Concept progression of high school students related to the concept of parallel electric circuits as the effect of applying CCROI integrated with T-ZPD strategy

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Abstract. The aim of study was to obtain an overview of the effects of application of conceptual construction-reconstruction oriented instruction (CCROI) using the Tetrahedral-ZPD (T-ZPD) strategy on the concept progression of high school students related to the concept of parallel electric circuits. The categories of concept progression reviewed included: consistent with scientific conceptions, progress well, not progress and degradation. A pre-experiment method with one group two conceptual test design was used in this research. The number of research subjects was 38 students consisting of 20 females and 18 males, in one of high schools in the West Bandung district of West Java province. Data were collected by conception test in the four-tier test format related to the concept of parallel electric circuits. The results showed that at the first conceptual test, the state of conception of the students are: scientific conception (8%), misconception (62%), and no conception (30%), whereas at the second conceptual test, the students' conception are: scientific conception (82%), misconception (13%), and no conception (5%). Based on the state of students’ conception it can be determined the number of students in each category of concept progression as follows: consistent with scientific conceptions (8%), progress well (74%), not progress (18%) and degradation (0%). These results indicate that the implementation of CCROI with the T-ZPD strategy has high effectiveness in facilitating the achievement of the category of concept progression that progresses well.

1. Introduction

Students come into class to take part in learning with various initial conditions. Some of them have had an initial conception of a concept and some of them do not have an initial conception. For students who have an initial conception, the initial conception may be in accordance with the scientific conception, but it may also be that the initial conception is not in accordance with the scientific conception or often referred to as alternative conception or misconception. According to the literature, many things are the source of the causes of misconceptions, including prior knowledge, daily life experiences, language, culture, teacher, textbooks, and instruction [1, 2]. Misconceptions should not be allowed to remain in the minds of students, because resistant to change with scientific ones and students may reject accepting new ideas [3] and they are obstacles for students in learning and understanding of some concepts in science. Misconception is a situation that is difficult to change [4],
because it is usually inherent in the minds of students and they are not aware that the conception they have is not in accordance with the scientific conception.

The learning process is carried out to facilitate all students with various initial conditions, so that all of them can achieve optimal learning outcomes. The teacher must think of appropriate models, strategies, approaches and teaching methods in order to accommodate all the initial conditions of the student. According to constructivist theory, students will construct conceptions related to a concept in two ways, namely the assimilation and the accommodation way [5]. The assimilation way is used by students who have an initial conception that is in accordance with scientific concepts or students who do not have conception. Internalization of conception in the minds of students who have a scientific conception or students who do not have conception can be done through the process of concept development (conception construction). Whereas the way of accommodation is used by students who have had an initial conception, but the initial concept is not in accordance with scientific conception or misconception. Internalization of conception in the minds of students whose initial conditions have misconceptions can be done through the process of conceptual change (conception reconstruction).

The learning approach that is often used for conception construction is a conceptual development approach (CDA). Whereas special approaches and strategies that are often used for conceptual reconstruction is the conceptual change approach (CCA). There have been many studies conducted by previous researchers about the use of conceptual development approach and conceptual change approach in physics learning separately, such as research on the use of CDA in physics learning conducted by Koponen & Huttunen [6] and Baweja [7], as well as research on the use of CCA conducted by Baser [8], Kang et al. [9], and Madu & Orji [10].

In this study, to accommodate various initial conditions of students, researchers combined the conceptual development (CDA) approach and conceptual change approach (CCA) in an integrated approach called CDCC-A (conceptual development & conceptual change approach). In its implementation in class, the CDCC-A approach is actualized in conception construction and reconstruction oriented instruction or abbreviated as CCROI. In the implementation, the concept of development was carried out at the beginning of learning, then continued with the identification of students' conceptions, then followed by the conception accommodation process and ended with identification of the students' final conception.

In learning physics, physical content that contains microscopic phenomena is often not easily understood by students. Explanation of this microscopic phenomenon needs to be supported by visual media that can model the invisible microscopic phenomena into a macroscopic phenomenon that can be observed by the eye [11]. Most of the science learning requires understanding at three levels of representation, namely macroscopic, sub microscopic, and symbolic [12]. In order to understand the physics concepts correctly, students must be able to understand the three representations. Physics learning should start from the macroscopic and symbolic and proceed to the submicroscopic aspect since such aspects are the most difficult to comprehend aspects [13]. Because of the concept of parallel electric circuits includes macroscopic and microscopic physics quantities, to optimize students' understanding of this concept, three levels of representation have been used in the learning process. The use of the three levels of representation in CCROI is realized in the form of the use of a multimedia visual such as video macroscopic phenomena, dynamic microscopic models and dynamic analogies. The use of a multimedia visual is expected to provide assistance to students to achieve a deep and comprehensive understanding. So that the use of multimedia visual in CCROI is packaged in a learning strategy called the tetrahedral-zone proximal development (T-ZPD) strategy.

This study was conducted to examine the effectiveness of the use of CCROI integrated by T-ZPD strategy in facilitating construction and reconstruction of conception that occurs in high school students related to the concept of parallel electric circuit. Gender is one of the aspects studied in this research to ascertain whether gender is one of the determinants of physics learning outcomes or not. Some research results show that gender has a strong influence on the achievement of physics learning outcomes, but several other research results indicate that gender is not a factor that influences physics
learning outcomes. This article reports the process and results obtained from the research activities that have been carried out.

2. Methods
The method used in this study is a pre-experimental by the design of one group with two tests. With this design, the research subjects were given conception test-1 and conception test-2 during the teaching process carried out (See Figure 1).

| Subject | Treatment for concept development | Conception test-1 | Treatment for conception accommodation | Conception test-2 |
|---------|----------------------------------|-------------------|---------------------------------------|-------------------|
| E       | X                                | O                 | X                                     | O                 |

*Figure 1. Research design used in this study*

Here E is experimental group, O is conception test, and X is treatment. The treatments are in the form of teaching activity using CCROI integrated with T-ZPD strategy. The research sample was students of class XII in one of the high schools in West Bandung district of West Java province, amounting to 38 students (20 female and 18 male). The research subjects were selected using a purposive sampling technique.

The instrument used to collect data in this study consisted of conception tests in the Four Tier Test format about parallel electric circuits or abbreviated as PECFTTest (Parallel Electric Circuits Four Tier Test). The categorization of conception states of high school students based on conception test results data with the four-tier test format was carried out using guidelines formulated by Gurel et al. [14]. The data analysis techniques used in this study include the calculation of the decrease in the quantity of students whose misconceptions and a description of the concept progression achieved by students after participating in the CCROI. Decreasing the quantity of students whose misconceptions between before and after the implementation of CCROI are calculated using equation (1).

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\Delta M (\%) = \frac{M_{CT-1} - M_{CT-2}}{M_{CT-1} - M_{ideal}} \times 100\%
\]

Here \(\Delta M\) is a decrease in quantity of students whose misconception, \(M_{CT-1}\) is the number of students who misconception at conceptual test-1, \(M_{CT-2}\) is the number of students who misconception at conceptual test-2, and \(M_{ideal}\) is the ideal minimum of number of student whose misconception, that is zero (0). The criteria for determining the level of decrease in the quantity of students who have misconceptions between conceptual test-1 and conceptual test-2 are: High if \(70\% \leq \Delta M\), Moderate if \(30\% \leq \Delta M < 70\%\) and Low if \(\Delta M < 30\%\) [15].

The concept progression reached by students during implementation of CCROI is marked by three categories of concept progression, as follows: (1) consistent with scientific conceptions (CSC), that is if students have a scientific conception both on conceptual test-1 and on conceptual test-2, (2) progress well (PW), that is if students on conceptual test-1 have misconceptions or no conception changes to have a scientific conception on conceptual test-2, (3) No Progress (NP), that is if students on conceptual test-1 have a misconception or no conception still have a misconception or no conception on conceptual test-2, and (4) Degradation (DG), if students who originally had a scientific conception (SC) changed into misconceptions (MC) or no conception (NC).

The dynamic microscopic model used to support CCROI related to the concept of parallel electric circuits in the form of a dynamic microscopic model of direct current electric circuit. This model was developed by Eugene Khutoryansky which is available for free and can be downloaded from the www.youtube.com page. Whereas the dynamic analogy representation used is a virtual simulation of the arrangement of highway traffic. The syntax of CCROI model is concept development, identification of students' conception, confrontation of conception beliefs, scientific explanation, enrichment and strengthening, and identification of students’ final conception.
3. Results and Discussion
The PECTTest results obtained by each high school student at the time before and after the CCROI activity were subsequently analyzed using a predetermined technique, to be further described. Table 1 and Table 2 shows the response of female (F) and male (M) students to each tier of conception tests constructed in the four-tier test format at the conception tests-1 and conception tests-2 related to concept of parallel electric circuits. Based on the answers of students in each tier, the number of students at each state of conception at the conception tests-1 and conception tests-2 could be identified.

Table 1. The answers of female students in each tier of conception test related to the concept of parallel electric circuits

| Students (S) | Conception test-1 | Students (S) | Conception test-2 |
|--------------|------------------|--------------|------------------|
|              | Tier1 | Tier2 | Tier3 | Tier4 |              | Tier1 | Tier2 | Tier3 | Tier4 |
| F            |       |       |       |       | S16, S18, S25, S30 | S1, S3, S4, T | S7, S10, E | S11, S14, E | S16, S20, M | S21, S25, M | S27, S30, M | S33, S36, M |
| E            |       |       |       |       | F     | S3, S11, F     | T     | S     | F     | S     |
| M            |       |       |       |       | S1, S5, S7, S33 | S10, S14, F | S20, S21, F | S22, S27, F | S35, S38, F |
| A            |       |       |       |       |       | F     | S     | F     | S     |
| L            |       |       |       |       |       |       |       |       |       |
| E            |       |       |       |       |       |       |       |       |       |

Where: T = True, F = False, S = Sure, NS = Not Sure

Table 2. The answers of male students in each tier of conception test related to the concept of parallel electric circuits

| Students (S) | Conception test-1 | Students (S) | Conception test-2 |
|--------------|------------------|--------------|------------------|
|              | Tier1 | Tier2 | Tier3 | Tier4 |              | Tier1 | Tier2 | Tier3 | Tier4 |
| M            |       |       |       |       | S2, S6, S8, S9, S12, S13, S17, S19, S24, S26, S28, S31, S32, S34, S37, S38 | T     | S     | T     | S     |
| A            |       |       |       |       | S8, S32, F | S15, S23, T | S | F | S |
| L            |       |       |       |       |       | S15, S23, T | S | F | S |
| E            |       |       |       |       |       | S15, S23, T | S | F | S |
|              |       |       |       |       | S17, F | S | T | S |
|              |       |       |       |       | S2, S9, S12, S19, S24, S26, S31, S34, S38, F | S | F | S |
|              |       |       |       |       | S19, S37, T | S | F | S |
|              |       |       |       |       | S6, S13, S26, F | S | F | S |

SC = 1, MC = 13, NC = 6

SC = 15, MC = 3, NC = 2
Students (S) Conception test - 1 Students (S) Conception test - 2

| Tier1 | Tier2 | Tier3 | Tier4 | Tier1 | Tier2 | Tier3 | Tier4 |
|-------|-------|-------|-------|-------|-------|-------|-------|
| SC = 2, MC = 11, NC = 5 | SC = 16, MC = 2, NC = 0 |

Where: T = True, F = False, S = Sure, NS = Not Sure

Table 3 shows the quantity of students whose misconceptions was remediated during implementation of CCROI related to the concept of parallel electric circuits.

**Table 3.** Quantity of students who are misconceptions on the concept of parallel electric circuits was remediated

| Gender | Students’ misconception at the CT-1 | Students’ misconception at the CT-2 | Decreased quantity of students (%) | Category |
|--------|-------------------------------------|-------------------------------------|-----------------------------------|----------|
| Female (F) | 13 | 3 | 77 | High |
| Male (M) | 11 | 2 | 82 | High |
| Overall | 24 | 5 | 79 | High |

In Table 3, it appears that before CCROI activity, students who have misconceptions on the concept of parallel electric circuits are quite large in number, namely 24 students (13 female and 11 male). In Table 3, it is also shown that the quantity of students whose misconceptions has decreased dramatically after attending CCROI activity. Based on data of the quantity of students whose misconceptions at CT-1 and CT-2, it can be calculated a decrease in the quantity of students whose misconceptions related to the concept of parallel electric circuits ($\Delta M$) using equation (1) which results in a decrease in quantity of female and male students whose misconceptions was 77% and 82% respectively. Furthermore, based on the state of students’ conception during implementation of CCROI related to the concept of parallel electric circuit, the concept progression achieved by students can be described, as shown in Figure 2. It appears that almost all students can achieve concept progression in the type of progress well (PW)

![Chart of concept progression achieved by students during teaching activity using CCROI related to the concept of parallel electric circuits](image)

**Figure 2.** Chart of concept progression achieved by students during teaching activity using CCROI related to the concept of parallel electric circuits
Table 8 can be seen that a decrease in the quantity of students whose misconceptions for both female and male students are in the high category. These results indicate that the use of CCROI integrated by T-ZPD strategy in teaching activity related to the concept of parallel electric circuits has high effectiveness in facilitating remediation of the misconceptions that occur in female and male students.

The results showed that there was no gender bias in the use of CCROI supported by dynamic analogies and microscopic models. Both female or male students achieved rapid progress of conception, from a state of misconception or no conception into a state of scientific conception. This shows that the use of CCROI supported by dynamic microscopic analogies and models can facilitate female and male students in reaching a level of sound understanding. These results are in line with the results of research obtained by several previous researchers, including there is no gender bias in increasing understanding of physics concepts [16], there are no significant differences in physics learning outcomes achieved by male and female students [17], and gender does not significantly impact students' scientific reasoning abilities [18]. It appears that there is no gender bias from the use of CCROI supported by dynamic analogies and models. This means that CCROI integrated by T-ZPD is suitable for use in teaching activity oriented to conceptual construction and conceptual change of both female or male students.

4. Conclusion

The conclusion that can be drawn from the results of this study is that the use of CCROI integrated with T-ZPD strategy has high effectiveness in facilitating the achievement of concept progression types progresses well with regard to the concept of parallel electrical circuits. The key to success of the CCROI integrated with T-ZPD strategy in students’ conceptual change lies in success of confronting belief stage in triggering students’ dissatisfaction with their conceptions and in success of scientific explanations stage that can facilitate students to achieve a deep-understand related to the concept of parallel electric circuits. Students can achieve a deep-understanding of parallel circuit as effect of the presence of the dynamic analog and models at the scientific explanation stage. There is no gender bias in the conceptual changes achieved by high school students as the effect of using the CCROI integrated with T-ZPD strategy.

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