Optimizing Students’ Conceptual Understanding on Electricity and Magnetism through Cognitive Conflict-Based Multimode Teaching (CC-BMT)

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Abstract. Conceptual change is one of the international issues that had been studied by many researchers since three decades ago. Students’ conceptual understanding could be optimized through the learning process in classroom. Nevertheless, students still have misconceptions that noticed the students conceptual change is still not successfully yet. In order to solve the problem, this study was conducted through four D research method (Define, Design, Develop and Disseminate) for 60 educational-university students that aimed to optimize students conceptual understanding using cognitive conflict-based multimode teaching (CC-BMT) in the learning process oriented conceptual change that concluded with: PDEODE*E worksheet design, simulation and natural phenomenon-based multimedia and Conceptual Change Text (CCT). The Electricity and Magnetism Conceptual Change Inventory (EMCCI) and CC-BMT have already been developed through the initial steps (define, design and develop) of four D model to produce the learning model that is able to optimize the students’ conceptual understanding. Finally, in the disseminate phase, the quantitative data which is analyzed by using conceptual change process based on the score as the the percentage result of EMCCI four tier diagnostic test. The analyzing data which is utilized a sequential coding analysis reports for electricity and magnetism that the students misconceptions (M) -18.33% and -15%; sound understanding (SU) 25% and 11.67%; partial understanding (PU) 16.67% and 20%; no understanding (NU) 23.33% and 16.67%; uncodeable (UC) is all 0% after implementing the CC-BMT learning strategy. It can be concluded that the implementing of CC-BMT is able to optimize students’ understanding on electricity and magnetism.

1. Introduction
Science course, especially physics course, is conceived as very complex since there are lots of abstract concepts in that course (e.g. Küçük & Çalık [1]; Cheng, Lin, Chang, Li, Wu, & Lin [2]). Students,
Therefore, confronted many problems to understand physics concepts, instead understand, and only memorize them. As discussed by Marek’s [3] article entitled “They misunderstand, but they’ll pass”, many students passed exams although they held several serious misconceptions. Physics education literature is full of misconceptions held by students about many electricity and magnetism concepts (such as electric field, Laurentz Force, magnetic field and so on). Pfund and Duit’s [4] studies provide an extensive bibliography of student misconceptions. The reports reveal a picture of very poor conceptual understanding, in spite of extensive schooling. Traditional instruction is not very effective in promoting conceptual understanding; since students’ misconceptions are very tenacious and well-constructed in their knowledge structures (see the bibliography on students’ alternative conceptions, e.g. Pfund and Duit [4]). Thus, it is very hard for teachers to change from their students’ misconceptions might need modification in a process known as conceptual change. The first conceptual change model, developed by Posner, et al. [5] has become the most influential theory since the beginning up to now. This model has been developed to describe the change of learning as the relationship between existing knowledge with new knowledge that leads to the four conditions. (1) dissatisfaction, (2) clarity (intelligibility), (3) the sensible thing (plausibility) and (4) success (fruitfulness). Various studies (e.g. Kocakulah & Kural [6]) utilized this model based upon cognitive conflict. Cognitive conflict strategy is more emphasis on students' self-esteem instability (destabilizing the student's confidence) on specific concepts through experience opposites as discrepant event. All models of conceptual change approach had been proven working effectively and optimally when researchers conducted a diagnosis prior to the respondent that would be the subject of subsequent research. Students’ conceptions closely correlate with conceptual change. In this case conceptual change can be stated that “change” from pre-conceptions to be scientific conceptions and/or can be stated that from misconceptions conditions to understanding concept. To provide conceptual change, first attempt has to be performed is to diagnose students’ misconceptions. In parallel to this attempt, researchers have developed an Electricity and Magnetism Conceptual Change Inventory (EMCCI) instrument in the form of four-tier test [7, 8]. The EMCCI instrument consists of two core concepts in the physics course, namely the electricity and magnetism concepts. The electricity concept covered all conceptions about Coulomb law, electric field and electric potential. The Coulomb law, electric field and electric potential concepts is sequentially given by the following equations.

\[
\vec{F} = k \frac{q_1 q_2}{r_{12}^2} \quad (1)
\]

\[
\vec{E} = \frac{\vec{F}}{q} \quad (2)
\]

\[
V = \vec{E} \cdot \vec{r} \quad (3)
\]

Furthermore, the magnetism concepts which were discussed involve Laurent force and magnetic field. In this article, the researchers focus on optimizing students’ conceptual understanding on electricity and magnetism through cognitive conflict-based multimode teaching (CC-BMT). The CC-BMT has several modes such as PDEODE+E worksheet, simulations regarding to multimedia and Conceptual Change Texts (CCT).

2. Research methodology

The method that has been utilised in this study is research and development method Four-D (Define, Design, Develop and Disseminate) [7-9]. In the define phase, the procedure that used is to define the educational university students’ conceptual understanding, cognitive conflict-based multimode teaching (CC-BMT) and Electricity-Magnetism Concepts are deeply analysed. On design and develop phases, CC-BMT and EMCCI have been created and developed based on the result of define phase. The EMCCI was validated by several experts included physics experts and assessment on physics experts. Afterward, it has been implemented to optimize students’ conceptual understanding on electricity and magnetism concepts. Finally, the CC-BMT and educational university students’ conceptual understanding has been analysed to obtain several research results and conclusion.
A research was conducted to obtain the profiles of 91 educational-university students in the disseminate phase. Within the research method, the EMCCI and CC-BMT were utilized and they were administered to educational-university students in duration of seventh time to a 100 minutes. The EMCCI was conducted prior the students who learned about electricity and magnetism concepts on the course of Basic Physics II.

3. Result and discussion
The CC-BMT and EMCCI have already been developed utilising Four D method. The briefly phases are discussed below regarding to the sequential explanation on the research and development processes.

3.1. Define
At define phase, the procedure which is utilised is to define the students’ conceptual understanding on electricity and magnetism concepts. The critical thinking indicators that utilized described in Table 1.

Table 1. The learning indicators regarding to the basic concepts of electricity and magnetism

| Electricity and Magnetism Concepts | Learning Indicators                                      |
|-----------------------------------|----------------------------------------------------------|
| Coulomb law                       | Formulating the Coulomb law regarding to the Coulomb apparatus experiment |
| Electric field                    | Identifying the electric field reletated to the parrallel-plats capacitors experiment |
| Electric potential                | Analizing the electric potential regarding to the parrallel-plats capacitors experiment |
| Laurent force                     | Formulating the Laurent force regarding to the magnetic force simulation |
| Magnetic field                    | Identifying the magnetic field on magnetic bars experiments which were aided android-teslameter installation |

3.2. Design
Based on define phase on describing the concepts regarding to the learning indicators, the Electricity and Magnetism Conceptual Change Inventory (EMCCI) [10-12] and Cognitive Conflict-Based Multimode Teaching (CC-BMT) have already been designed in term of optimizing students’ conceptual understanding on electricity and magnetism. The design of EMCCI and CC-BMT are based on the four tier test format and constructing and reconstructing processes in order to optimize students’ conceptual understanding on electricity and magnetism concepts. The design of EMCCI is graphed in the Figure 1.

Figure 1. Design of Electricity and Magnetism Conceptual Change Inventory (EMCCI) in the four tier test format
Furthermore, the Cognitive conflict based multimode teaching is design as Figure 2.

![Diagram](image)

**Figure 2.** Design of EMCCI and CC-BMT development

3.3. **Develop**

The EMCCI instrument is precisely formed in the develop phase. Each items on the EMCCI is formed based on learning indicators and conceptual describing in the define phase. The EMCCI instrument consisted of 13 instruments (electricity concept) and 14 instruments (magnetism concept). An example of EMCCI instrument which has already been developed on magnetism concept is shown in the Figure 3.
An electron with initial velocity \( \vec{v} \) enters the uniform magnetic field \( \vec{B} \) region, with direction toward the paper. The electron velocity is perpendicular to the magnetic field direction as shown below.

Ignoring the earth’s gravity. How many forces do act on the electron when it pass?

A. One, it is the force acts on the moving electron outside the uniform magnetic field.
B. One, it is the magnetic force.
C. Two, they are the forces act on the moving electron inside the uniform magnetic field and the magnetic force.
D. Two, they are the electric force outside the uniform magnetic field and magnetic force.
E. There is no force acting on the electron.

The level of confidence I:

a. Sure  b. Not sure

Explanation:
A. The electron movement in the magnetic field need force which is not a null.
B. The Electron which is moving in the magnetic field is only acted by a magnetic force.
C. The magnetic field produced the magnetic force which influenced the electron without is influenced by the initial velocity because the electron has no interaction.
D. The Electron is influenced by the velocity and magnetic force.
E. ………………………………………………………………………………………………………………………………………………………………………………………
    ………………………………………………………………………………………………………………………………………………………………………………………
    ………….  

The level of confidence II:

a. Sure  b. Not sure

**Figure 3.** Example of oscillation and sound wave critical thinking test item that was designed and developed

Not only instrument test has been validated, but CC-BMT learning model also has been validated by three expert judgments as is described at Table 2.
Table 2. The recapitulation of expert judgments to the CC-BMT syntax

| No | Validation Aspects | Recommendations                                                                                                                                 |
|----|--------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| 1  | The CC-BMT syntax reflects to the conceptual and cognitive approaches in its learning activities. | The three validators state that CC-BMT syntax has already reflected the conceptual and cognitive-constructive approaches in its learning activities. |
| 2  | The CC-BMT syntax reflects to the learning activities which is oriented to enhancing conceptual understanding, unveiling misconceptions and conceptual change. | The three validators state that the CC-BMT syntax developed has already reflected to the learning activities which is oriented to enhancing conceptual understanding, unveiling misconceptions and conceptual change. |
| 3  | The CC-BMT syntax reflects learning activities which oriented to constructed and reconstructed conceptions to the students. | The three validators state that CC-BMT syntax has already reflected to the learning activities which is oriented to constructed and reconstructed conceptions to the students. |
| 4  | The CC-BMT syntax reflects learning activities which is implemented through multimode teaching. | The three validators state that CC-BMT has already reflected to the learning activities which is implemented through multimode teaching (CCT, PDEODE*E tasks, computer multimedia) |
| 5  | The CC-BMT syntax reflects learning activities which is implemented through ICI learning model. | The three validators state that CC-BMT syntax has already reflected to the learning activities which is implemented through ICI learning model (conceptual focus, use of texts, research materials, and students’ interactions). |

3.4. Disseminate
The end of the phase in the four D model is disseminate phase. In the disseminate phase, the EMCCI has been tested to the educational university students to obtain several data for surveying the students’ conceptual understanding in the initial and the final steps. Then, the treatment which has been implemented namely CC-BMT, is successfully in the optimizing students’ conceptual understanding as Table 3 for electricity concept and Table 4 for magnetism concept.

Table 3. The frequency and proportion of students’ responses to the EMCCI in the each conceptions categories on electricity

| Cathegory | Electricity Concept | % Conceptual Change |
|-----------|---------------------|---------------------|
|           | Pretest (f maximum is 60) | Post-test (f maximum is 60) |                  |
|           | f   | %    | f   | %    |                  |
| SU        | 8   | 13.33| 23  | 38.33| +25.00           |
| M         | 15  | 25.00| 4   | 6.67 | -18.33           |
| NU        | 20  | 33.33| 6   | 10.00| -23.33           |
| PU        | 14  | 23.33| 24  | 40.00| +16.67           |
| UC        | 3   | 5.00 | 3   | 5.00 | 0                 |

Moreover, Table 4 performs the quantitative analysis of students’ conceptual understanding which is interpreted from conceptual change process on magnetism concept after implementing the CC-BMT.
Table 4. The frequency and proportion of students’ responses to the EMCCI in the each conceptions categories on magnetism

| Category | Magnetism Concept | % Conceptual change$^2$ |
|----------|-------------------|-------------------------|
|          | Pretest (f maximum is 60) | Post-test (f maximum is 60) | f | % | f | % |
| SU       | 6 | 10 | 13 | 21.67 | +11.67 |
| M        | 18 | 30 | 9 | 15 | -15 |
| NU       | 21 | 35 | 11 | 18.33 | -16.67 |
| PU       | 15 | 25 | 27 | 45 | +20 |
| UC       | 0 | 0 | 0 | 0 | 0 |

Notes:

$^1$ SU, M, NU, PU and UC sequentially stand for Sound Understanding, Misconceptions, No Understanding, Partial Understanding and Uncodeable.

$^2$ The sign of “+” performs the enhancing of conceptual change and the sign of “-” performs the reducing the conceptual change process.

Based on the Table 3 and Table 4, we have analysed that the students have already changed their conceptions from misconceptions conditions to the scientific conception (sound understanding). Several reasons are able to answer the implementing effect of CC-BMT such as conceptual focus, constructing and reconstructing process of their persistent conceptions and so on. This result is related to several researchers who have ever did research about students’ conceptual understanding from conceptual change analysis (e.g. Costu, Ayas & Niaz [13]; Srivastava, John, Gosling & Potter [14]; Dass [15]). Beside that, the CC-BMT has also computer simulation which is able to unveil misconceptions and restructuring students’ conceptions as a several research results (e.g. Zulfikar et al. [16]; Kaniawati et al. [17]; Wibowo et al. [18]; Samsudin et al. [19])

4. Conclusion
The conceptual change should be occurred to optimize students’ conceptual understanding on electricity and magnetism concepts. Both electricity and magnetism concepts have a core concept that is electric field and magnetic field [9]. Regarding to the development of CC-BMT, researchers briefly report that the learning model is able to optimize the students’ conceptual understanding related to the electricity and magnetism concepts.

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