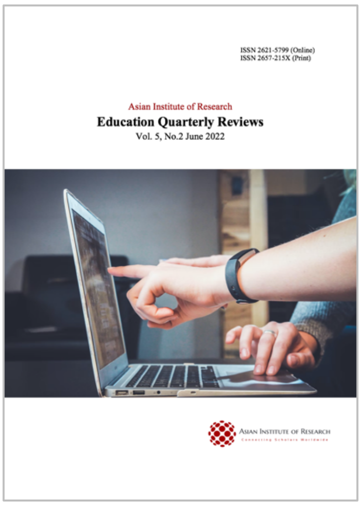

Education Quarterly Reviews

Gürses, A., Şahin, E., & Güneş, K. (2022). Investigation of the Effectiveness of the Problem-Based Learning (PBL) Model in Teaching the Concepts of "Heat, Temperature and Pressure" and the Effects of the Activities on the Development of Scientific Process Skills. *Education Quarterly Reviews*, 5(2), 67-73.

ISSN 2621-5799

DOI: 10.31014/aior.1993.05.02.469

The online version of this article can be found at:
https://www.asianinstituteofresearch.org/

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The Asian Institute of Research

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The Asian Institute of Research
Education Quarterly Reviews
Vol.5, No.2, 2022: 67-73
ISSN 2621-5799

DOI: 10.31014/aior.1993.05.02.469

Investigation of the Effectiveness of the Problem-Based Learning (PBL) Model in Teaching the Concepts of "Heat, Temperature and Pressure" and the Effects of the Activities on the Development of Scientific Process Skills

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Abstract
This study aims to reveal the effectiveness of the problem-based learning (PBL) model in teaching the concepts of heat, temperature and pressure, as well as the effect of the activities on the development of scientific process skills. For this purpose, the change in the academic achievement levels of the students constituting the sampling group was tried to be determined with a pilot application designed based on this model. The research was carried out on a single group based on a pretest-posttest applied quasi-experimental design. Teaching activities addressing the concepts of heat, temperature and pressure and designed according to the PBL model were carried out in a private school over a two-week period. In this context, a unique problem situation was designed, in which two brothers watched and discussed the volume changes of small and large inflated balloons with the effect of temperature, and student-centered activities were carried out, in which demonstration, lecture, question-answer and discussion methods were dominantly used. The problem situation, which includes important connections such as gas, gas pressure, temperature and heat concepts, the relationship between heat and temperature, and the relationship between temperature and pressure, which are known to be quite difficult to understand by 8th-grade students, were implemented sequentially in a single scenario. From the pretest-posttest results, it was determined that there was a significant positive difference in the academic achievement levels of the students constituting the sampling group after the application, and there was a very large difference between the pretest-posttest scores (66.0-92.5). As a result, it can be said that very striking results can be achieved in understanding the selected concepts and the relations between them, with the scenario and appropriate teaching activities designed in a sufficient time based on the problem-based teaching model, and especially the effective and interactive use of demonstration and question-answer methods. Moreover, the results of the pre-test and post-test related to the integrated science process skills test showed that the application in question led to a positive and significant difference in the scientific process skills of the students.

Keywords: Problem-Based Learning, Conceptual Success, Integrated Science Process Skills, Student-Centered Education

1. Introduction

Developments in the field of science and technology affect and change our education system as well as every aspect of our lives. Developed and developing societies need individuals who can adapt to these changes and make sense of these changes. Education aims to raise individuals not only who know but also who always criticize, examine, learn, think, innovate, and adapt to these innovations. It is very important to teach individuals with high-level thinking skills, who actively participate in the learning process, how to use this knowledge in terms of ways of obtaining information, evaluating the information obtained, and solving the problems they encounter (Çelik et al., 2012). In this context, the problem-based learning approach is a prominent and promising model. The problem-based learning approach (PBL), which used the principles of John Dewey's learning-by-doing approach and was first applied at the Case W. University School of Medicine in the USA in the 1950s, was also implemented at McMaster University in Canada in the late 1960s and more recently in primary school and high schools (Kaptan and Korkmaz 2001; Temel 2014). PBL, which is a student-centered and active learning-based approach, covers the application process with problem solving or understanding (Ali 2019). In PBL, students encounter the problem for the first time and take an active role in the process of obtaining information, thus constructing their knowledge in a meaningful and permanent way under the guidance of the teacher, and just like a scientist. They try to find solutions to problems by following scientific research steps. In this process, their dependence on their teachers decreases and they become self-learning individuals (Tosun et al., 2013). The problem-based learning model is one of the most effective approaches that can be used in science lessons, as it enables students to transfer the knowledge and skills they have learned to daily life and to produce solutions to new problems they encounter every day (Yew and Goh 2016). In teaching activities based on the PBL model, scenarios involving real problem situations are carried to the classroom in a student-active manner by using a wide variety of media tools (Kaptan and Korkmaz 2001). Today, one of the main purposes of science education is to raise individuals who find solutions to the problems they encounter in daily life. These kinds of individuals are expected to ask questions, examine, investigate, and make connections between scientific concepts and daily life, and look at their environment as a scientist. In order to be successful in such a process, it is very important to use scientific process skills effectively.

PBL is a model that enables students to use their scientific process skills effectively, while at the same time providing active participation of students in the teaching process and giving them responsibility (Hmelo-Silver 2004). Scientific process skills consist of basic skills that give students a sense of responsibility, facilitate learning and increase the permanence of knowledge (Tosun et al. , 2013). In the 21st century, individuals need to have some basic skills in order to keep up with the complex world order. Students are expected to ask questions, wonder, do research, see inconsistencies and contradictions, make good observations and make correct inferences from their observations, think scientifically, be creative and entrepreneurial, think multi-dimensionally, make decisions, be responsible, and express themselves. In addition, in this context, it is extremely important for students not only to memorize information, but also to be able to access and use information, and to be able to produce new information. However, in this way, individuals with the quality of scientists can be raised. In particular, the sense of curiosity is the key feature for individuals to start and continue research, and the tools that can be used for its satisfaction are scientific process skills. These skills are also needed to recognize, identify and solve existing problems (Shahali et al., 2010). The main purpose of PBL approach, which is also called the "contemporary education" approach, is to enable students to actively use all their scientific process skills in reaching and producing information (Da Silva et al., 2018). Undoubtedly, children are curious and ask endless questions like scientists, and this characteristic should never be suppressed. In this respect, developing scientific process skills should be one of the main goals (Köğce 2005). The aim of this study is to reveal the effectiveness of the problem-based learning (PBL) model in teaching the concepts of heat, temperature and pressure and the effect of the activities on the development of scientific process skills. Science process skills have been defined as the basic skills which make it easier to learn science, enable students to be active and develop a sense of responsibility for their own learning, increase the permanence of learning, and also show research ways and methods (Kaya et al., 2012).

Science process skills are the multidirectional skills that are used to comprehend and develop knowledge and transferable, appropriate for all fields of science, and include skills such as problem-solving, designing experiments, and drawing accurate conclusions (Coil et al., 2010). These skills are used to construct knowledge, think about problems, and generate results. Developing these skills allows students to pose and solve problems, think critically, make decisions, and satisfy their curiosity rather than memorize concepts (Köseoğlu et al., 2008). The science process includes the mental and physical skills necessary for collecting information, organizing and explaining this information in different ways, and solving problems. It is very significant to develop these science process skills for research for which they used scientific methods for children. Most of the learning-teaching approaches are designed to provide students with the knowledge, the processes necessary to obtain this knowledge, and the ways of thinking (Şimşek and Karapınar 2010). Especially, it is argued that the best way to learn in primary schools is to use science process skills and that dealing with objects and events enables to learn actively in the studies. In the science process skills, each skill needs cognitive improvement and the improvement in one of them triggers the others. For instance, the improvement in observing, classification, and measuring skills develops inference skills (Aydınlı et al., 2011; Dökme 2005; Maranan 2017). Even though different researchers have made different classifications while defining science process skills there is no difference in the definition of skills. Science process skills have a hierarchical structure but this structure is not rigid. For instance, making observations is considered one of the basic process skills, but it is also used in the most complex processes. All skills interact with each other (Akar 2007; Gürses et al. 2014).In science education, basic and integrated processes skills are the key skills used in studies. Generally, the basic process skills classify as observing, classifying, measuring, using numbers, establishing a space-time relationship, predicting, inferring and communicating (Ekici and Erdem 2020). On the other hand, integrated process skills are classified as determining and controlling variables, forming and testing hypotheses, making operational definitions, planning and conducting experiments, and interpreting data (Tatar 2006; Fugarasti et al., 2019).

In Turkey, the concepts of heat, temperature and pressure are included in the curriculum of the science course starting from the fourth grade of primary education. The fact that students have permanent misconceptions about the concepts of heat and temperature by mixing them with each other has led to many studies on teaching strategies and the elimination of misconceptions about these concepts and the concept of pressure (Gülay and Tekbıyık 2015). Therefore, the presented study mainly focused on revealing the effectiveness of the problem-based learning (PBL) model in teaching the concepts of heat, temperature and pressure, and the effects of the activities on the development of scientific process skills.

2. Material and Method

The research was carried out on a single group based on a pretest-posttest applied quasi-experimental design. Teaching activities addressing the concepts of heat, temperature and pressure and designed according to the PBL model were carried out in a private school over a two-week period. In this context, a unique problem situation was designed, in which two brothers watched and discussed the volume changes of small and large inflated balloons with the effect of temperature, and student-centered activities were carried out, in which demonstration, lecture, question-answer and discussion methods were dominantly used. The sampling of the research consists of a total of 31 8th grade students, 12 boys and 19 girls. The conceptual achievement test (CAT), which was developed and whose validity and reliability were determined, was administered to only a group of students as a pre- and post-test before and after the application, which started with the implementation of a problem situation originally developed by the researchers. The success of the application was evaluated statistically using the SPSS 14 Data analysis software, taking into account the difference between the pre-test and post-test results. In addition, an integrated scientific process skill test (BPSST) was applied to the students before and after the application in order to determine the effect of the application based on the PBL model on the change of students' scientific process skills.

2.1. Conceptual Achievement Test (CAT)

These tests, administered before and after the application, include 16 different but similar multiple-choice questions, 8 for the pre-test and 8 for the post-test. Pre-test questions are intended to measure students' current knowledge before the application. However, the post-test questions were re-developed to determine the success of the students in learning the selected concepts. In order to determine the content validity of the tests applied, teachers and academicians who are experts in the relevant field were interviewed and their validity was confirmed.

2.2. Integrated Science Processes Skill Test (ISPST)

The integrated science process skill test consists of 25 items covering all fields of science and has a Cronbach alpha coefficient of 0.81. The test consists of four subtests: controlling variables, forming hypotheses, experimenting and interpreting data (Gürses et al., 2014). The obtained data were analyzed at a significance level of 0.05 using SPSS 14 software, and paired-sample t-test and descriptive statistical analysis were used to evaluate the effect of the application on students' achievement levels.

The scenario dealing with the problem situation chosen in this study is given below:

> *"Ayça 5 and Alp are 13 years old two siblings. Their parents, who work hard during the week, took them to a very nice restaurant for dinner at the weekend. Before the meal started, a sweet waitress presented Ayça with a chubby balloon. This made Ayça very happy. Meals and then desserts were eaten. Ayça did not let go of the plump balloon for a moment, and after the meal she said to her mother, "I want another uninflated balloon." Of course, this request was not broken and she placed the different colored uninflated rubber balloon given to her in her bag. As soon as he got home, she tried to inflate the balloon first, but couldn't make it as big as the previous chubby balloon. Although Alp helped him, neither of them could make the new balloon as big as the chubby balloon. After a few games, it was time for Ayça to sleep. But he didn't want his chubby little balloon to get cold, so she tied the balloons to the heater's valve. But what he saw when she woke up in the morning shocked him. The chubby balloon was now just tiny bits of rubber, that is, it had burst. However, the small balloon that he could not inflate with his brother had turned into a huge balloon. Ayça rushed to Alp's side crying. "Why did you explode the chubby?" she said. Alp "I swear I didn't blow it up." he said. Finally, Ayça wiped her tears and "Then why did it explode?" she asked. Alp thought about it and asked Ayça, "Where did you leave them?" she asked. He said, "I put them next to the heater so they don't get cold." he replied. "Hurrah!" Alp shouted. I know why the chubby popped and the little bubble got bigger. Ayça said, "Brother, can you please tell me?", and then Alp said, "I want you to listen to me carefully." 1. To inflate, I and you blew on the balloon did, but still we couldn't make the balloon as big as the other one, this means that we fill the balloon with something to inflate it.*
>
> *2. The chubby exploded when it got hot next to the heater because it was so full. It means that its warming increased the desire of the thing we filled in it to escape outside. When it couldn't escape, it tore the rubber membrane, so the balloon burst.*
>
> *3. Although you and I blew into the little bubble, we couldn't overfill it. But when the small balloon got hot, the contents started to move faster, making the elastic, expandable rubber balloon huge. Meanwhile, Alp said "The temperature in our room was very high, so I sweated a lot."*
>
> *4. I think the chubby balloon in our room, which was warmer than other days, couldn't stand the higher temperature like me and it burst, but the little balloon just got bigger.*
>
> *After these explanations, Ayça was confused. But Alp's eyes were shining with pride and he couldn't wait to share these explanations with his teacher.*

And now the teacher will try to share and explain this incident with other Ayça and Alp at school and even in the classroom."

3. Findings and Discussion

In this section, the statistical evaluation of the pre-test and post-test results applied to the sample group to determine the change in conceptual achievement and scientific process skills was made.

Table 3.1: Kolmogorov-Smirnov and Shapiro-Wilks Test relating to Normality of Conceptual Achievement Test

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Difference Score	.146	31	.093	.936	31	.063

Since the level of significance was found to be 0.063>0.05 in the normality test, it was concluded that the distribution was normal (Table 3.1).

Table 3. 2: Descriptive Statistics of Achievement Test

	Mean	N	Std. Deviation	Std. Error Mean
Pre-test	66.03	31	14.824	2.663
Post-test	92.52	31	8.846	1.589

As can be seen in Table 3.2, the pre-test average is considerably lower than the post-test average, which indicates an exceptionally positive change in student achievement.

Table 3.3: t-test results for related samples between pre-test and post-test scores for the sampling group

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Differences Lower	Upper			
Pre-test Post-test	-26.484	19.223	3.453	-33.535	-19.433	-7.671	30	.000

The t-test results given in Table 3.3 show that the level of significance (2-tailed) is 0.000<0.05 and therefore there is a significant difference between the students' pre-application success levels and their post-application success levels. The results of the Kolmogorov-Smirnov and Shapiro-Wilks test for the normality of the science process skills test are given in Table 3.4.

Table 3.4: Kolmogorov-Smirnov and Shapiro-Wilks Test relating to Normality of Scientific Process Skills Test

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Difference	.110	31	.200*	.968	31	.456

From Table 3.4, it can be seen that the level of significance in the normality test is 0.063>0.05 and accordingly, it can be said that the distribution is normal.

Table 3.5: Descriptive Statistics of Scientific Process Skills Test

	Mean	N	Std. Deviation	Std. Error Mean
Pre-test	52.52	31	11.159	2.004
Post-test	64.39	31	13.520	2.428

From Table 3.5, it can be seen that the average of the pre-test results related to the scientific process skill test is lower than the average of the post-test results.

Table 3.6: t-Test Results for Related Samples between the Science Process Skills Pre-Test and Post-Test Scores of the Sampling Group.

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Differences				
				Lower	Upper			
Pre-test – Post-test	-11.871	16.280	2.924	-17.843	-5.899	-4,060	30	.000

The t-test results given in Table 3.6 show that the level of significance (2-tailed) is 0.000<0.05. Accordingly, it can be said that the students' scientific process skills changed significantly and positively after the application.

4. Conclusions

As a model focused on problem analysis, student-centered learning, and the application of knowledge, PBL is a promising alternative to existing teacher-centered education programs. The key to effective teaching using this model is to present students with an interesting and unusual problem. The problems developed in this model have a critical role as initiator and intensifier for students' learning and active participation. In such a teaching process, students become self-motivated and focused on a specific goal while trying to recognize and solve the problem.

Descriptive statistics on the mean scores of the pretest and posttest show that the posttest grades are significantly higher than the pretest grades. In addition, paired sample t-test results also confirm the existence of a statistically significant difference between students' average success. The original problem situation used in this study can combine important connections such as gas, gas pressure, temperature and heat concepts, heat and temperature relationship, temperature and pressure relationship, which are quite difficult to understand for 8th grade students, in a single scenario.

Therefore, it can be said that the problem situation developed for the application based on the problem-based learning model can be extremely effective in learning these concepts and the relations between them by the effective and interactive use of demonstration and lecture methods in a sufficient time. On the other hand, the pre- and post-test results of the integrated science process skill test showed that there was a significant positive difference in terms of these skills of the students after the application. This positive change is an expected result for the scenario designed with its accurate content and interactive nature.

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