Computer simulation-assisted conceptual change text (CS-CCT): a FODEM study on fluid dynamics

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Abstract. Previously, the development of CCT has been conducted since the previous decade until current age. However, the latest version of CCT has several weaknesses in such aspects as: the visualization of abstract phenomena and it has seldom been assisted by computer simulation. This research aims to develop Computer Simulation-Assisted Conceptual Change Text (CS-CCT) by way of a continuation of the previous research combined with computer simulation. A Formative Development Method (FODEM) has been utilized to obtain a valid and comprehensive data collection. A FODEM consist of three components that are: (1) needs analysis, (2) implementation and (3) formative evaluation. Participants were occupied from 33 students who studied in one of Senior High School located in Bandung city. Participants were taken using random sampling techniques. Data obtained from the results of the pre-test using the four tier-test instruments and classroom learning. Then, the data codification technique was conducted to distinguish students based on 5 levels of conception. The result shows that CS-CCT is able to be designed and developed in term of facilitating students to change their conceptions. Thus, it could be concluded that the development of CS-CCT is able to facilitate students conceptual change on fluid dynamics conceptions.

1. Introduction
Since the last decade, research on the development of CCT has been intensively conducted. CCT is the development of textbook which is then developed based on conceptual change approach that includes dissatisfaction (dissatisfied of the concept), intelligibility (concept can be easily understood), plausibility (concept must be reasonable) and fruitfulness (concept must be efficient) [1-3]. CCT can overcome the problem of misconceptions often experienced by students [2,4,5]. In the development process, CCT is a learning material that facilitates the transformation of students' knowledge [2,4,5]. However, the CCT that developed as learning materials has not been able to visualize abstract things in physics learning. Physics learning aims to provide knowledge related to the concepts, principles, and laws underlying a phenomenon [5]. A phenomenon tends to be abstract and needs to be visualized in order to be easily understood [6]. Thus, students' understanding of abstract phenomena must be raised in learning materials to change the conceptions that students have.

Computer simulations can overcome the problem of visualizing abstract phenomena [5,7]. The concept visualized with computer simulations that displayed directly in front of the students will enable the students to understand the concept correctly. This makes the concept embedded and useful for them [1,8]. This study has the purpose of connecting CCT with Computer Simulation (CS) as the development of CCT in order to visualize abstract phenomena in physics learning. Computer Simulation-Assisted Conceptual Change Text (CS-CCT) is designed to solve the visualization problems experienced by students [5,7]. CS-CCT developed with the aim of visualizing abstract phenomena and focusing on the
concept of fluid dynamics. Concepts in physics learning are often misunderstood [9,10]. One of them is the concept of fluid dynamics. The concept of abstract fluid dynamics such as the Bernoulli principle and ideal fluid concept needs to be visualized in order for students to have a concept intact [11]. In the fluid dynamic concept, there is often a misunderstanding especially on the principle of Bernoulli (as shown by equation 1).

\[ P_1 + \frac{1}{2} \rho v_1^2 + \rho gh_1 = P_2 + \frac{1}{2} \rho v_2^2 + \rho gh_2 \]  

(1)

At the preliminary of the research on CS-CCT, a Physics Education Technology (PhET) simulation will be used which can be downloaded for free. PhET simulations can visualize abstract phenomena on the concept of fluid dynamics such as the principle of continuity and Bernoulli principles.

![Figure 1. Physics education technology (PhET) simulation](image)

PhET simulation is able to show a certain concept correctly and in an easier way. Figure 1 shows a sub-material of physics learning which is the principle of continuity. The understanding of continuity principle needs to be changed due to a misconception experienced by students. Students assume that a section with the bigger area will result from a faster fluid movement and vice versa.

2. Methods

2.1. Participant

There are 33 students involved in this research (17 years old on average) which are the second grader in one of a Senior High School in Bandung city. The students consist of 10 females and 5 males. None of the students have learned about fluid dynamics. Furthermore, it is done in S1-S33 code based on absent in class.

2.2. Design

The research method used is FODEM (Formative Development Methods). FODEM consists of three components: needs analysis, implementation, and formative evaluation [12,13]. The first component is Needs Analysis (NA), in this section, the needs and deficiency of design and the development of CS-CCT are analyzed in order to visualize abstract phenomena. In the Implementation (I) phase a trial and evaluation of learning are conducted so the CS-CCT that has been made can be used optimally. In the Formative Evaluation (FE) phase, we measured the extent to which CS-CCT able to function. In this phase, we can see from the four-tier test answers of students before and after learning. Then the results are categorized into 5 levels of conceptions [15,16]. The followings Figure 2 is the design of FODEM.
2.3. Instrument
The research instrument used is a multiple-choice test that has been tested and can diagnose the levels of student conception. This test instrument is a four-tier-test development test instrument on the fluid dynamic concept. The instrument consists of 10 multiple choice questions. Four tier test consists of 4 main points packed in multiple-choice. Tier-1 which contains the question of a concept, tier-2 contains the level of belief of the selected answer tier-1, tier-3 contains the reasons for the answer selected on tier-1 and tier-4 in the form of a confidence level of the tier-3 answer.

2.4. Analysis Data
Data can be analysed from multiple choice answers of students. Then the results of this answer we categorize into 5 levels of conception, namely Understand (U), Partial Understand (PU), Misconception (MC), Not Understand (NU) and Un-code (UC) [15,16]. In term of developing CCT-CS, we need to know the conceptions level of students who hold misconceptions so that their learning is focused on conceptual change. In making CCT-CS, we need to know how severe the level of conception students has for learning and focus on conceptual change.

3. Results and Discussion
Based on the results of the study using CS-CCT on the concept of fluid dynamics, CS-CCT developed by using FODEM (Formative Development Methods) get the results which will be explained in detail as follows.

3.1. Needs Analysis (NA)
Conceptual Change Text (CCT) is based on 4 components of dissatisfaction, intelligibility, plausibility, and fruitfulness [1-3]. CCT was found to be able to transform students’ conception when it completes those 4 components. In the component of dissatisfaction, the learning was created in a way it could encourage student dissatisfaction of a concept and results from students tend to find out what he did not know. Intelligibility components emphasize a concept to make it easily be understood. The next component is plausibility, the component emphasizes that for a concept to be acceptable, it has to be reasonable. Then the last component is fruitfulness, where the concept that students get has to be efficient. Thus, the CCT packaged with these four components will lead to a changing conception learning [1]. Changing the conception of students can be directed if there is no concept is difficult to be described by students. The concept in physics learning that is difficult to be described mostly related to abstract phenomena. Trough analysing the corresponding problem, the development of research on CCT is combined with computer simulation (CS) [6]. As a step to develop CCT in order to visualize phenomena on the learning of physics, Computer Simulation-Assisted Conceptual Change Text (CS-CCT) is created. CS-CCT is expected to overcome the problem of visualization on CCT so that there is an optimal change of conception. CS-CCT components are designed as in Figure 3 below.
Figure 3. The components CS-CCT design.

Figure 3 was designed by adapting the CCT made by Ozkan [5,6] and combined with CS. CS-CCT consists of 4 main components: question, theoretical concept, simulation, and the application of a concept. The question of the concept is understandable. Theoretical concept contains fluid dynamic concepts that facilitate students to capture information. Theoretical concept consists of concept for the identifying question of phenomena, cognitive conflict, and review the different phenomena. PheT simulation is used to find out how far students understand fluid dynamic by making observations. This simulation serves to visualize the concept of abstract fluid dynamic and needs to be presented directly to be more easily understood by the students. The process concept changes were observed from the answers to question phenomena and conflict cognitive in the CS-CCT section. Then a more detailed development of CS-CCT can be seen in the Figure of 3, 4 and 5.

Figure 4. Example of a developing CS-CCT design Bernoulli’s law question.

The question shown in Figure 4 is aimed to capture students’ conception of Bernoulli’s law sub-material. In the figure, students are asked how a plane fly and able to turn in the air. Most student will find the burning process that occurs in the plane as the main factor regarding the phenomena, meanwhile, the explanation of this phenomena is based on Bernoulli’s law.
Figure 5. Example of a developing CS-CCT design-Bernoulli’s law conception.

Based on Figure 5, the theoretical concept that aims to provide information that can know the correct conception. In addition, there are several questions that aim to cause conflict cognitive. Students will read the next phenomenon. This is because CCT emphasizes repeating concepts that are similar to the concept of understanding that will be better. In Figure 6, given a simulation related to another phenomenon based on Bernoulli’s law to strengthen students’ conception. The simulation explains a sub-concept of Torricelli which guide students to do experiment and instruction about factors that influence Torricelli. A common misconception experienced by students is that the distance and velocity of water movement are influenced by height and air pressure from outside the pipe.

To better understand this Bernoulli principle, let’s review the following PhET simulation.

Figure 6. Example of a developing CS-CCT design – simulation and application of Bernoulli’s laws.

The developed CS-CCT then entered the stage of validity testing by expert judgment. The purpose of this test is to find out how much CS-CCT can be used in general. The recapitulation of the expert validity test is shown in Table 1.

Table 1. Recapitulation of validity by expert Judgement.

| No. | Rated aspect | V1 | V2 | V3 |
|-----|--------------|----|----|----|
| 1   | Coverage and depth of material in CS-CCT | 4  | 5  | 5  |
| 2   | Sequence and systematic presentation of concepts in accordance with learning objectives | 5  | 5  | 5  |
Based on Table 1, CS-CCT has a result of 0.98 which can be categorized very well and can be used in general [11].

3.2. Implementation

The implementation is done directly by applying CS-CCT that has been made to the learning. At this stage, an arrangement has been made to promote an optimal usage of CS-CCT. CS-CCT will be tested in class which divided into small groups with 3-4 person for each group. A directed instruction is applied so students can be monitored by researchers [12]. An analysis of the result will be done in order to revise and evaluate before it can be used in general learning. However, on this preliminary design experiments and evaluations were only done in small groups. The followings are a classroom testing process and a small group evaluation is shown in Figure 7.

![Figure 7. Implementation CS-CCT in classroom](image)

3.3. Formative evaluation

Evaluation is used to find out how well CS-CCT able to functions. In the need analysis (NA) and Implementation (I) stage, the Evaluation is done as a whole which is then called as formative evaluation [13,14,17]. In the need analysis stage, a detailed evaluation is undergone by experts. Then a revision was done to enable CS-CCT functions as it is supposedly. At the implementation stage, the learning evaluation is based on student answers related to the question sheets in CS-CCT. At the evaluation stage, Students are given the test with a four-tier test format that can know the conception that students have. The students’ answers were then analysed and categorized according to the 5 levels of conception [2,15,16]. The average distribution of misconceptions that need to be changed can be seen in the 2-D column chart shown in Figure 8.
Figure 8. The average distribution of misconception student’s.

Based on Figure 8, the conception of students who experience misconceptions needs to be changed. One of them is in question number 6. The distribution of students' conceptions in question number 6 is shown in Table 2 below.

Table 2. Distribution Students’ Conception on number 6.

|   | U   | PU | MC | NU | UC |
|---|-----|----|----|----|----|
|   | S6, S8, S15, S17, S20, and S27. |    | S1, S2, S3, S4, S9, S13, S16, S18, S21, S22, S24, S28, S29, S30, S31, and S33. | S5, S7, S10, S12, S19, S23, S25, S26, and S32. | S14 and S11 |

Based on Table 2, several students can be called misconceptions in question number 6, namely the continuity principle. For example, students with S13 code. Changing conception using CS-CCT can be seen from the answer S13 which looks at Figure 9.

Figure 9. One answer for S13 in CS-CCT.

Based on Figure 9, answer S13 indicates changes in conception when using CS-CCT. Something similar is experienced by students who experience misconceptions or other conceptions understands. Thus, CS-CCT is developed can be used to change students' conceptions towards the expected ones. This is consistent with several studies which state that CCT with the help of simulation can remedy student conception [18,19]. The concept of remediation in question is a change in conception towards what is expected. Changing conception in detail and comprehension based on the post-test and CS-CCT overall will be published in the next paper.

Figure 8. The average distribution of misconception student’s.
4. Conclusions
Based on these studies, the student's conception of fluid dynamics can be improved by using CS-CCT. The developed CS-CCT emphasizes a simulation combined with CCT that are aimed to visualize abstract phenomena that often occur and tend to make misconceptions on a concept. In the formative evaluation phase, CS-CCT can facilitate the changing of student's concept to the expected concept of fluid dynamics. In the next study, we will develop Computer Simulation to be applied to CS-CCT facilitate understanding. CS-CCT will be developed with the help of E-FluDyS simulation. This CS can only be used exclusively for fluid dynamic materials and can change student conceptions towards expected changes.

5. References
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