if they have a percentage of 75% (Borich, 1994).

3. Result of Validation Studies

3.1 Prototype Model of the Developed Critical Thinking Cycle (CTC)

The CTC model is a learning model designed to develop critical thinking dispositions and critical thinking skills simultaneously during learning activities. This model has six learning phases, including 1) thinking issue/problem, 2) teaching critical thinking through modeling, 3) seeking and exploring truth, 4) thinking together by explaining and discussing with experts, 5) conducting implementation trial, and 6) evaluating critical thinking.

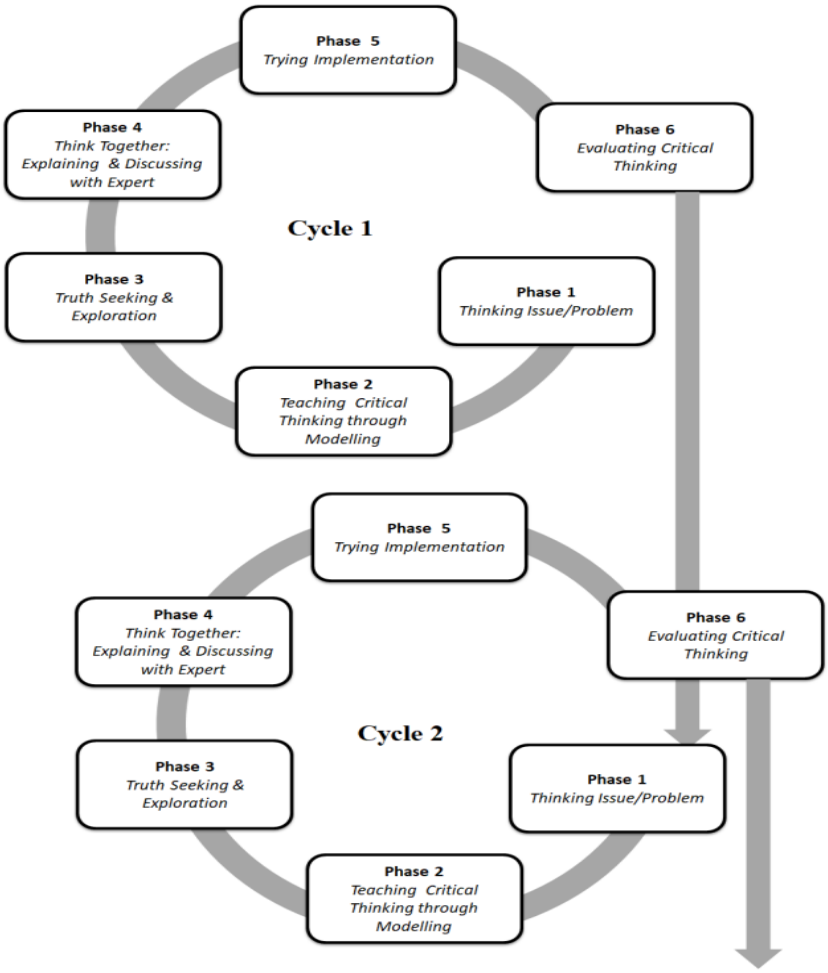

Figure 1. CTC model

This CTC model is designed concerning 1) empirical evidence and logical theoretical rationale for its planning, 2) learning objectives of the developed model, especially to overcome the problem of low critical thinking disposition and critical thinking skills of pre-service teachers, 3) teaching behavior/activities required for learning, and 4) learning environment needed to achieve learning objectives (Arends, 2012) (Joyce et al., 2009). These characteristics are designed in the CTC model book consisting of syntax, social system, reaction principle, support system, instructional impact, and accompaniment impact (see Table 2).

Table 3.1. CTC model description

Syntax	Learning Activities
Phase 1: *Thinking Issue/ Problem*	• Attracting curiosity (inquisitiveness) and observing phenomena/issues related to the concept being studied • Providing statements/issues that raise cognitive conflicts and questions • Guiding students to be confident in thinking (self-confidence) and sharing the results of the identification of problem issues through discussion activities

Phase 2: *Teaching Critical Thinking through Modelling*	• Motivating and discussing on how to think critically of certain issue/problem • Modeling and guiding to formulate problems/claims against issues that need to be solved systematically • Modeling and guiding several thinking strategies in claiming the issues to be solved by the objectives • Modeling and guiding for open-mindedness in selecting and formulating alternative solutions to problem-solving or proving claims
Phase 3: *Seeking Truth and Exploration*	• Providing opportunities for students to seek the truth (truth-seeking) and all information that have been formulated in the previous stage through exploration activities systematically (systematicity) as well as independently
Phase 4: *Thinking together:* *Explaining & Discussing with Expert*	• Interpreting data, explaining, and analyzing the exploration results • Conducting discussions with experts and presenting the results by citing and attaching data sources • Making a wise decision (maturity of judgment) to conclude the exploration results by rejecting or accepting the claim.
Phase 5: *Conducting Implementation Trial*	• Presenting new issues or questions to help students apply, explain, and expand their knowledge and skills • Clarifying certain points and relating prior knowledge and skills to new knowledge or problem situations.
Phase 6: *Evaluating Critical Thinking*	• Reflecting on all learning steps to develop disposition and critical thinking skills. • Evaluating the disposition and critical thinking skills, as well as knowledge obtained • Using the results of evaluation and reflection as improvements and recommendations for the next lesson

2. Results of Aspect Evaluation on Content and Construct Validity Component of CTC Model

Table 3. 2

Results for components assessed in content and construct validity and reliability test

No	Components	Mode	Average	Criteria	Reliability
A.	**Content Validity of CTC Model**				
1	Need for CTC model development	4.00	4.00	Very valid	100 (Reliable)
2	Meeting the updating knowledge (*scientific knowledge*)	4.00	3.56	Very valid	88.59 (Reliable)
3	Describing CTC model development	4.00	3.70	Very valid	95.65

					(Reliable)
B.	**Construct validity of CTC model**				
1	Rationality of CTC model development	4.00	3.75	Very valid	83.33 (Reliable)
2	Theoretical and empirical support of CTC model				
	a. Phase 1: *thinking issue/problem*	4.00	4.00	Very valid	100 (Reliable)
	b. Phase 2: *teaching critical thinking through* modeling	4.00	4.00	Very valid	100 (Reliable)
	c. Phase 3: *seeking truth and exploring*	4.00	4.00	Very valid	100 (Reliable)
	d. Phase 4: *thinking together: explaining & discussing with experts*	4.00	4.00	Very valid	100 (Reliable)
	e. Phase 5: *conducting implementation trial*	4.00	4.00	Very valid	100 (Reliable)
	f. Phase 6: *evaluating critical thinking*	4.00	4.00	Very valid	100 (Reliable)
3	CTC model planning	4.00	3.75	Very valid	83.33 (Reliable)
4	Implementation and components of CTC model (syntax, social system, reaction principle, support system, instructional impact, and accompaniment impact)	4.00	3.73	Very valid	93.33 (Reliable)
5	Learning environment	4.00	3. 50	Very valid	100 (Reliable)
6	Assessment and evaluation	4.00	3. 50	Very valid	100 (Reliable)

3. Validity Result of CTC Model's Learning tools

Result of validity test for CTC model learning tools shows that all components used in this model were very valid (see Table 4).

Table 4. Construct validity of CTC model's learning tools

No	Learning tools	Mode	Average	Criteria	PA
1	Semester lesson plans	4	3.73	Very valid	90.37 (Reliable)
2	Lecturing units	4	3.80	Very valid	89,53 (Reliable)
3	Student worksheet	4	3.67	Very valid	95,45 (Reliable)
4	Student book	4	3.80	Very valid	100 (Reliable)
5	Critical thinking disposition and critical thinking skills evaluation	4	3.50	Very valid	95.37 (Reliable)
6	Critical thinking skills test	4	3.50	Very valid	85.71 (Reliable)

4. Discussion

In this research, two of four criteria for the good quality of supporting tools used in content validity and construct validity are relevance and consistency (Plomp, 2013) (Nivieen & Folmer, 2013). Based on the results of content validity (relevance) and construct validity (consistency) on the prototype of the CTC model test (see Table 3), it is seen that the CTC model's learning tools are valid and reliable (see Table 5).

Table 5. Relevance and consistency of CTC model

Aspect of Validation		Result
CTC Learning Model		
Content Validity (*Relevance*)	Score Validity	Very valid
	Agreement Percentage	94.92 (Reliable, PA ≥ 75%)
Construct Validity	Score Validity	Very valid
(*Consistency*)	Agreement Percentage	93.33 (Reliable, PA ≥ 75%)
Learning Tools		
Construct Validity	Score Validity	Very valid
(*Consistency*)	Agreement Percentage	93.33 (Reliable, PA ≥ 75%)

Based on data analyses, the CTC model considers meeting all criteria of both validity tests (relevance and consistency) of model development. Relevancy serves as a basis in developing learning models. This development has to consider the needs and the latest scientific developments. Accordingly, the CTC model developed in this research was designed based on the need to increase pre-service teachers' critical thinking skills through learning in order to ready the graduates to face challenges and rapid changes of the Industrial Revolution 4.0 (Ali & Awan, 2021) (Ridho et al., 2021) (Ridho et al., 2021) (Ulger, 2018) (Hafni et al., 2020). Moreover, the CTC model in this research was purposely developed to overcome problems that occur, namely low critical thinking disposition and skills of pre-

service science teachers that was found in the preliminary study. The results of the preliminary study show that the critical thinking disposition and critical thinking skills of students are still very low. Both need to be developed simultaneously through learning (Fikriyati et al., 2022).

Based on the consistency model criteria, the CTC model was designed logically and rationally, proved by the results of validity testing that all components have good quality and meet the standard for learning characteristics. This model fulfills all characteristics which indicate logic and rationality, such as empirical evidence and logical theoretical rationale from its planning and implementation including teaching behavior/activities, learning environment, assessment, and evaluation (Arends, 2012). These characteristics are incorporated into the five components of the CTC model, namely syntax, social system, reaction principle, support system, instructional impact, and accompaniment impact (Joyce et al., 2009).

Some experts suggest improving and developing components descriptions that are related to how this model possibly trains critical thinking in problem-solving of new concept discovery or solves authentic problems especially in implementing the newly discovered concepts. In addition, the suggestions were also related to the type of appropriate science materials to be implemented in the CTC model and the possibility of implementing this model in senior high schools (or only possible for universities/higher education). Another suggestion also mentions the need for further description on whether the CTC model can be used to investigate scientific material that requires proving hypotheses through experimentation or claims through a series of truth-seeking information. These suggestions are inputs that are expected to be able to improve the product (CTC model) that has been outlined in form of a book prototype which allows other researchers to use it easily according to the stated descriptions.

In this study, the validity of learning tools that support the CTC model was tested and analyzed. The results of the construct validity of learning tools indicate that all aspects tested are valid and reliable (see Table 4, 5). All aspects can be categorized as very valid (see Table 5), meaning that the learning tools in form of semestrial lesson plans, lecturing units, student worksheets, student's books, and critical thinking disposition and skills evaluation are very valid and can be implemented in the further stage to of development research (determining the effectiveness and practicality of the CTC model).

The results find that the developed learning tools should be able to encourage students' curiosity and critical thinking so the problems need to be carefully selected. This is in line with the findings from empirical evidence that using actual issues in teaching-learning makes the content more interesting, meaningful, challenging, and relevant so it increases students' engagement and motivation and develops their attitudes, skills, and understanding during the process of examining science-related issues (Ansori et al., 2018) (Wellington, 2002). This issue will be solved and verified through exploration and truth-seeking activities. In developing critical thinking, students should be persistent and active in taking initiative in various discussions without fear of being evaluated or criticized. Prior research suggests the need for effective efforts to facilitate discussion activities with others in order to minimize student fear and insecurity(Alotaibi, 2013) (ŽivkoviĽ, 2016). Moreover, other research also indicates the importance of motivation through guidance from lecturers to optimize students' critical thinking development (Alotaibi, 2013) (ŽivkoviĽ, 2016). The CTC model is designed to facilitate students' need to seek the truth, increase their courage and desire for a better knowledge, ask critical questions, as well as seek reasons and evidence for the issue discussed even though the findings are different from their assumptions. This supports the results found by Anshori, Ibrohim, & Widodo (2018) who mention that truth-seeking affects the development of students' critical thinking dispositions.

The CTC model is a learning model intervention developed based on the theoretical study as well as an empirical learning model based on constructivism approach that is capable of training critical thinking, namely PBL and LC (Pu et al., 2019) (Ulger, 2018) (Cahyarini et al., 2016) (Budprom et al., 2010). This model has six learning steps in which each cycle always ends with evaluation and reflection to improve the development of critical thinking in the next lesson (see Fig. 1). Critical thinking

dispositions are attitudes/behavior that can be developed together with critical thinking skills. Yet, it takes longer period (duration) to develop critical thinking dispositions than to develop or improve critical thinking skills (P. A Facione, 2015).

5. Conclusion

Based on the results, it is seen that the CTC model's criteria are very valid and reliable (94.92% for content validity and 93.33 for construct validity). In conclusion, CTC model has excellent relevance and consistence as proved from both score percentage of content and construct are higher than 75% (≥75). This research developed a CTC model consisting of six stages, namely (1) thinking issue/problem, 2) teaching critical thinking through modeling, 3) truth-seeking and exploration, 4) thinking together: explaining and discussing with expert, 5) implementation trial, and 6) critical thinking evaluation. Further research is needed to find out the effectiveness and practicality of the CTC model in increasing critical thinking disposition and skills.

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