Using simple hands-on experiments to develop students' concept on the kinetic theory of gases

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Abstract

The research objective is to develop students' concept on the kinetic theory of gases. The samples of this study were 33 grade-11 students from class 5/1 of Um Mao Prachasan School, That Phanom District, Nakhon Phanom province who were studying in the 2nd semester of the academic year 2014 and were selected by purposive sampling. The research design was in the one-group pretest posttest design. The tools that were used in this study consisted simple hands-on experiments and active learning, a conceptual test regarding ideal gas and kinetic theory of gases as well as a behavioral assessment form. The research results revealed that the use of simple hands-on experiments along with active learning could enhance the understanding of scientific concepts. The students' average normalized post-instruction gain was 0.6, which was in a medium level.

Keywords: active learning, kinetic theory of gases, simple hands on experim

Introduction

Physics education researchers agree that active learning can enhance students' understanding of concepts. The heart of active learning is the learning environment which allows students to participate and construct their knowledge by themselves according to the theory of constructivism. There are several methods to provide active learning depending on the students and the classroom contexts such as *RealTime Physics*, *Workshop Physics* and Interactive Lecture Demonstrations. The active learning strategies as mentioned above focus on encouraging students to gain direct experience from the observation of the real physical world, such as hands-on experiments, according to the learning cycle which consists of prediction, small group discussion, observations and comparison of observed results with predictions.

It is difficult to apply active learning in classrooms under the Thai context. This is because most teachers offer passive teaching which focuses on lecturing while students like tutorial teaching which emphasizes problem solving in order to pass the exams to enter into universities. Moreover, they never conduct any experiment for different reasons; for example, the materials or equipments for the experiments are expensive or they do not have any; teaching by conducting experiments takes a long time, etc.

For the above reasons, the researcher would like to encourage active learning. The subject matter which is difficult to conduct the experiments due to the abstract content and the lack of equipments for the experiments in schools' laboratories is the topic of ideal gas and kinetic theory of gases. In this study, the researcher will make use of simple, easy-to-find materials and equipments for the demonstration so that students can observe the real phenomena.

Materials and Methods

Hands-on Experiments

Hands-on experimental sets which were used in this research were:

1. **Boyle's Law** : The experimental set for the demonstration of Boyle's Law consisted of a 50-ml syringe and a small balloon. The first step of the experiment was to close the end of the syringe tightly. Next, the balloon was blown up until it reached the appropriate size. A rubber band was used to fasten the balloon. Then, the balloon was put in the syringe. The students had to guess *whether there would be any change happening to the balloon or not when the plunger was pushed towards the balloon, and how.* This experiment proved Boyle's Law which states that, at constant temperature for a fixed mass, the volume of a gas and the pressure are inversely proportional.

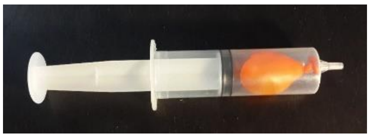

Figure 1 shown the experimental set for the demonstration of Boyle's Law

2. **Charles's Law**: The experimental set for the demonstration of Charles's Law consisted of 1) 2 5-ml syringes, 2) 3 50-ml beakers, 3) food dyes, 4) hot water, 5) cool water and 6) room temperature water. First of all, room temperature water mixed with food dye was put in the first beaker. Hot water was put in the second beaker and cool water was put in the third beaker. Then, 2 ml of air was sucked into both syringes, followed by 2 ml of food dye from the first beaker. The students had to guess *whether the volume of water mixed with food dye in the syringes would change or not when one syringe was put in the hot beaker and the other was put in the cool beaker, and how.* This experiment proved Charles's Law which states that, at constant pressure for a fixed mass, the volume of a gas and the Kelvin temperature are directly proportional.

Figure 2 shown the experimental set for the demonstration of Charles's Law

3. The experimental set for the demonstration of kinetic theory of gases consisted of 1) a 6 – 12 V. DC motor, 2) a cylinder (a plastic tube), 3) metal bullets, 4) a foam stick of the same size as the cylinder, 5) a power connector, 6) a set of 12-volt adjustable DC power supply and 7) a pair of cords with jacks. First, the power supply was connected to the experimental set for the demonstration of kinetic theory of gases. Next, 7-10 small metal bullets were put in the cylinder, followed by the foam stick which was dropped in the cylinder above the bullets. Afterwards, the switch was turned on and the motor's vibration speed was selected. The students were asked to observe the vibration of the bullets (the bullets were like gas molecules which are constantly moving according to the gas model). Then, the students had to guess *how the movement of the bullets and the level of the foam would be like when the potential difference continued to increase from 6V until 12V.* The teacher and the students discussed about this experiment until they reached the conclusion that the pressure of gas was caused by gas molecules hitting the wall of a closed container. If the gas volume decreased, the number of times that the gas molecules hit the wall would increase, resulting in higher gas pressure. This conclusion was in accordance with the kinetic theory of gas, and the students could see that gas molecules moved freely with no certain direction.

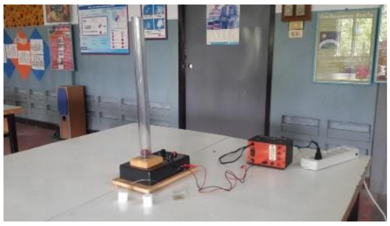

Figure 3 shown the experimental set for the demonstration of kinetic theory of gases

Figure 4 shown the visual lab from Phet

The Methods to Conduct the Research

This research was in the one-group pretest posttest design. The samples were 33 Grade-11 students who were selected by purposive sampling. The methods to conduct the research were as follows:

1. The students took the pretest.
2. The students conducted hands-on experiments regarding Boyle's Law,

Charles's Law and the kinetic theory of gases respectively.

3. The students conducted an additional visual lab experiment in the link https://phet.colorado.edu/th/simulation/gas-properties as seen in Figure 4.
4. The students took the 1st posttest.
5. The students took the 2nd posttest after 14 days to test their knowledge retentio

Results

The presentation of the research results was divided into 4 parts, which were: 1) the difference between the average score of the pretest and the average score of the 1st posttest, 2) the average normalized gain of each topic, 3) the knowledge retention 14 days after the teaching and learning and 4) the students' behaviors towards the teaching and learning.

1) The difference between the average score of the pretest and the average score of the 1st posttest

According to the results of the data analysis to measure the difference between the average score of the pretest and the average score of the 1st posttest regarding the hands-on experiments, it was discovered that the average score of the posttest (69.70%) was higher than that of the pretest (24.36) with the statistical significance of .05 (t=24.53). Such finding proved that the students had conceptual understanding.

Table 1 compares the mean, percentage, standard deviation and t-test of the pretest with those of the 1st posttest.

Test	Number of Student	Statistics			
		$\bar{X}$	%	S.D.	t
Pretest	33	6.09	24.36	2.18	24.53*
1st Posttest	33	17.42	69.70	3.30	

2) The average normalized gain of each topic

According to the analysis of the whole classroom's learning progress by the method of normalized gain, the average normalized gains <g> from high to low were those of Boyle's Law, Charles's Law and the kinetic theory of gases respectively. The sum of <g> values of all topics totaled .60, which was considered the medium gain.

Table 2 displays the average normalized gain of each topic.

Topic	%Pre - test	%Post - test	%Actual gain	%Possible gain	Avg.Normalized gain
Boyle's Law	29.55	79.55	50.00	70.45	0.71
Charles's Law	23.11	71.59	48.48	76.89	0.63
Kinetic Theory of Gases	17.17	50.17	33.00	80.68	0.41
Total	24.36	69.70	45.33	75.64	0.60

3) The knowledge retention 14 days after the teaching and learning

Table 3 compares the mean, percentage, standard deviation and t-test of the 1st posttest with those of the 2nd posttest.

Test	Number of Student	Statistics			
		$\bar{X}$	%	SD	t
1st Posttest	33	17.42	69.70	3.30	0.55**
2nd Posttest	33	17.55	70.18	2.77	

According to the comparison of the average score of the 1st posttest (the students took the test immediately after learning) and that of the 2nd posttest (the students took the test 14 days after learning) using t – test dependent with the statistical significance of .05, it was discovered that the t – test totaled 0.55, which fell into the crisis period. Statistically, it meant that both posttest scores were indifferent. Therefore, it could be concluded that the students who learned about ideal gas and kinetic theory of gases through active learning methods had knowledge retention.

4) The students' behaviors towards the teaching and learn.

Table 4 demonstrates the results of the analysis of students' behaviors towards the teaching and learning.

Topic	Behavior	mean	interpret
1	Attention and participation in activities	3.24	Very Good
2	Involvement in discussions and opinion sharing	3.33	Very Good
3	Unity within groups and between groups	3.12	Very Good
4	Responsibility	3.03	Good
5	Questioning and answering of questions	2.97	Good

The results of the analysis of students' behaviors towards the teaching and learning using a behavioral assessment form were at good and very good levels. Very good behaviors included the involvement in discussions and opinion sharing, attention and participation in learning activities and unity within groups and between groups. As for the behaviors which were at good level, they included the questioning and answering of questions and responsibilities.

Discussions and Conclusions

According to the research results, the provision of active learning together with simple hands-on experiments revealed that the students had better scientific concept on the kinetic theory of gases. They had knowledge retention after the learning was over and also positive behaviors during the teaching and learning. Such results might be due to 1) the eagerness of students who would like to know whether the actual results of the experiments would match their prediction or not; 2) the fact that the teacher organized discussions among the students and between the students and the teacher both before and after the experiments, which allowed the students to reflect their understanding at the moment; 3) the active learning pattern of which teaching cycle comprised the predict-observe-explain steps that allowed the students to observe real experiments and create their own, long-lasting knowledge; 4) the connection which made the students realize that the Physics contents that they learned in class were all related to daily life, which enabled them to appreciate the learning and 5) the use of open-ended questions during the activities which enhanced the students' analytical skills. Such findings are in accordance with the researches of Pornrat Watthanakasiwit [1]; Balasubramanian [2] and Timothy [3] which discovered that the learning which allows students to do activities by themselves enables them to gain first-hand experience as they can utilize scientific process skills to solve problems on their own. As a result, they learn by understanding without the need to learn by heart. Nevertheless, the application of active learning requires the teachers who are capable of controlling the class during the activities and raising the questions which stimulate students' learning. Moreover, the teachers should get all the equipments ready and prepare back-up tools as well.

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