Journal of Education and Practice
ISSN 2222-1735 (Paper) ISSN 2222-288X (Online)
Vol.9, No.33, 2018

Effects of Problem Based Learning Approach on 5th Grade Students' Misconceptions about Heat and Temperature

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This paper is a part of first author's masters thesis supervisedby the second author.

Abstract

The purpose of this study was to investigate the effect of Problem Based Learning (PBL) approach on 5th grade students' misconceptions about certain topics of "Heat and Temperature". This study is an experimental study with a pre-test, post-test, control group design. Sample of the study consisted of 64 fifth grade students (27 in experimental group, 37 in control group) who were attending an elementary school in a town which is located at Central Anatolian Region in Turkey. Students in experimental group were instructed by applying Problem Based Learning approach and control group was taught by utilizing traditional teaching methods. Instructional period took 13 weeks. Students' misconceptions were determined by administering the "Heat and Temperature Concept Test" just before and 3 weeks after the instructional period. The results of the study showed that PBL approach was more effective than traditional instruction in reducing the misconceptions about Heat and Temperature topics.
Keywords: *Problem Based Learning, Science teaching, Heat and Temperature, Misconceptions, 5th grade students*

1. Introduction

People sometimes make generalizations relying on their limited observations, or make incorrect inferences from their observations, experiences, or interactions with the world around them. Knowledge constructed through such a process might be contradictory to accepted scientific views about a subject. Terms such as misconceptions, pre-conceptions, children's science, naive beliefs, alternative conceptions, intuitive science, alternative frameworks are used to describe this sort of knowledge. Sometimes the knowledge is so robust that, replacing it with scientific explanations might be very difficult. Furthermore, it might be even much harder to learn the new topics which are related to the concept. Since pre-conceptions are influential in learning, it is important for educators to be aware of misconceptions that their students held about a specific topic and should design their instructions by taking the students' cognitive framework into consideration.

Studies about alternative conceptions in various science topics constitute an important part of science education research. Significant amount of studies conducted to examine how students understand certain science concepts revealed that students in all educational levels hold various alternative conceptions. For example, research on children's understandings about living things show that they see plants in nonliving things category and think that only moving things are living things (Bayraktar & Kuvvet, 2017; Brule et al., 2014). Physics education research shows that, people think that bigger objects exert greater force (Savinainen et al., 2017). Many people think that the moon has its own light, and the reason for the Moon's different shapes is shadow of the Earth on the Moon (Nielsen & Hoban, 2015; Åberg-Bengtsson, Karlsson, & Ottosson, 2017). Some people think that gravity doesn't exist in the space (Bar, Brosh, & Sneider, 2016). Most people believe that gases do not have mass (Adadan & Oner, 2014).

Heat and temperature is one of the most studied topics in misconceptions research. The results of the studies showed that many students held some specific alternative conceptions on the subject. For example, most students believe that heat and temperature are the same (Gonen & Kocakaya, 2010; Cakir-Olgun, 2008; Kali & Linn; 2008). Some students believe that temperature of a body does not depend on its' heat, and depends on the kind or size of it (Aydin, 2007; Keser, 2007; Bulus-Kirikkaya & Gullu, 2008). Students experience difficulty in conceptualizing heat transfer and thermal equilibrium. For example, most students do not comprehend that different types of materials have different thermal conductivity (Keser, 2007; Karakuyu, 2006; Baser & Cataloglu, 2005, Alwan, 2011, Lewis & Linn, 1994).

Bulus, Kirikkaya & Gullu (2008) study with 300 students at 5th grade showed that about %50 students think that heat is measured by thermometer, % 65 think that temperature is a kind of energy, and about %35 of them think that when something burns, it gives out temperature. All these results showed that students confuse heat and temperature. Interviews with the teachers and students in the schools where the research was conducted revealed that in science and technology classes, students do activities and experiments related to the topics covered in the lesson. Considering this fact, researchers commented on the necessity to survey the previous knowledge of the students at the beginning of experiments/activities, since previous experiences and perceptions might lead them to draw incorrect conclusions from the activities/experiments.

It is agreed upon that traditional learning methods are not very effective in eliminating misconceptions, creating meaningful learning, and increasing students' creativity. Constructivist teaching/learning activities on the other hand, take into account of students' pre-conceptions, make connections between new information and existed knowledge, promote inquiry and encourage cooperative learning.

Problem based learning is one of the constructivist based learning approaches, in which students learn about a subject in the context of real world problems. The goals of PBL include helping students develop flexible knowledge, effective problem-solving skills, effective collaboration skills, and intrinsic motivation (Hmelo-Silver & Eberbach, 2012). Working in groups, students identify what they already know, what they need to know, and how and where to access new information that may lead to resolution of the problem. The main role of the instructor is to facilitate learning by providing appropriate scaffolding and support in the process (Barrett, 2010).

Primary instructional materials for PBL are scenarios which are basically stories in which real life problems take place. The most important goal of scenarios is to help students to achieve the determined objectives of the instruction by means of specific processes. Furthermore, scenarios make students think that the subject to be learned is necessary and helpful. Scenarios also stimulate students to inquire and help them to put into practice what they have learned. Schmidt (1983) describes the process of Problem-Based Learning as seven stages:

- clarifying and agreeing on terms and concepts that are unclear
- define the problem and review terms which need more depth or explanation
- analyze, brainstorm and create potential hypothesis
- discuss, evaluate and organize possible explanations into potential hypothesis
- generate and prioritize learning objectives, divide research workload
- private study time to research objectives
-during next tutorial report back gained information, create an explanation and synthesize new information in relation to the problem

During instruction consistent with the stages of PBL, students create hypotheses in order to solve the problem; they make investigations, conduct experiments to test their hypotheses. Consequently, they are expected to use science process skills which are crucial in science education. Most important, students construct their knowledge by means of their own effort, which is the essence of constructivist approach.

Considering the principles of PBL, it could be hypothesized that it has a potential to develop many different skills. As a matter of fact, literature about PBL is full of evidence which support this claim. According to the results of the studies on the subject, Problem Based Learning has been shown to develop students' critical thinking skills (Yaman, 2003; Smith & Hung, 2016, Kong et al., 2014; R Haridza & Irving, 2017; Martyn et al., 2014; Temel, 2014); improve self-efficacy beliefs (Kaptan & Korkmaz, 2002; Smith & Hung, 2017; Hodges, Gale, & Meng, 2017) promote creative thinking skills (Yaman & Yalçın, 2005; Yoon et al., 2015;) increase academic achievement (Karaöz, 2008; Bayrak, 2007; Ayyıldız & Tarhan, 2017; Simons & Klein, 2007, Horak & Galluzzo, 2017). PBL is also effective in improving science process skills (Tatar, 2007; Keil, Haney & Zoffel, 2009; Hmelo-Silver, Duncan, & Chinn, 2007), concept learning (Li & Tsai; 2017; Becerra- Labra, Gros-Marti,& Martinez Torregrosa, 2014; Hung, 2015) as well as overcoming misconceptions (Akinoğlu & Tandoğan, 2006, Loyens et al, 2015; Diana et al., 2015; Kamp et al, 2014).

Although studies on the effectiveness of PBL on various skills are abundant in many different subject matters, number of studies on its effects on reducing misconceptions in science is limited. Furthermore, very few studies conducted with primary school students. The purpose of this study is to examine the effect of Problem Based Learning (PBL) approach on 5th grade students' misconceptions about "heat and temperature".

2. Method

Sample

The sample of the study consisted of sixty four 5th grade students who were attending to an elementary school in a town called Bozkır which was located in Central part of Turkey. Students' ages ranged between 10 and 12 twelve years. Experimental group consisted of 27 students (12 boys and 15 girls) and control group consisted of 37 students (18 boys and 19 girls).

Heat and Temperature Concept Test

Students' misconceptions were identified by means of "Heat and Temperature Concept Test". Six objectives were chosen in Heat and Temperature Teaching Unit which is titled "Let's Know Matter" which is included in 5th grade Science and Technology Curriculum. Questions in the concept test were developed as to be relevant with these objectives. Content validity is assured by one science education expert and the two teachers of control and experimental group teachers' reviewing the test and giving feedback. Based on experts' suggestions questions were modified and administered to 5th grade students in another primary school in the neighborhood area. By means of pilot study, clarity of the test questions and its' potential to detect misconceptions has been checked before the intervention. Pearson's Product Moment Correlation coefficient was found 0.78 for multiple choice questions of the test. Heat and Temperature Concept Test was consisted of 9 multiple-choice questions, 6 two-tier questions, and 7 open-ended questions. The following are examples of the questions.

Question 7. Which one of the materials sitting on your room for long time has greater temperature: ceramic tea cup, wool shirt, plastic ball, and metal plate.
a) Wool shirt
b) Ceramic tea cup
c) Plastic ball
d) Metal plate
e) All have the same temperature
II. Explain why you choose this option.

Question 12. Which of the following statements is/are true?
I. Heat transfers from hot object to cold object, when two objects at different temperatures came in contact.
II. When you heat something up, its temperature rises.
III. Cold objects do not have heat.
a)Only I b)Only II c) Only III d) I and III e)I, II, and III

Question 21. How can you cool down a glass of hot water? Please explain.

Scenarios

The researchers designed the scenarios by specifically addressing the misconceptions which were determined from the pre-test results. Eight scenarios were designed for the whole instructional period.

Scenario(s)	Related Misconception(s)
Heat or Temperature?	*Temperature and heat are the same things.*
Ceren & Her Baby Brother	*1.When two objects heated equally the temperature of the object with bigger mass increases more* *2.Cold objects have no heat* *3. Objects which gained the same amount of heat would reach the same temperature regardless of their mass.*
Red Riding Hood Lets' Go to Picnic	*1. Wool objects are good for keeping objects warm, but bad for keeping objects cold.* *2. Aluminum foil does not conduct heat. It is the best substance for keeping the objects cold.*
Little Scientists	*Temperatures of the objects sitting in the same room depend on their mass, volume, and the substance they are made of*
Curious Kid	*When the heat transfer completed, temperature of the objects will not be the same*

An exemplary scenario addressing the misconceptions "Wool objects are good for keeping objects warm, but bad for keeping objects cold" and "Aluminum foil does not conduct heat. It is the best substance for keeping the objects cold" presented below.

Let's Have a Picnic

Çagan is a 5th grade student in an elementary school. On a nice sunny day, Çagan and his classmates decide to have a picnic. They make plans about what they will do at the picnic and what they will take with them to eat and drink. Because the weather is hot, Cagan decides to take ice water to the picnic. He goes home to find the thermos, however he could not find it because his mom have lend it to the neighbor. He wanders in the kitchen desperately, thinks: whether should I put the water in a plastic container, or glass container, or wrap it with aluminum folio, or wrap it with a wool fabric, or what else can I use to keep the water cold. However, he could not make up his mind. Can you help Çagan to decide? Which material he should choose and why?

Teaching Process

Control group students were taught "heat and temperature" concepts by employing teacher-centered traditional teaching methods, such as teacher are explaining the content, asking questions, and whole class discussion. The experimental group students were presented real life problems by means of scenarios related to heat and temperature concepts. For PBL sessions, first, students were asked to form study groups with their preferred friends, give a name to their group, and indicate the group members names on the forms they were given. This part is prepared considering that it would be helpful in subsequent parts of the process by creating a consciousness of being a group in students.

After presenting the problem situation by means of the scenarios, students were encouraged to think and inquire about the problem. In the next step, students were asked to write about what they know on the topic in order to detect their pre-conceptions and alternative conceptions -if they have any- about the topic and indicate what they need to know to solve the problem. Students, then, were asked to plan what they need to do to solve the problem, distribute the tasks to the group members and to write down their hypotheses. Following this step, students, made a literature search related to the problem and gathered information, and tried to solve the problem by means of information at hand and/or by executing activities or experiments they planned. Some of these studies were conducted out of school because course period was limited to complete all these activities.

3. Findings

Misconceptions were detected before and after the PBL instruction through the use of Concept test. Pre-test results showed that students held several misconceptions about Heat and Temperature topics. Some examples of the misconceptions are: *"Temperature and heat are the same things" "Temperatures of the objects sitting in the same room differentiate depending on their mass, volume, and the substance they are made of", "Cold objects have no heat" "Objects gaining the same amount of heat would reach the same temperature regardless of their mass"* The following table shows frequencies of the misconceptions before and after the Problem Based Learning implementation.

Table 1. The Percentages of Students' Alternative Conceptions as determined in Pre-test and Post-test

Alternative Conceptions	PBL (N=27)		Control (N=36)	
	Pre %	Post %	Pre %	Post %
The temperature of an object depends on its size.	44	7.4	58.3	45.9
Temperature of an object always changes when it is heated	51.8	22.2	19.4	62.1
Temperature and heat are the same things.	70.3	59.2	61.1	78.3
Cold objects have no heat	74	37	72.2	72.9
When two objects heated equally the temperature of the object with bigger mass increases more.	40.7	7.4	55.5	35.1
Objects which gained the same amount of heat would reach the same temperature regardless of their mass.	22.2	7.4	19.4	10.8
Temperatures of the objects sitting in the same room depend on their mass, volume, and the substance they are made of.	51.8	25.9	38.8	48.6
When the heat transfer completed, temperature of the objects will not be the same.	18.5	14.8	22.2	35.1
Wool objects are good for keeping objects warm, but bad for keeping objects cold.	18.5	7.4	16.6	27
Aluminum foil does not conduct heat. It is the best substance for keeping the objects cold.	25.9	33.3	8.3	40.5

Table 1 shows the frequency of the students having some specific misconceptions before and after the treatment in both experimental and control groups. A total of 10 misconceptions detected in the study. According to the table, all misconceptions but one decreased remarkably on the experimental group students. However, on the control group, frequency of students having 2 specific misconceptions decreased, the others remained the same or increased.

4. Discussion

According to the results, students' misconceptions about heat and temperature decreased more in experimental group than in the control group. These results show that PBL is an effective approach in reducing the misconceptions when compared to traditional instruction. PBL's effectiveness is related mainly its' role on leading students to carry out experiments/ hands on activities to solve the problem presented to them by means of scenarios.

When implementing PBL approach, students were presented scenarios prepared for the specific topic of interest. For example, in the scenario titled "Little Scientists" Selin and her friends are curious to know whether different kinds of liquids have same temperature under the same conditions. They take different liquids (water, olive oil, molasses) and measure their initial temperatures. Then they leave them in different media (hot, cold, and rainy) for a while and then measured their last temperature. As a second task they changed the amount of these liquids (two times more, three times more, or cut in half) and measure their temperature again. The problem given in this scenario is that what results Ceren and her friends would reach at the end of these experiments. The goal here is to help students to gain the concepts of "different kinds of materials that sit at the same medium would have (reach) the same temperature and the temperature is independent of their masses". The post test results show that the experimental group students' misconceptions have decreased significantly.

The results show that the misconception that "When two objects heated equally the temperature of the object with bigger mass increases more" was decreased to 7.4 % from 40.7 % in experimental group; whereas for control group this rate decreased to 35.1 % from 55.5 %.. The reason for decrease in experimental group is more than the control group, their doing an experiment when solving the problem in "Ceren and her baby brother" scenario. Ceren takes two different size of pots from kitchen and fills them with water. Ceren measures the initial temperature of each pot of water and see they are the same. Then she puts them on identical heaters and heats up same period of time, then measures their final temperatures. At the end of the scenario students are asked to guess the final temperatures of the each pot of water. Students were encouraged to solve the problem by

doing a similar experiment. The students made the very same experiment by themselves and solve the problem. Doing the experiments on their own made the biggest effect in overcoming misconceptions.

The misconception that "cold objects have no heat" was decreased to 45% from 74 % in experimental group whereas there was no change in control group students. The reason for this decrease in experimental group is the activity they made for solving the problem in "Ceren and his baby brother" scenario in which they measured the temperature of two ice cubes which have different volumes. This activity designed for students to grasp that temperature does not depend on the mass of the objects. This activity also helped students to realize that cold objects also have temperature and it can be measured. However large number of students did not change their idea that cold objects have no heat. The reason that the decrease in this specific misconception is small might be the experiment is made with ice. Because the temperature is 0 degrees for ice and 0 might mean that the property does not exist for the students.

Heat is transferred from one place to another. Temperature increases as a result of increase in heat. However, according to the results of the current research, although students conducted a series of experiments related to heat transfer, vast majority of them still believed that "it is the temperature that is transferred from one matter to another, not the heat". This result also means that students confused the heat and temperature concepts. Table 1 shows that, students' misconception "heat and temperature are the same" changed % 59.2 from % 70,3 only, whereas control group students' misconceptions increased to % 78,3 from % 61.1. This result is consistent with Gonen and Akgun (2005) study with pre-service science teachers. In their study % 7.89' of the participants stated that it was the temperature transferred from hot system to cold system, and, % 5.26 of them stated that both heat and temperature transferred.
The scenario designed for this misconception is a young boy Ali's curiosity about his neighbor's putting a hot bowl of soup in a bigger container with cold water in it. Students conducted a very similar activity to solve the problem. This problem designed for students to grasp that heat is transferred from hot object to cold object. However, this scenario does not seem to be successful to reach this goal. Although, examining the experimental group students' answers to the questions at the end of the PBL session suggest that they reached the correct understanding about the heat transfer, their answers to the concept test showing a contradictory result might be partially originated from their misunderstanding of the related question.

Results of the current study showed that experimental group students' misconception "*aluminum is always cold because it is metal*" decreased to % 7,4 from % 48,2. However, examination of the answers to the question: "What can you say about the temperatures of a metal and wooden spoon which are put in a hot pot of soup?" shows that their misconception still survives. This result might be due to the fact that students were not given a problem which directly focuses on the temperatures of a wooden and metal objects sit in the same medium. Consequently, they did not conduct an experiment related to it. It is understood that students have difficulty in generalizing the results of the experiments they did for the liquids to the solid materials. Furthermore, students did not have a chance to measure temperature of solid objects, because the thermometers were not available. From this result, it can be deduced that students at this age are not quite successful to transfer the knowledge in different situations.

In order to overcome the misconception that aluminum is best way to keep objects cool, and the wool is good only to keep objects warm, experimental group students were presented with a number of scenarios. The problem of the scenario titled as "*Red Riding Hood"* is: what kind of material is the best for keeping the food warm that the little girl was taking to her grandmother. Students were asked to help Red Riding Hood on this matter. The aim of this scenario was to drive students to do research on heat transfer/heat insulation and find solutions for the problem. The scenario titled as "*Let's go to Picnic"* had similar aims. The problem situation for this time is to find out what kind of material should be preferred to keep water cool for long. Students were guided to carry out experiments with different materials (glass, plastic, porcelain, wool, aluminum, etc.) to find out which one of them is better for heat insulation.

As indicated earlier the number of the previous studies is limited on the primary school level. The result of the current study is consistent with these few studies such as Yurd(2000) & Karaoz (2008) concluded that a problem based learning method called Know-Want-Learn was effective in reducing 5th grade students' misconceptions about the topics related to Light and Sound, and improving their attitudes toward science and technology course. Karaoz (2008) study showed that implementing PBL in teaching of Force and Motion teaching unit has a positive effect on 6th grade students' science process skills, academic achievement and attitudes toward science. Studies conducted on other subject matters also indicated that PBL is effective in reducing misconceptions and increasing academic achievement (Loyens et al., 2015; Kamp et al., 2014).

Conclusion

In this study, the effect of Problem-Based Learning on students' misconceptions in Heat and Temperature topics in 5th grade science and technology class was examined. The results obtained from the study showed that PBL is more effective in reducing the misconceptions when compared to traditional instruction. The reason for this is that the PBL facilitates critical thinking, and promotes inquiry skills. According to Saban (2000), PBL has three basic principles:

1. Students encounter a real life problem
2. Problem is designed in a way that, by solving it students reach the desired goals of the studied topic.
3. Students are guided to think critically and encouraged to conduct investigations.

According to Keser (2007), in order to learn the concepts meaningfully: a)students' pre-conceptions should be identified b) connection should be made with real life events c) experiments related to the content should be conducted c) students should be helped to think critically and synthesize information through the use of simple problems. PBL contains all these elements therefore it is effective in learning the concepts meaningfully. Result of the current study also suggests that PBL is successful at reducing misconceptions.

In summary, this study showed that PBL approach is more effective than traditional approach overcoming students' misconceptions related to Heat and Temperature topics. Although the present study conducted with students at a considerably younger age, the results are similar to that of conducted with students at upper grades. This result suggests that PBL might be effective for young students' learning science as well as older students. Experimental group students learning the lesson by scenarios, making connections with the real life problems, conducting inquiry activities resulted in their acquisition of scientifically correct concepts. Using constructivist theory based teaching methods instead of traditional methods is critical for reducing students' misconceptions and to prevent new misconceptions to occur.

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