Development of computer simulation-assisted conceptual change model (CS-CCM) to change students’ conception on gas kinetic theory

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Abstract. This study aims to develop computer simulation-assisted conceptual change model to change students’ conception on gas kinetic theory. This study has been conducted to senior high school students because gas kinetic theory is an abstract concept, so that the conceptions usually increase misunderstanding and misconceptions of students. The research development has been implemented in the ADDIE development model. The ADDIE model consist of: Analyse, Design, Develop, Implement, and Evaluate. Respondents in this study amounted to 26 students (average age of 17 years old), who came from one of high school in Belitung. The test instrument used is three tier open ended questions consisting of 7 questions and the results of the test were categorized into five categories consisting of misconception (M), not understanding the concept (NU), sound understanding (SU), partial understanding (PU), and not being encoded (UC). The results show that CS-CCM can be designed and developed to facilitate change students conception on gas kinetic theory. Thus, it can be concluded that the development of CS-CCM is able to facilitate conceptual change of students’ conception on gas kinetic theory.

1. Introduction
Computer simulation has become one of the learning media which is often used by science teachers to help students in learning the concept of science that is microscopic and macroscopic by visualizing the concept [1,2]. The use of computer simulations provides a positive benefit in building students' conceptions which is compatible with the concepts that scientists believe, for example by using computer simulations, students can manipulate a model to see how it works in various conditions and see the results of the changes in the form of graphics or other representations provided by computer simulation program used. Computer simulations can be interpreted widely as computer programs that attempt to imitate a particular system model [1]. The use of computer simulations helps students to learn about the abstract concept of science [2], so that many researchers use computer simulations [3-8] on learning that aims to alter or enhance understanding of students’ conceptions, such as research entitled use of simulations in correcting misconceptions on electrical [3]. Although many studies have shown positive results from the use of computer simulations that students have improved to a better direction [3-8], teaching techniques that only use computer simulations still have some drawbacks [1], for example, for certain concepts that are concern about misconceptions, the use of computer simulations instead of making students initially understand the concept of being misconceptions [3]. This is what...
makes many researchers aware that is needed a supporting other combined with computer simulation so that the use of computer simulation is more effective [4]. Based on this, the researchers tried to use computer simulations combined with a model with the aim that the misconceptions of students change in a positive direction.

The model chosen by researchers to be combined with computer simulation is conceptual change model. Conceptual change model (CCM) is one of the learning models that focus on changing student conception. CCM was developed by Posner et al. [9,10], based on Piaget's idea [9,11] on assimilation and accommodation. Assimilation is an individual process of placing or classifying new events or stimuli into an existing scheme, and accommodation is an individual process of forming a new scheme that fits the stimulus and modifies the existing scheme so it can be suitable with the stimulus provided [11]. In CCM, student dissatisfaction with early conceptions that students have is an early trigger in the learning process. If the student is not satisfied with the previous conception and the available replacement concepts are intelligible, plausible, and/or fruitful, accommodation of the new conception can follow [12]. One of the researchers who developed CCM is Stepans [9,13] with six phases: commit to a position or outcome phase, expose beliefs phase, confront beliefs phase, accommodate the concept phase, extend the concept phase, and go beyond phase.

The result of the combination of CCM and computer simulation is computer simulation-assisted conceptual change model (CS-CCM). CS-CCM is a learning model developed based on CCM Stepans [13] by adding computer simulation assistance to the model. Computer simulations are used for the aim of new conceptions are being learned can be intelligible, plausible, and/or fruitful [12]. With the existence CS-CCM, it is expected that the abstract concepts, especially in the subject of physics, can be better understood and changed students’ wrong initial conception.

Initial conception is the initial understanding of the student before learning or also called naïve conception [14]. The naïve of conception is divided into two, i.e., knowledge which is easily revised or deleted through instructions (preconceptions) and knowledge that is very resistant to change, remains strong when faced with instruction (misconception). This naïve conception must be improved so that students' understanding increases to a concept. Changes in conception are the processes used to correct or remove naïve conceptions. This process is necessary so that students do not produce a defective mental model [14]. The change of conception must involve a change of ontological categories in the cognitive structure of the student, since students think of several concepts from various ontological categories that are categorized by scientists. By term, ontology, is defined as "the science of existence" [15]. Concepts are placed in ontological categories according to their ontological properties. There are three main categories most frequently used are material, process, and mental state [15]. The ontologies category change means that the concept was initially mis-categorized by the student after the treatment was re-categorized by the students according to the category of scientist. Therefore, a learning process involved in changing student conceptions is required, as well as providing a framework for designing instructions that facilitate expected change [16].

In learning, students' understanding of the concept is categorized into four levels of understanding, consisting of misconceptions, not understanding, sound understanding, and partial understanding of concepts [17]. To improve students' understanding of concepts, there needs to be a change of conception to a better direction in the misconception category, not understanding concepts and understanding some concepts. CS-CCM is used in order to change student conception in a better direction.

In this study, CS-CCM will be studied on one of the concepts of physics, namely the gas kinetic theory. The gas kinetic theory is an important concept due to the basis for understanding thermodynamic concept, so students must understand this material in accordance with the concepts provided by the experts. Gas kinetic theory has 5 sub-chapters to be studied, consisting of ideal gas properties, ideal gas laws, ideal gas equations, gas kinetic theory, and energy ecipartition theorem. Here is one example of the concept description of the sub-chapters of ideal gas laws, namely Boyle's and Gay Lussac's laws [18].

When the gas is pressed while keeping the temperature steady it will be found that the pressure increases when the volume is reduced. With a good approach, the gas pressure, \( P \), changes in reverse
with the volume, \( V \). This means that, at a constant temperature the product of pressure and gas volume is constant. This result was discovered by Boyle [18], called Boyle's law [18]. Which if written in mathematical equations then obtained:

\[
P V = \text{constant} \tag{1}
\]

Gay Lussac [18] states that: "If the volume of gas in a closed vessel is kept constant, the gas pressure, \( P \), is proportional to the absolute temperature, \( T \)." Which, if written in a mathematical equation, is obtained:

\[
\frac{P}{T} = \text{constant} \tag{2}
\]

Based on the above description, this study aims to develop a model that refers to the conceptual change of computer-aided simulation model to change the student's conception on gas kinetic theory. Because the gas kinetic theory has many abstract concepts so that students often get a misconception of concepts.

2. Methods

2.1. Research Design

The purpose of this research is to develop conceptual change of computer-aided simulation model to change student conception on gas kinetic theory. The ADDIE model [19] is a research and development method that will be used in this study. The ADDIE [19] model consists of: Analyze, Design, Develop, Implement, and Evaluate, the concept is shown in Figure 1.

![Figure 1. Concept the ADDIE model [19].](image-url)

Based on figure 1, it was found that the five stages of the ADDIE model are interconnected. The first step is analyze. The purpose of this stage is to identify possible problems. The steps that are generally carried out by researchers at this stage are validating the problem, determining instructional goals, confirming the intended participants, identifying the resources needed, determining the most effective solution for the problem, and writing a structured settlement plan.

The second stage is design. The purpose of this stage is to verify the product that can be used to solve problems and determine the right test method. The steps that are generally carried out by researchers at this stage are registering assignments, writing performance goals, generating testing strategies, and calculating the effectiveness of products to solve problems.

The third stage is develop. The purpose of this stage is to produce and validate learning resources. The steps that are generally carried out by researchers are producing learning content, selecting or developing supporting media, developing guidelines for students, developing guidelines for teachers, making formative revisions, and conducting trials.

The fourth stage is implement. The purpose of this stage is to prepare a learning environment and involve students to see the effectiveness of the product. The steps that are generally carried out by researchers are preparing teachers and preparing students.
The fifth stage is evaluate. The purpose of this stage is to assess product quality and instructional processes, both before and after implementation. The steps that are generally carried out by researchers are determining evaluation criteria, selecting evaluation tools and conducting evaluations [19].

At each stage, evaluation and revision are generally carried out before the researcher continues to the next stage so that the best results or products are obtained to solve the problem. If after the implementation is carried out and it is found that the product made cannot solve the problem, then the analysis phase is again carried out.

2.2. Study Participants
Participants amounted to 26 people with an average age of 17 years who came from one of high school in Belitung. Participants were selected by incidental sampling technique. This technique is chosen because the model is tested based on the class specified by the teacher who will use the CS-CCM model.

2.3. Instrument and Data Collection Process
PhET is an interactive simulation of physical phenomena. Using PhET in learning allows students to connect real-life phenomena and concepts learned. So, this study uses a computer simulation of PhET interactive simulation in accordance with the material under study, namely the gas kinetic theory. PhET interactive simulation used is shown in Figure 2.

![Figure 2. PhET Interactive Simulation which is used for CS-CCM.](image)

The test instrument used to see the effectiveness of learning using CS-CCM is with three tier open ended questions consisting of 7 questions. And five open-ended questions are also asked to gain student feedback on the learning process using CS-CCM and whether CS-CCM can change the student’s conception in a positive direction. In addition, interviews were conducted with teachers who implemented learning scenarios to get input from the CS-CCM model that was good for use in the classroom. The sample questions three tier open ended are shown in Figure 3.
2.4. Data Analysis

Data were analyzed after participants filled out the pre-test and post-test. The results of the pre-test and post-test were categorized into five categories consisting of misconception (M), not understanding the concept (NU), sound understanding (SU), partial understanding (PU), and not being encoded (UC). The categories are shown in Table 1.

| Category                               | Tier 1 | Tier 2 | Tier 3 |
|----------------------------------------|--------|--------|--------|
| Sound Understanding (SU)               | True   | True   | Sure   |
| Misconception (M)                      | False  | False  | Unsure |
| Not understanding the concept (NU)     | False  | False  | Unsure |
| Partial understanding (PS)             | True   | False  | Sure   |
|                                        | True   | False  | Unsure |
|                                        | False  | True   | Sure   |
|                                        | False  | True   | Unsure |
| Not being encoded (UC)                 | (if one, two or all are not filled) | |

3. Result and Discussion

The development of CS-CCM on the concept of gas kinetic theory emphasizes the change of student’s conception in a positive direction. CS-CCM was developed based on the steps of the ADDIE Model [19] which are detailed as follows.

3.1. Analyze

The analyzing phase is a needs assessment process such as a phase for identifying research problems [8]. The first analysis begins with the observation of the process of physics learning in the classroom, obtained the results of analysis that required the development of a model that emphasizes the changing conception of students with strong instruction. Furthermore, the analysis conducted on the lesson plans shows that the learning scenario has not emphasized the change of student conception. This affects the process of learning in the classroom because lesson plans is a teacher guide in implementing learning in the classroom. Based on the results of the analysis, the researcher did the development of conceptual change of computer-aided simulation model in which there are also learning steps.
3.2. Design
In this step, the design in question is the CS-CCM design that will be used in the learning process. The CS-CCM design concept focuses on the instruction given to students about abstract concepts on the material of the gas kinetic theory. This instruction is in the form of computer simulations that are used as phenomena used for confrontation of the initial conception they believe in, so that the misconception that the student believes can be directed toward concepts that fit the concept of the scientist. The CS-CCM steps are given by Figure 4.

![Figure 4. The CS-CCM steps.](image)

3.3. Develop
The development stage is the process of realizing the design into reality [8,19]. Which means the steps that exist in the design is manifested in the form of learning scenarios. For CS-CCM in this study the computer simulation used is PhET Interactive Simulation which examples are given by Figure 2. Examples of learning scenarios can be seen in Table 2.

| Table 2. Example of learning scenario. |
|----------------------------------------|
| Learning Structure | Learning Activities | Time |
| CCM learning scenario | Core Activities | Phase 3: Confront belief phase 1. The teacher directs students to look for, for example the relationship and temperature based on the literature. 2. Student start looking for answer based on books or other supporting literature | 15 minutes |
| CS-CCM learning scenario | Core Activities | Phase 3: Exploration of computer simulation 1. The teacher directs students to start the experiment using computer simulations. 2. Students begin computer exploration to see the relationship of pressure to temperature, the relationship of pressure to volume and the relationship of volume to temperature. | 15 minutes |

3.4. Implement
Implementation is a concrete step to implement the learning system that has been created [8,19]. After CS-CCM, validated by experts and made several revisions at the design and development stage, CS-CCM is then given to the participants. Researchers do not directly provide learning by using CS-CCM but that gives learning is a physics teacher in high school. Teachers provide learning based on scenarios that have been developed by researchers. The researcher here acts as an observer, who is in charge of observing the implementation of CS-CCM learning in the gas kinetic theory.

3.5. Evaluation
Evaluation is the process by which an assessment of the product is performed, so it is known whether the product is in line with initial expectations or not. In this study the evaluation was conducted by
interview, pre-test and post-test students. Interviews were conducted with teachers who conduct learning in class and students to get input on CS-CCM learning scenarios that were implemented previously.

Based on the results of the interview between the teacher and students, there were several inputs regarding the stages of the learning scenario, so the researcher revised learning scenario. One of the results of the pre-tests and post-test obtained from question number four is shown in Figure 5.

![Figure 5. The result of the pre-test and post-test from question number four](image)

Figure 5 shows the results of students' answers to problem number 4 discussing Charles's law that underlies the ideal gas equation. Students are categorized as sound understanding, if students answer tier 1 with "Water in bottle II will rise and go to bottle I", tier 2 with "At constant pressure, when the bottle I is put into cold water the temperature of the bottle drops which results in air volume shrink. This is what causes the water in the bottle II to be sucked into the bottle I ", and tier III with" Sure ". Of the 26 students, before the treatment there were no students who were aware of the concept and after being treated about 34.62% (9 people) became aware of the concept. Students who understand this concept come from students who misconceptions, do not understand the concept and understand some concepts. It can be concluded that around 34.62% of students experienced a positive change.

Students who are categorized as having misconceptions, if students answer tier 1, for example (based on answers from one student) with "There is no change in bottle II", tier 2 with "Change only occurs when bottle I is dipped in hot water" and tier 3 with" Sure ". Of the 26 students, 50% (13 people) of students who experienced misconceptions were treated before treatment and after being treated about 26.92% (7 people) experienced misconceptions. Students who still experience misconceptions here come from students who have misconceptions from the beginning and students who do not understand the concept. It can be concluded that there was a decrease in students with misconceptions around 23.08%.

Students who are categorized as not understanding the concept, if students answer tier 1, for example (based on answers from one student) with "The water in the bottle II will drop due to the air pressure from bottle I", tier 2 with "due to the air pressure in the bottle I the big one so that the water in bottle II will go to bottle I "and tier 3 with" not sure ". Of the 26 students, before treatment was carried out around 30.77% (8 people) students did not understand the concept and after treatment was around 11.54% (3 people) students still did not understand the concept. It can be concluded that there was a decrease in students who did not understand the concept around 19.23%.

Students who are categorized as understanding some concepts, if students answer tier 1, for example (based on answers from one student) with "Water in bottle II will rise and go to bottle I", tier 2 with "because the temperature in cold water is lower than the pressure higher air causes the water in bottle II to rise and go to bottle I "and tier 3 with" sure ". From 26 students, before being treated about 19.23% (5 people) students understood part of the concept and after treatment was around 26.92% (7 people) students understood some concepts. It can be concluded that there is an increase in students who
understand some concepts around 7.69%, this is because students who initially experience misconceptions and do not understand the concept experience change to understand some concepts, and there are students who do not experience a change in conception.

4. Conclusion

Based on the results of data analysis, it can be concluded that CS-CCM development on changing student's conception on gas kinetic theory through ADDIE (Analyze, Design, Develop, Implement and Evaluation) model can change student's conception to a better direction. CS-CCM consists of seven stages, i.e. commit to a position or outcome phase, expose beliefs phase, confront beliefs phase, explore computer simulation phase, accommodate the concept phase, extend the concept phase, and go beyond phase.

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