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## Improving of students' critical thinking ability through learning based on CCM-CCA assisted virtual experiments on optical materials

M Makhrus<sup>1</sup>, S Ayub<sup>1</sup>, Wahyudi<sup>1</sup>, N N P S Verawati<sup>1</sup> and A Busyairi<sup>1</sup>

<sup>1</sup>Physics Education, Universitas Mataram

E-mail: makhrus.fkip@unram.ac.id

**Abstract.** This study aims to improve students' critical thinking skills of optical material through the application of CCM-CCA assisted by virtual experiments. The study was conducted using a mixed-method that is using the exploratory design. The subjects of this study were 30 students in the physics education study program. Students' critical thinking skills are obtained through critical thinking tests. The results showed that the CCM-CCA assisted by virtual experiment was feasible to use for an optical material. Students' critical thinking skills have increased in 5 indicators of critical thinking, namely basic clarification, basic decisions, inference, further explanation, reasoning. Learning instructions based CCM-CCA assisted with virtual experiments on optical materials are valid and can be used in learning. Students' critical thinking skills have improved after learning with CCM CCA with the help of virtual experiments. The inference indicator experienced the highest increase among other indicators.

### 1. Introduction

The challenge of education in the 21st century is not easy. Education is faced with the problem of how to prepare students to face global challenges. The way to face these challenges is by developing students' skills in general and specifically including critical thinking and problem solving, communication, collaboration, creativity, and innovation. 21st century demands included in the 2013 curriculum as one of the learning objectives are critical thinking skills [1]. Critical thinking skills are closely related to cognitive abilities because to solve a problem someone must understand the problem [2]. Critical thinking skills can help students in making questions, hypotheses, making observations and collecting data, as well as making conclusions on a given problem [3]. Critical thinking skills are the ability to compare two or more information to gain knowledge through testing of distorted symptoms and scientific truths. There are six basic elements in critical thinking abbreviated with FRISCO, namely F (Focus), R (Reason), I (Inference), S (Situation), C (Clarity), and O (Overview) [4]. Critical thinking skills is a way of thinking to explore clarity by questioning all matters relating to information obtained in detail, so that truth is found on the information conveyed and produce conclusions objectively. Critical thinking is the ability to analyze, criticize, and submit ideas; inductive and deductive reasons; and to reach factual conclusions based on knowledge or belief [5].

Improvements in basic physics learning activities need to be done so that critical thinking skills and student achievement can improve. One of the solutions that can be used is the application of the Conceptual Change Model with Cognitive Conflict Approach commonly called CCM-CCA. This learning model was developed to facilitate the change of concepts in students by reducing their misconceptions [6]. The main purpose of learning with CCM-CCA is to help students to develop scientific thinking skills, build correct conceptual understanding, and to apply the concepts



that have been held, thus learning will become meaningful. CCM-CCA consists of 7 learning phases, namely: 1) presenting the context of the problem or creating cognitive conflict (preliminary), 2) commit to a position or outcome, 3) expose beliefs, 4) create cognitive conflict, 5) accommodate and extend the concepts, 6) problem solving or testing (resolution), and 7) evaluation [7]. Learning through CCM-CCA will connect students in active learning from the first stage of learning [8]. The use of learning models in improving critical thinking skills can be integrated into learning instructions. The use of the CCM-CCA learning model will be maximized if collaborated with simple media or media based technology.

Alternative learning media that can be used are virtual experiment media. Virtual experiments are experiments using virtual media such as computer simulations or virtual laboratory media [9]. The advantages of virtual experiments are that they can explain abstract concepts that cannot be explained through verbal learning and virtual experiment becomes an alternative solution for broken laboratory equipment [10].

Improvement critical thinking skill in Physics Education Study Program can be done by using a CCM-CCA learning model assisted with virtual experiments. The learning instructions developed are in the form of plan of learning activities, student worksheets, virtual experiment media and critical thinking test instruments.

### 25 Method

The subjects of this research were 30 students who took a basic physics course. The study was conducted using a mixed-method, namely using the Exploratory Design. This method consists of three processes: 1) qualitative processes, 2) quantitative processes, and 3) the process of data interpretation is based on the first and second processes. Data on critical thinking skills of students was obtained by using assessment student worksheets during the learning process and the critical thinking skills test instrument. Analysis of the level of critical thinking skills using equations [11]:

$$Critical\ Thinking\ Level\ (CTL) = \frac{Score\ Obtained}{Maximum\ Score} \times 100\% \quad (1)$$

The results of the calculation of the level of critical thinking skills according to the equation above will be interpreted to the following table of critical thinking categories.

27 Table 1. Levels of critical thinking ability of students

Percentage (%)	Critical Thinking Ability Categories
80 < CTL ≤ 100	Very good
60 < CTL ≤ 80	Good
40 < CTL ≤ 60	Enough
20 < CTL ≤ 40	Less
0 ≤ CTL ≤ 20	Very less

### 3. Result and Discussion

Learning instructions developed based on CCM-CCA are plan of learning activities, student worksheets, virtual experiment media, and critical thinking tests. Learning instructions are a guide for educators to carry out learning activities the validation of the CCM-CCA learning instructions was carried out by researchers conducted by the FGD (Focused Group Discussions) method. This validation was carried out by three experts in the physics education. This learning instruction was developed on the CCM-CCA model based on constructivist theory. The constructivist theory sees students as people who continually check new information against old rules and then revise these rules if they are no longer useful. This is consistent with the views of Piaget and Vygotsky who emphasize that changes in cognition only occur when the previous conception experiences an imbalance for new information. Other supporting theories are information processing theory and meaningful learning theory which states that learning is said to be meaningful if the information to be learned by students is arranged according to the cognitive structure owned by students so that students can associate new information with their cognitive structure. The results of validation show that plan of learning activities and student worksheets that have been developed by

researchers can be projected activities to be carried out by lecturers in supporting learning in the classroom and can function as a lecturer guideline so that they can manage to learn using the CCM-CCA learning model well.

The learning instructions developed by researchers refer to the steps of the CCM-CCA learning model that allow students to experience 4 (four) thought processes as a condition for conceptual change, namely: (1) dissatisfaction with existing conceptions, (2) intelligibility of the new conception, (3) logic (plausibility) of the new conception, and (4) success (fruitfulness) where the new conception must be valued or valued in a pragmatic context. The cognitive conflict that occurs from the beginning of learning will make students motivated to take learning seriously and try to solve the problems presented by lecturers related to demonstrations or experiments conducted. The learning objectives in plan of learning activities have been formulated operationally, clearly, following the characteristics of students, specific, measurable, in the form of concrete actions, and have been calculated following the time of their implementation. The learning activities contained in plan of learning are designed according to the learning objectives developed and following the CCM-CCA learning scenario.

The results of the virtual experiment media validation showed that the media was feasible and able to bring up cognitive conflict following the objectives of CCM-CCA learning. While the results of the validation of the critical thinking test consist of three main components, namely material, construction, and language are in a valid category. The results of the validation show that the critical thinking test can be used to measure critical thinking skills. Based on the results of the validation, it is known that all learning instructions are valid and appropriate for use. The results of the validation of learning instructions by the expert as follows in Table 2.

**Table 2.** The validation results of learning instructions based on ccm-cca are assisted by virtual experiments

Learning Instructions Based CCM-CCA	Expert Validation Score			Average	Criteria
	V1	V2	V3		
Plan of learning activities	3.16	3.50	3.32	3.37	Very Valid
Students worksheet	3.45	3.64	3.18	3.42	Very Valid
Virtual experiment media	3.60	2.95	3.15	3.23	Valid
Critical thinking tests	3.50	3.25	3.62	3.46	Very Valid

So, it can be concluded that learning instructions are feasible to be implemented in students. Then the implementation in 30 students took part in an optical material. 30 students were given a pretest and a posttest to see their critical thinking skills before and after learning with CCM-CCA assisted by virtual experiments. Analysis of students' critical thinking skills is obtained through critical thinking tests. Based on the results of the analysis the critical thinking skills are obtained as follows.

**Table 3.** Comparison of critical thinking skills in pretest and posttest

Test	Critical thinking score			Average category
	Lowest	Highest	Average	
Pretest	20.00	44.00	28.53	Less
Posttest	52.00	90.00	74.67	Good

Based on Table 3 it can be seen that students' critical thinking skills after learning are better than before learning with CCM-CCA assisted by virtual experiments. This can happen because learning with CCM-CCA allows students to criticize different concepts from their preconceptions so that the balance in their cognitive is impaired and students will find solutions to their solutions. Virtual experiments become a media that can help students' cognitive continuation while helping visualize the actual concepts so that there is a change in the concept of students. At the end of learning, students can be confident with the new concept because it has been proven through experiments with virtual experiments. The examples of wrong concepts are incident ray, reflected ray, and normal lines which sometimes students still misunderstand. Another material that

sometimes experiences misconceptions is related to diffraction and refraction of light which is sometimes considered to be the same. However, CCM-CCA assisted by virtual experiment learning [26] correct students' misconceptions because students prove it directly and can be accepted scientifically. The distribution of students' critical thinking skills presented in Figure 1 below.

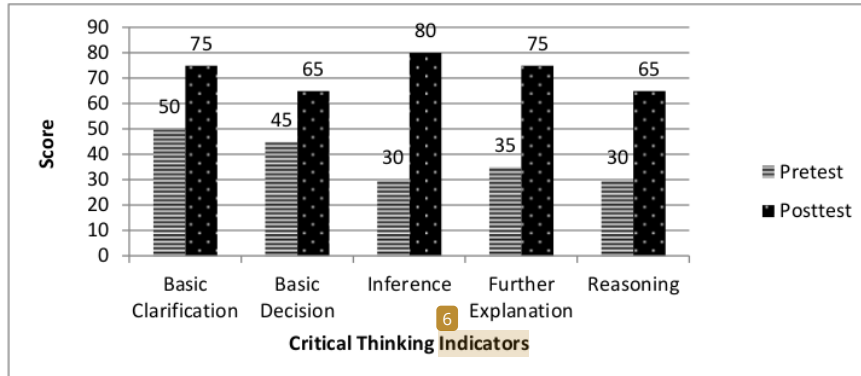


Figure 1. Comparison of critical thinking skills

Figure 1 shows that students' critical thinking skills on all indicators have increased. The highest increase occurred in the inference indicator. Students' critical thinking skills can be improved because virtual experiments can bring up cognitive conflicts and can help solve students' problems in optical material. Stated cognitive conflict disturbs the mental and cognitive balance of students because of their incompatibility of understanding with current concepts [12]. Cognitive conflict can be used as an alternative in learning because it can improve students' thinking skills [13]. Students who are aware of the incompatibility between scientific concepts with the initial concept will try to find solutions to these problems. CCM-CCA can improve critical thinking skills because it is assisted by virtual experiments that can bring up cognitive conflicts by visualizing abstract concepts so that students directly feel the incompatibility of their concepts with scientific concepts. This will help students to correct the wrong concepts and improve their thinking skills including critical thinking.

To measure the effectiveness of the treatment that has been given, students are given a final test with the same material, number, and weight of the questions as the initial test questions. The final test results show that there is an increase in critical thinking skills in students with an average score of the final test higher than the initial test. The increase in the average value is the effect of the treatment given. Critical thinking skills can be improved because students are confronted directly with situations that conflict with the concept through virtual experiments, then directed to an experiment or demonstration to prove the truth of the concept which in this case also through the help of virtual experiments. In this study, students are allowed to express their conceptions and criticize those that are different from their conceptions. By being directly involved in the learning process students can improve critical thinking skills well.

Increased physics critical thinking skills can be seen from the results of the N-gain test. N-gain test results on 30 students showed an increase in the medium and high categories. Cognitive conflict requires the ability to think more during the process of giving conflict to change the misconception that is owned. In the process of thinking, the knowledge students get cannot be separated from the knowledge that has been obtained previously. Maintaining the relationship between old knowledge and the knowledge that will be received by students to become students' new knowledge is very important.

In this study, students experience the process of assimilation and accommodation so that students build their knowledge at any time until the concepts they understand do not conflict with the concepts of scientists. So that the process of assimilation and accommodation can truly satisfy students, the stimulation of cognitive conflict is needed. These stimuli can be in the form of explanations and demonstrations in the form of examples that contradict student understanding.

Furthermore, students are allowed to conduct scientific thinking activities and conduct investigations through experiments to prove the truth of the concepts they already have and concepts that contradict their conceptions in the hope that students can rebuild/reconstruct their thoughts, so that misconceptions that they have can be eliminated. The conceptual change process is slow and gradual because it requires a continuous effort to intentionally re-examine students' conceptual understanding and usually students lack their own belief in the process of change. Conceptual changes that occur in students have been shown with a change of opinion sheet that is filled out by students at the end of learning, where students experience changes in opinion towards conceptions that were previously believed.

#### 4. Conclusion

Learning instructions based CCM-CCA assisted with virtual experiments on optical materials are valid and can be used in learning. Students' critical thinking skills have improved after learning with CCM CCA with the help of virtual experiments. The inference indicator experienced the highest increase among other indicators.

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