A computer based learning resource to support students to learn gas law and kinetic theory of gas

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Abstract. Physics is a subject that closely related to nature and being a basic for the development of technology. To give students a real experience, it is suggested to deliver the concept of physics through observation and hands-on experiments. However, some experiments are difficult to be carried out in the classroom. Carrying the experiment on gas law and kinetic theory of gas to the classroom may be challenging. Moreover, in the kinetic theory of gas, microscopic model of gas cannot be observed directly. In this study, we have developed a computer-based learning media that allow students to investigate the ideal gas law through computer simulations. The microscopic model of gas based on theory kinetic gas is also visualized in this computer-based learning media. Students can use this learning resource to help them study gas law and kinetic theory of gas by themselves. The computer-based learning resource is equipped with simulation of experiments, explanation, exercise, and quiz.

1. Introduction
Experiment in science education is necessary. Experiment is important to build students’ critical thinking skill and intuition, promoting logical development and problem solving skill, improve the ability to understand theory, allow students to observe phenomena, test hypothesis, develop data analysis skill, improve attitudes towards and interest in science, etc. [1,2,3]. However, in some occasions, carrying out real experiments in the classroom is difficult. It may be due to complexity of instruments, limited time that teachers have difficulty of class management during the experiment, etc. Those limitations may be overcome by adapting experiment activity in the computer program [4,5].

The impressive development of computer technology gives rise to the use of computer-based media in learning physics. Computer assisted learning in physics education is also have been studied widely. Enormous number of physics education software arise. Esquembre [6] classified them into some categories according to its principles of use, i.e. tools for the acquisition and manipulation of data, multimedia software, micro worlds and simulation, modeling tools, and telematics and internet tools.

Simulations are programs that contain a model of physical process and display visualization of it. Simulation program can encourage student to explore the physical system, set physical parameter, manipulate physical quantity and observe the result of the manipulation. Simulations provide students with opportunity to develop their understanding about the physical phenomena and laws through the hypothesis making and idea testing, manipulate parameters so that students can develop an understanding of the relationships between physical concepts, variable, and phenomena, and investigate phenomena that would not be possible to experience in a classroom or even in laboratory [6].
One of topics covered in high school physics is gas law. Most of school do not have plenty amount of apparatus to conduct gas law experiment in the classroom. Moreover, gas law is related to the concept of kinetic theory of gas. There are a lot of abstract concepts in kinetic theory of gas, most of them related to the microscopic point of view of gas. Many students cannot understand them easily because they cannot be observed directly in daily life. Abstract concept in physics classroom makes the information become hard to be grasp, moreover it makes the course become boring and difficult. [7]

Some previous studies show that computer assisted instruction is successful to improve student success in physics classroom significantly [7,8,9]. Computer based media may help students to understand abstract concepts in gas law and kinetic theory of gas because computer based media possible to provide animation of gas molecule and simulation of experiments.

In this study we have developed a computer based learning resources to support students to learn kinetic theory of gas. This computer based learning resources contain materials with communicative animations, simulations of experiments, exercise, and quiz.

2. Method
In this study we adapt 4D models [10] that consist of four steps i.e. define, design, develop, and disseminate. We did students, task, and concept analysis in the define phase. The result of the analysis is used to design the prototype of the computer-based media. We decided to combine simulation of experiment, demonstration video, tutorials, problem-solving practice and quiz in the learning resource. The develop phase is conducted by involving some validation and tests. The computer-based media has been gone through expert appraisal and developmental testing to small and large group of high school students. We revise the media based on each step of developmental testing results until we yield the finalized media. We obtained students’ comments on the media use by questionnaire answers. Moreover, we also investigate the effect of the use of the computer-based learning media for individual learning in the students’ conceptual understanding by conducting pre-test and post-test. We use one group pretest and posttest design in this research and then analyze the normalized gain score using the following formula [11].

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 g = \frac{\% \text{posttest score} - \% \text{pretest score}}{100 - \% \text{pretest score}}
\]

3. Result and discussion

3.1. The features
The learning resource consists of some features such as material, simulation of experiments, exercise, quiz, and scientists’ biography. The features contained in this media is shown in the homepage, such as shown in Figure 1. Material contains introduction to physical concepts, concepts’ explanation, basic mathematical derivation, and some example of related physical phenomena. The material is accompanied by videos and animation.
This learning resource also contains simulation of ideal gas experiments. As the experiments are not always easy to be carried out in the physics class, we developed some simulations that may be an alternative to substitute hands-on experiments. Students are guided to find the relationship between pressure and temperature ($P-T$), volume and temperature ($V-T$), and pressure and volume ($P-V$) in ideal gas system through the simulation. Students have to represent their result in a graph form and interpret the result. The activity in the simulation can be used in both ordinary class and individual study. In an ordinary traditional class, teacher will be the facilitator who guide students to take data, analyze, and present the result. However, the media still can be used for individual study where there is no instructor because the media provide detail guides from taking the data to interpreting the data (see Figure 2).

![Simulation of P-V relationship](image)

**Figure 2.** Simulation of $P$-$V$ relationship. The simulation contains some activities such as (a) data taking, (b) data analysis, (c) confirmation of result through automatic simulation, and (d) interpretation of result.

Besides $P$-$V$-$T$ relationship in ideal gas, simulation of root-mean-squared (rms) speed of gas molecules is also provided. The simulation shows the relation between temperature, relative mass, and rms speed of gas molecules, which is adopted from PhET [12]. The relation between some quantities in kinetic theory of gas is derived mathematically within a simple assumption. This explanation aims to give the students a comprehensive understanding from theoretical point of view and experimental result.

Exercise allows students to apply some concepts that have been studied in the material to solve some problems. As an exercise, the solutions of each problem are provided. Move up to the next level, students can do Quiz to evaluate their individual study. The Quiz is constructed from 4 levels with different
difficulties of problems. Students have to pass $\geq 80\%$ score if they want to go the next level. The questions in each level are always randomly changed if students restart the quiz.

3.2. Developmental Testing

The program has been validated through expert appraisal and has been tested to senior high school students. We asked some teachers to review this program. Overall, teachers agree that this program is potentially can be used to help students learn gas law and kinetic theory of gas material. The program was revised based on some advices from experts and physics teachers before directly tested to students.

We did first trial to a small group consists of 4 students. They were given a pre-test to measure their initial knowledge of gas law and kinetic theory of gas material. After that, they learnt the material individually through the learning resource that we have developed. A post-test was given to them to measure their final understanding on the material after they used our program. Using equation (1), the result of pre- and post-test are analyzed to yield the normalized gain-score. The average gain score from the first trial is 0.68, which is categorized as medium gain [11]. At the end of the session, they also filled up the checklist about their opinion of the quality and usability of the learning resource.

We received some advices from this first trial and thus we did a minor revision on the media. We did the second trial to a larger group of students. On the second trial, there are 61 students from two schools are involved. Similar to the first trial, we conducted pre-test before they used the program and post-test after they used the program. The average gain score from the second trial is 0.55, which is categorized as medium gain [11]. Table 1 shows the average of pre- and post-test score and gain score.

Table 1. The comparison of pre- and post-test score and the gain score.

| Group            | Average pre-test score (out of 100) | Average post-test score (out of 100) | Average gain score ($g_{av}$) | Criteria |
|------------------|-------------------------------------|--------------------------------------|-----------------------------|----------|
| Smaller group    | 38.33                               | 80.00                                | 0.68                        | Medium   |
| (4 students)     |                                     |                                      |                             |          |
| Bigger group     | 41.99                               | 73.87                                | 0.55                        | Medium   |
| (61 students)    |                                     |                                      |                             |          |

*Average gain score is calculated by averaging each individual gain scores in the group.

After each trial, we give students some checklist to know their opinions about the quality and usability of the media. There are some statements in the checklist and they must answer yes or no. The statements actually ask about 5 main aspects, i.e. the fitness of media for individual learning purpose, the usefulness of media to learn ideal gas and theory kinetic gas, layout quality, language quality, and accessibility of the media. Overall, most of students are agree that the fitness of media for individual learning purpose, the usefulness of media to learn ideal gas and theory kinetic gas, layout quality, language quality, and accessibility of the media are excellent.

4. Conclusion

A study has been conducted to develop high quality of computer based learning resource on the material of gas law and kinetic theory of gas. The program has been tested to groups of students. Based on the gain score analysis, the media is potentially can be used to improve students’ understanding on ideal gas and kinetic theory of gas effectively. Students’ response on the usability and quality of the media overall can be categorized as excellent. Hopefully, this learning resources can be used widely and give good impacts on students.

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