# A Problem-Based Learning scenario that can be used in science teacher education*

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## Contents



## Abstract

The purpose of this study is to introduce a problem-based learning (PBL) scenario that elementary school science teachers in middle school (5th-8th grades) can use in

* This teaching scenario was used in the program entitled "Science Teachers in Training for Izmir Active Learning Activities I" that was held on September 1-7, 2014 in İzmir, Turkey, sponsored by the Scientific and Technological Research Council of Turkey (in Turkish: Türkiye Bilimsel ve Teknolojik Araştırma Kurumu, TÜBİTAK) in the scope of the Call for 4005 Science and Community Innovative Educational Practices.

their in-service training. The scenario treats the subjects of heat, temperature and thermal expansion within the scope of the 5th and 6th grade science course syllabi and has been drawn up to represent the stage-by-stage solution of a real life problem. The scenario was tried out in 2014 as a research project funded by the Scientific and Technological Research Council of Turkey (TÜBİTAK) in different geographical regions and provinces of Turkey (7 regions and 26 provinces) with 40 elementary school science teachers (20 women and 20 men). The face-to-face interviews conducted with 11 participating teachers and the unstructured observations made throughout the PBL scenario that is introduced in this article reveal that such a scenario is effective and useful and can be used during in-service teacher training.

**Keywords**: Problem-based learning, elementary school science teacher, in-service teacher training, heat, temperature, expansion

# Introduction

The fundamental duty of teacher education is to prepare teachers newly starting out in their careers for the classroom environment and to equip them with the basic skills they will need in their professions (Wilson & Cameron, 1996). Graduates of teacher training programs need to have the type of personality, skills and attitudes that will enable them to cope with the daily conflicts in the classroom (Goodnough, 2005).

Traditionally, teacher training has generally been focused on presenting pre-service teachers with a bulk of theoretical knowledge that will be of use to them in their teaching practices (Edwards & Hammer, 2006). Many of the courses in teacher training curriculums teach student-centered activities (e.g., cooperative learning, group projects, etc.) but no relationship is drawn between the courses that are offered in separate clusters of knowledge. For this reason, teachers starting out in their careers are unable to associate their own personal experience with the scientific education they receive at the university. Teachers may benefit from the synergy created from drawing associations between courses, and concepts may be thus made more meaningful (Şahin, 2007).

Problem-based learning (PBL) is a tool that provides teacher educators with the opportunity to have their students encounter situations that they may be confronted with in their careers later on. The PBL method, which was first used with medical students to enrich them with the opportunity to practice what they learned in "real life" situations instead of being confined to course content, has recently been shown by researchers working in education to have benefits for teacher training.

Teacher training is an educational field that is particularly suited to the objectives and methods of the science of education, which constructs the framework of problem-based learning. This field is rapidly shifting toward educating newly graduated pre-service teachers in accessing the information they will need in their own learning and decision-making processes, evaluating this information and developing their analytical thinking capabilities (Edwards & Hammer, 2004). Some universities abroad have foreseen that the problem-based learning alternative approach has the potential to boost their students' success when they enter the real environment of the classroom and have thus restructured their programs to include this model.

In a review of the literature, it can be seen that the number of studies and the research on the use of problem-based learning in teacher training is much less than in other fields, that not enough attention has been paid to programs and teaching applications, that only a few universities abroad (British Columbia University in Canada; Stanford University, Mississippi State University, Delaware University in the U.S.; Monash University, August State University in Australia) have structured their teacher training programs in line with this model and that pilot studies and projects on PBL have been undertaken at some universities (University of Wisconsin-Madison in the U.S.; Norwegian University of Science and Technology in Norway; Wollongong University in Australia, New Brunswick University in Canada; Dokuz Eylul University in Turkey).

## The PBL Process

PBL may take on many shapes and forms but is based on the fundamental treatise that "learning is a process through which the student actively constructs and applies knowledge" (Gijselaers, 1996). Learning is student-centered and there is less teacher dominance in this methodology than in the traditional approach. Learning is an active process and students take on more responsibility to learn compared to traditional methods of learning. Learning through independent work and group work are two important characteristics of PBL. Learning takes place in a process whereby students work together in groups of 7-8 to solve problems taken from real life (Şahin, 2007).

The characteristics of the problems used in PBL are of special importance. PBL methodology takes care to use open-ended problems that reflect typical issues in a particular field, serve the purposes of learning, are conducive to having the students form a synthesis of what they have learned and use this knowledge, essentially leading them on the road to thinking.

The conditions causing the problem and a clear definition of the problem are provided. The problems are generally presented in the form of scenarios in which events related to the problem are narrated. The scenario is based on real events or on narratives that have been likened to real-life situations. The scenarios may comprise tiny stories or dialogues that transpire between a few people (Açıkgöz, 2002). The students define the problem, produce hypotheses for the solution, put forth their knowledge and discuss what they need to know. They conduct research from outside sources (faculty members that have made presentations, scientific consultancy sessions, the library, the Internet) and bring what they have learned to the attention of their friends at the next group session (Mierson & Freiert, 2004).

This article introduces a problem-based learning application prepared within the scope of the project funded by the Scientific and Technological Research Council of Turkey (in Turkish: Türkiye Bilimsel ve Teknolojik Araştırma Kurumu, TÜBİTAK) and encompasses the implementation of a PBL scenario exploring heat, temperature and expansion, presented to a group of science and technology teachers. This PBL scenario was used in the project entitled "Science Teachers in Training for Izmir Active Learning Activities I" that was held on September 1-7, 2014 in İzmir, Turkey within the scope of the TÜBİTAK Call for 4005 Science and Community Innovative Educational Practices. The goal of the TÜBİTAK 4005 project is to provide teachers with knowledge about innovative methods and techniques, using interactive teaching for the purpose of promoting positive attitudes toward science among students and the community. The implementation of the project was designed to be in line with the content of the participating teachers' 5th and 6th grade Science classes. Seventeen different activities were presented and in all of them, approaches that would foster active learning (such as case-based learning, learning stations, creative drama, the conceptual change approach) were applied. The twelve activities comprised working in small groups (8 groups of 5 individuals each). The PBL implementation described in this article is only one of the 17 different types of activities mentioned above and has been presented here in detail. At the same time, the article has also presented the researcher's observations and the opinions of some of the participating teachers regarding the process of the PBL application. The sub-problems of the research are as follows:

1. What were the observations of the researcher over the time the instructive application was carried out?
2. What were the thoughts of the participating teachers about the PBL application?

# Methodology

The method of the case study was used in the research. This method was chosen so that both qualitative and quantitative data collection instruments could be used together and the opportunity would be provided for an in-depth review that could be carried out in a short time (Yıldırım & Şimşek, 2011). The article relates the process carried out during the application of the PBL activity with the science teachers (what happened during the activity and how this affected the study group), including qualitative data on the thoughts of the science teachers about the process and an introduction to the PBL activity. No quantitative data have been presented in this article.

## Study Group

The probabilistic sampling method was used to determine the study group (Büyüköztürk et al., 2008). Defined criteria (considering region, province and gender variables) were used to choose a sampling of middle school science teachers (who would be participating in the project voluntarily) from different geographical regions and provinces of Turkey; the study group was selected by drawing lots from among this larger group. The scenario presented in the study was tried out in 2014 as a research project funded by the Scientific and Technological Research Council of Turkey (TÜBİTAK) in different geographical regions and provinces of Turkey (7 regions and 26 provinces) with 40 elementary school science teachers (20 women and 20 men).

## Data Collection Methods

The data presented in this article were collected using qualitative and quantitative data collection methods (observations and interviews). The process of the PBL activity was observed by an adviser trained in observational technique (who was only assigned with the job of observing) and the researcher herself. The "Activity

Observation Form" was used for the activity. This form was drawn up as an unstructured qualitative observation form by the researcher in order to be able to evaluate the activity process in its different dimensions (the social dimension of the setting, participation in the activity, cooperation, the use of the worksheets, the use of the time allotted, etc.). The opinion of an expert was enlisted prior to the research regarding the "content validity" of the observation form. The observation form was filled out in detail during the activity in accordance with note-taking technique. At the same time, the entire course of the activity was recorded on a camera installed in the room. The observations in this research were made, in accordance with the classification of Frankel and Wallen (2006), by an observer who was a nonparticipant spectator.

Eleven (11) teachers who were willing to participate in the interviews were interviewed. At the end of the activity, the teachers were asked to report all their positive and negative thoughts about it. During the interviews and with the permission of the teachers, their voices were recorded on a recording device. The teachers were not identified on these voice recordings and only pseudonyms were used. The researcher carefully listened to the voice recordings and transcribed them on a written form.

To contribute to establishing the validity and reliability of the observations in the research, observation notes were included in the research findings in the form in which they were originally expressed. To contribute to establishing the validity and reliability of the interview results, some excerpts from the interview transcripts were presented in the research results.

### Implementation of PBL Method

This study aims to introduce a problem-based learning material (named “I'm So Cold”) that has combined some of the physics subjects to be taught in undergraduate classes. When preparing the scenario for “I'm So Cold”, the aim was to develop teachers’ skills in areas such as participating in the learning process, teamwork, developing learning performance, and combining concepts related to heat, temperature, thermal expansion and the First Law of Thermodynamics. The PBL presented within the scope of the project took place in a total of 3 hours (180 minutes) of instruction, of which the first 30 minutes was devoted to the introduction of theoretical knowledge on the PBL process (the steps in PBL and the mode of implementation, the process followed in the PBL sessions) and the remaining 150 minutes to the actual PBL implementation. The PBL implementation was carried out in 5 groups of 8 individuals each. Each group was led by an educator guide. The scenario treated the subjects of heat, temperature and thermal expansion within the scope of the 5th and 6th grade science syllabi and was drawn up to represent the stage-by-stage solution of a real life problem.

The scenario was built for learners to teach them how they could learn through a search for information and then implement what they learned. In this sense, these learning strategies are both qualitative and quantitative problem-solving methods. They include complex and sometimes ill-defined or open-ended real-life problems.

All the scenarios are fictitious, yet they are based on real scientific fact. When the scenarios were being constructed, they were all supported by explanations and pictures that would arouse interest. There are two versions of the scenario, one being the learner's copy and the other, the tutor's copy. Unlike the learner's copy, the tutor's copy has all the scenario-related learning objectives as well as the answer key so teachers can better guide their students.

In the following pages (pp. 11-22) can be seen a tutor's copy that contains the hypothesis and answers expected from the students, for use by teachers during the sessions. In the student's copy, the boxes have been left empty and students are expected to form their own hypotheses and answers. In this version, the questions directed to learners are all open-ended and the hypotheses and answers produced during teamwork can be different from the ones suggested in the tutor's copy.

In the process of PBL, the tutor generally provides the information, but does not answer the questions. Before the session starts, the tutor undertakes the responsibility of making the educational environment suitable for learning (providing books, a calculator, computer, Internet access, as necessary), guiding learners through group discussions, providing equal opportunities for learners in discussions, encouraging them to produce different hypotheses and find different solutions, guiding the group to discuss different areas of a subject when the discussion ends quickly, and informing learners about the session to follow (the venue, time, etc.).

Implementation of PBL follows the procedure below:

All the learners are given learner's copies and are presented the problem in the first session. In learner's copies, different parts of every session (e.g. Part 1, Part 2) will be on separate pages, and learners will not be allowed to move to a different part before completing the one they are working on. They will discuss the problem in small groups and clarify the situation. After defining the problem, they will develop hypotheses. The tutor will encourage them to brainstorm about the problem, based on their existing knowledge. At the end of every session, the learners, in their respective groups, will identify the information necessary for solving that specific problem; in other words, what they should learn. All the activities will be conducted on the scenario script, both in written form and verbally. Before coming to the second session, the learners will be expected to research what they should learn individually, outside of class. To help them to do this, some reference books will be recommended to them. In the first fifteen minutes of the second session, they will be provided with a learning environment where they will be able to review that information (information-sharing and peer education). After that, the scenario script to be used in the second session will be handed out to the learners, and they will be encouraged to solve the problems using both quantitative and qualitative problem-solving strategies. They will perform the required mathematical operations, and then discuss the solution in their groups. The last session has been designed in a way that will enable them to go over what they have learned so far. Then, every individual in a group will assess their personal performance and participation in the PBL process.

## PBL Scenario

The PBL scenario, whose details are presented below, has been designed to be appropriate to the science teachers' class level. It can be used at the high school level as well, as long as a few changes are made. The scripts in the “I'm So Cold” scenario are presented below consecutively.

### SESSION 1
### Part 1

Mr. Şahin and his family have moved to a new house. A heating system is installed in the house before they move in. With the coming of winter, the house needs to be heated. So the family wants the heating system to be turned on so that they can meet their heating needs. About 25 minutes after the radiators are turned on and the house begins to be heated up, they suddenly realize that the house is not getting any warmer. When they check the boiler on their balcony, they find that the water has been depleted and the heating system has automatically stopped because of this for safety (The heating system of the house is shown in Figure 1).

**1. What is the problem here?**

- There is a problem with heating the house. After the system is turned on, the radiators no longer give out any heat.

**2. Write down your hypothesis about the source of the problem.**

a. There might be a problem with the connections in the plumbing in the house.
b. There might be a problem with the mechanical installations of the heating system.
c. The water in the radiators might have evaporated.
d. The inner parts of the heating system (the parts of the installation where pipes cannot be seen) might have a water seepage somewhere.

**3. What can be done to solve this problem?**

a. The plumbing of the house (the connections in the heating system) can be checked.
b. The mechanical installations of the heating system can be checked.
c. Some technical information can be found about the heating system (the amount of water in the boiler, heat efficiency, etc.).
d. The infrastructure of the heater can be examined and whether or not there is a water seepage somewhere in the plumbing can be checked, and if there is, this leakage can be closed off.

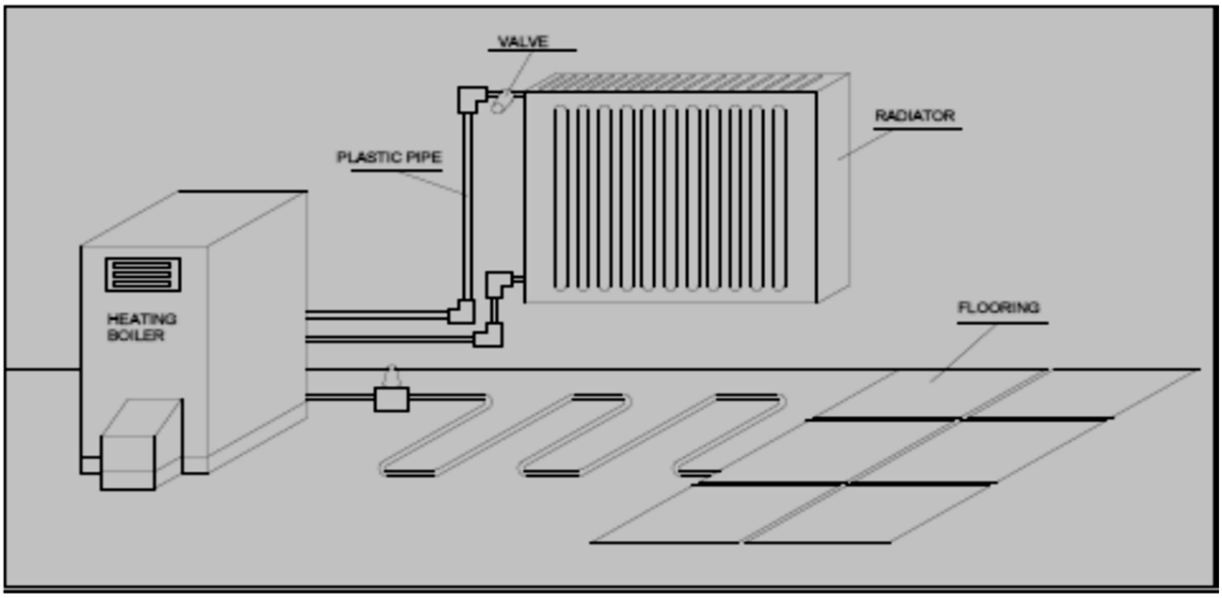


**Figure 1.** A Simple Diagram of the Heating System

**SESSION 1**
**Part 2**

Mr. Şahin calls in the thermodynamic authorized service and explains the problem to the technicians so that the source of the problem can be determined and solved. The technicians from the authorized service check the system and explain that there is no problem with the mechanical installation of the heater and also no problem with the plumbing in the house or the connections in the heating system installations. The technicians dwell on the fact that there is a significant reduction in the level of water in the boiler.

1. **Please summarize the information provided.**

| |
|---|
| • It was determined that there was no problem in the connections between the house plumbing and the heating system.<br>• The work of the technical service technicians who came to examine the problem showed that there was no problem in the mechanical equipment of the heating system. |

2. **Compare what you know now with your hypotheses.**

| |
|---|
| a. There might be a problem with the connections in the plumbing in the house. **(eliminated)**<br>b. There might be a problem with the mechanics of the heating system. **(eliminated)**<br>c. The water in the radiators might have evaporated.<br>d. There might be water seepage in the parts of the installation where the pipes are hidden. |

3. **Discuss the physical mechanism of a reduction in the water level of the heating system boiler (in terms of physical laws and principles).**

| |
|---|
| a. Water evaporation<br>b. Heat exchange of matter |

**SESSION 1**
**Part 3**

The service personnel think that the heat resulting from when the heating system is in operation (fuel is consumed), causes the water to evaporate and a steady decrease in the water occurs and stops the system (it is believed that the water may evaporate from the open ends found on the radiator cores and in the water tank in the heating system).

**1. Please explain what heat is.**

- Heat is the energy transferred from a hot object to a cold object when two objects are in interaction.

**2. What is evaporation?**

- This is the phenomenon in which liquids are heated and are converted to gas.

**3. Which laws in physics may be associated with heat and evaporation?**

a. Zeroth Law of Thermodynamics
b. Heat exchange

**4. What are the physical quantities related to water evaporating?**

- Temperature
- Specific heat
- Heat of evaporation

**5. What should we know/learn?**

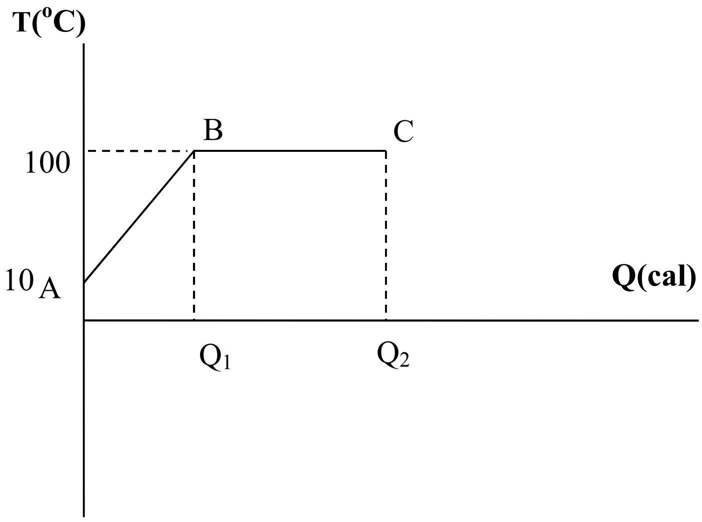
- Zeroth Law of Thermodynamics: If A and B systems are in thermal balance, A system is in thermal balance with system C, which is in thermal balance, and C system is in thermal balance with B system. This state of equilibrium is defined as temperature.
- The heat obtained from two interacting systems is equal to the heat emitted.

## SESSION 2
### Part 1

The technical service personnel convey the problem at Mr. Şahin's house to the company engineer. The company engineer reviews the technical information about the heating system. According to the catalog, the boiler's water capacity is 30 liters and when fuel is consumed, a 25000 kcal of heat energy is obtained. The heat productivity of the heating system is 70%. This energy causes the water circulating in the radiators to heat up. The company engineer makes a calculation based on the supposition that all the water in the boiler evaporates and figures out how much energy must be produced and in what time this must happen.

1. **If we say that the average temperature of our city in the winter months is approximately 10°C, let's calculate the energy that's needed for the water to evaporate completely.** (Make the density of water: 1 g/cm$^3$ and Heat of evaporation: 540 cal/g)

The calculations show that the tank has 30 liters of water. If we say that the average temperature of our city in the winter months is approximately 10oC, let's calculate the energy that's needed for the water to evaporate.




**Boiling point:** The temperature at the point at which a liquid's steam pressure is equal to atmospheric pressure is called its boiling point. The transition of the liquid to the gas phase at this temperature is called boiling; the opposite, that is, the transition from the gas phase to the liquid phase, is called condensation.

The heat required for the transition from A to B:

$Q = m.c.\Delta T$

Q: the heat required for the water to reach the temperature 100oC

m: mass

c: specific heat

ΔT: temperature change

Since the average temperature in our city in the winter months is 10oC and because the temperature of the water in the heating system will be equal to this when the system is not turned on, we first have to heat the water to boiling point. Then we have to calculate the energy that will be needed for the water to evaporate. We first have to find the energy needed for the transition from A to B and then from B to C and finally, we add this all up and find the energy we need to calculate

The heat required for the transition from B to C:

$Q = m.L_b$

m: mass

$L_b$: Heat of evaporation

Q: Heat needed for water to change the gas state

**Specific heat:** This is the amount of heat per unit mass required to raise the temperature of matter 1oC. This changes according to the type of matter. This is a differentiating property of matter.

**Temperature change:** The difference between the first and last measured temperature.

**Heat of evaporation:** This is the energy required for a unit mass of matter that has come to boiling point to evaporate.

For water;

**Specific heat:** 1 cal/g. $^oC$

**Heat of evaporation:** 540 cal. /g

We found in the review of the situation that there was 30 liters of water in the heating system. Since 1 liter is 1 $dm^3$, 30 liters is 30 $dm^3$. If we use what we learned before, we can say that m=V.d (m: mass; V: volume d: density) Water density:1 $g/cm^3$ 1 $dm^3$=1000 $cm^3$

30 $dm^3 = 3 \cdot 10^4$ $cm^3$

m=30000 $cm^3 \cdot 1$ $g/cm^3$

$m = 3 \cdot 10^4$ g is the density of this water

Since the water will be approximately 10$^o$C, the water will first pass through A-B in the graph above before it reaches the boiling point, and the energy needed for this is $Q_1$.

Since water boils at 100$^o$C, the temperature change is:

$\Delta T = 100 - 10$

$\Delta T = 90^o C$

$Q_1 = Q_{AB} = m.c.\Delta T$

$$Q_{AB} = 3.10^4 g.1\frac{cal}{g.^0C}.90^\circ C$$

$$Q_{AB} = 27.10^5 cal$$

The interval at which the water coming to boiling point evaporates is the interval B - C on the graph. The energy necessary for this ($Q_2 - Q_1$);

$Q_2 - Q_1 = Q_{BC} = m \cdot L_b$

$$Q_{BC} = 3.10^4 g.540\frac{cal}{g}$$

$$Q_{BC} = 162.10^5 cal$$

The energy needed for the water to evaporate:

$Q = Q_{AB} + Q_{BC}$

$= 27 \cdot 10^5\ cal + 162 \cdot 10^5 cal$

$= 189 \cdot 10^5\ cal$

2. **How much energy is transferred to the heating system when it is turned on and where does the remaining energy go?**

We had learned that the heating system supplies 25000 kcal of energy and that 70% of this energy is spent on the water. (1kcal=1000cal, 25000kcal=$25 \times 10^6$cal and 70% of this value is transferred to the water. This is $25 \cdot 10^6 \times 0.70 = 17.5 \cdot 10^6$cal.

In real life, there are other materials in the system besides water (iron pipes, the metal and plastic components in the boiler). These materials need some energy to heat up as well.

3. **Let's calculate the amount of time needed for the heating system to make the mass of water evaporate.**

We had learned that the heating system supplies 25000 kcal of energy and that 70% of this energy is spent on the water. The heating system supplies 25000 kcal of energy in an hour. We just calculated that $189 \cdot 10^5$cal is required for the evaporation of all of the water in the heating system.

(1kcal=1000cal, 25000kcal=$25 \times 10^6$cal and 70% of this value is $17.5 \times 10^6$cal.

Therefore, the time needed for the heat system to supply this much energy is:

$$t = \frac{189.10^5}{17,5.10^6}$$

t = 1.08 hours

t ≅ 65 minutes

4. **Interpret the result found in item 2.** **(Reminder:** The heating system was stopping 25 minutes after all of the water was depleted**)**

| |
|---|
| Our heating system was stopping 25 minutes after all of the water was depleted. We calculated the time needed for evaporation to be 65 minutes. Our calculations refuted the idea that the water could evaporate because the heating system was supplying too much energy since the time needed for the entire mass of water to evaporate is longer. |

5. **Compare what you know now with your hypotheses.**

| |
|---|
| **a.** There might be a problem with the connections in the plumbing in the house. **(eliminated)**<br>**b.** There might be a problem with the heating system (mechanical installations). **(eliminated)**<br>**c.** The water in the boiler might have evaporated. **(eliminated)**<br>**d.** There might be water seepage in the parts of the installation where the pipes are hidden. |

## SESSION 2
### Part 2

The calculations of the company engineer showed that all of the water in the boiler could not evaporate in the space of 25 minutes and that the problem stemmed from another mechanism; this was conveyed to Mr. Şahin. The engineer said that there could be a problem in the plumbing infrastructure (in the hidden pipes) and that the water seepage could be coming from there. The heating system is turned on once again and the same problem occurs. When the water in the boiler is depleted, the water continues to fill up the tank. At this point, the neighbor downstairs complains. The complaint is that there is water dripping down from the living room ceiling. It is therefore understood that the seepage is in the pipes in the living room. An estimate is made as to from where in the living room the water may be dripping and Mr. Şahin has the repairmen pull up the flooring in the living room (see Figure 2) and the leak is found. It is seen from an examination of the area that a nail had been nailed into one of the pipes in the plumbing at the time the floor covering was laid out.

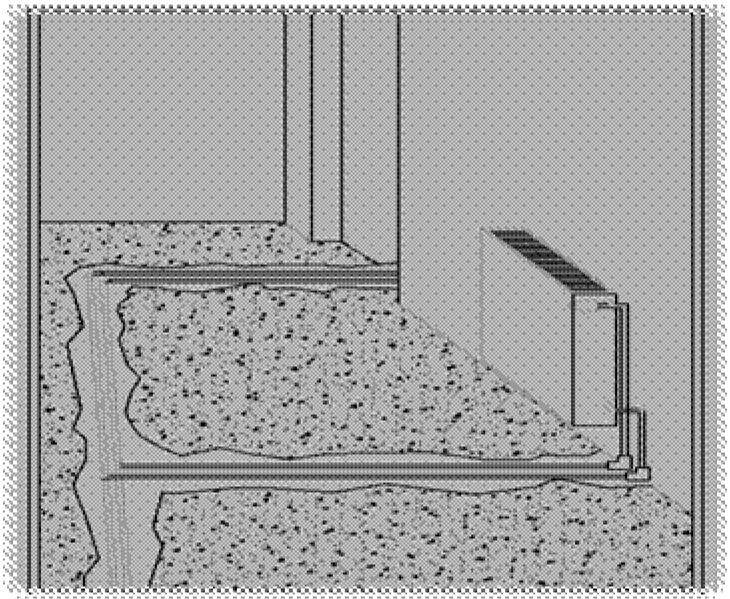


**Figure 2.** The pipes in the living room

1. **What made the neighbor complain?**

| |
|---|
| The neighbor complains when water starts dripping down from the ceiling after the heater is turned on and water is added. |

2. **In line with the information given in the text above, what do you think the reason could be for the water loss that came about after the heater was turned on?**

| |
|---|
| The water loss could be caused by a problem in the lower installation of the heating system. The loss could be because of a problem in the installation pipes. |

3. **Which concept, principle or law in physics is the answer you gave to item 2 related to?**

| |
|---|
| Heat, temperature, expansion |

## SESSION 2
### Part 3

Even when the heater is not turned on, there is still some water in the pipes in the infrastructure of the heater. This shows that when the heater is not on, there is no water loss in the boiler and that the water loss occurs when the heater begins to operate. It is thought that after the heater is turned on, it is the expansion in the iron nails and plastic pipes that causes the water loss (the loss in the boiler).

**1. What is expansion?**

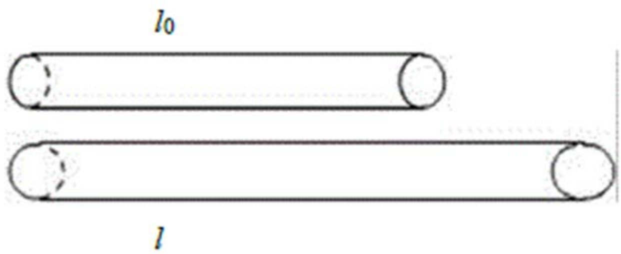
When objects are exposed to heat, their molecules start to move faster and the distance between them increases. As a result, the object expands, or in other words, its volume increases.

All expansions are actually increases in volume. When a long iron rod is heated, it lengthens and its thickness increases as well. Since the increase in its thickness, however, is negligible compared to the growth in its length, this expansion is described as only "lengthening." The same thing happens in surface expansion. When the surface of a metal sheet expands, this expansion is much greater than the increase in its thickness, and therefore the expansion in the thickness is neglected. This is called surface expansion.

**2. Explain in detail expansion in solids (with the necessary theoretical information and formulas).**

Expansion in solids:
Because a heated solid material will expand in all three dimensions, expansion in solids occurs in the following way:
1) Linear expansion
2) Area expansion
3) Volume expansion

**1. Linear Expansion:**




Let $\ell_0$ be the length of a metal rod before it is heated. When we heat the metal rod, it will grow longer and reach its final length of $\ell$. The change in length will be $\Delta\ell = \ell - \ell_0$

$\ell_0 =$ original length of the metal

$\lambda =$ the linear expansion coefficient of the metal

$\Delta T = T_{son} - T_{ilk} =$ the change in the temperature of the metal

$$\Delta\ell = \ell - \ell_0 = \ell_0.\lambda.\Delta T$$

**2. Area Expansion:**

$S_0$ $S$

Let $S_0$ be the surface of a metal sheet before it is heated. When we heat this metal sheet, the surface will increase and become its final surface $S$. The area expansion change is $\Delta S = S - S_0$

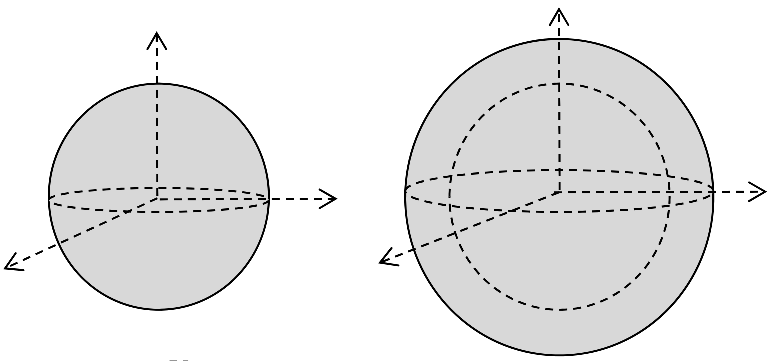
$S_0$ = the original surface area of the metal

$2\lambda$ = the area thermal expansion coefficient

$\Delta T$ = the change in the temperature of the metal

$$\Delta S = S_0.2\lambda.\Delta T$$

**3. Volume Expansion:**



$V_0$ $V$

Let $V_0$ be the original volume of a metal sphere before heating. When we heat the metal sphere, its final volume is $V$. The change in volume is $\Delta V = V - V_0$.

$V_0$ = the original volume of the metal

$3\lambda$ = volumetric thermal expansion coefficient of the metal sphere
$\Delta T$ = the change in temperature; where,

$$\Delta V = V_0.3\lambda.\Delta T$$

**3. Think about how the nail looks imbedded in the lower plumbing pipe and review this in the light of the principle of solids expanding.**

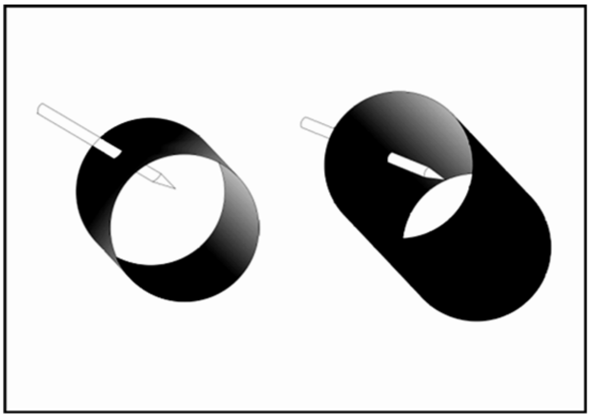
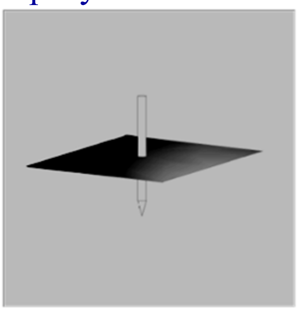
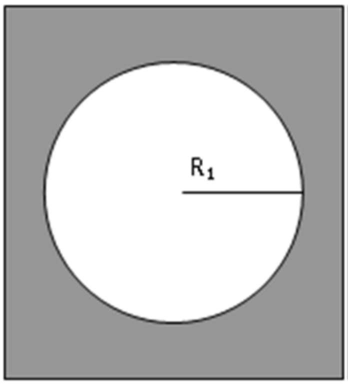


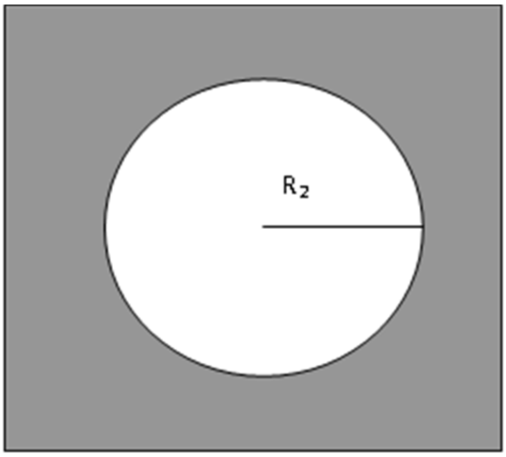
**Figure 3.** How the nail in the plumbing pipe looks from two different angles

We found the place where the water had leaked. When we opened it up and took a look, we saw that a nail had been driven into one of the pipes in the plumbing. Different views of the nail driven into the pipe can be seen below. Let's solve the problem using our knowledge about expansion. The water seepage occurs after the system is heated up. In other words, the expansion of the embedded nail and the pipe with the increase in the heat is what leads to the water loss. If we were to simplify this occurrence:



When we look very simply at the state of the nail as it looks in the figure, we can see the expansion in both the pipe and the nail.




State before heating (for pipe) State after heating (for pipe)

Before the heating system is turned on, as seen in the figure above, when the nail closes up the hole in the metal (since both have the same radius), there is no water seepage. When the heat is turned on, however, and the system starts heating up, the figures below (Radiuses $R_1$ and $R_3$) occur.



Since $R_2$>$R_3$, a space forms between the nail and the pipe and it is through this space that the water seepage occurs. The seeping water starts leaking down through the ceiling of the neighbor below.) occur.

## 4. What must we learn?

- Learning that dimensions increase when matter is heated.
- Learning that dimensions change when temperatures of matter change.
- Learning about which properties of matter expansion depends on.

## SESSION 3
## FINAL

It was found that the system stops automatically when the heat is turned on and a while later, the water in the heater is lost. It was found that the reason the water got depleted in the heater was because a nail had been driven into one of pipes in the plumbing. Because the temperature rises once the heater is turned on, both the nail and the pipe expand, and water then seeps between the pipe and the nail. It can be understood from this that different materials expand in different amounts. The area thermal expansion of the water pipe was more than in the nail (the heat expansion coefficient of plastic materials is about 10 times more than that of metals).

After finding where the water leaked from, the repairmen removed the nail from the pipe it had been embedded in. The leak in the perforated pipe that allowed the pipe to expand was repaired with a repair solution. After this repair was completed, there was no other place for the water in the heater to leak from. Mr. Şahin turned on the heater again and the heater continued to work even hours later. The heater was now operating and problem-free. So the problem with the heater in Mr. Şahin's house had been solved.

**Can you now write up a one-session short scenario based on the inspiration the one above has given you?**

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| |

## Results and Interpretations

The results of the research and the interpretation of the findings based on the qualitative data collected over the course of the study were presented under the headings given below. In addition to qualitative data, the discourse of the teachers immediately after the activity as well as questions and answers were included.

### Findings Derived from the Observation Transcripts

The PBL activity was observed in accordance with the observation dimensions outlined in the observation form (participation in the activities, cooperation between teachers, the use of the scenario worksheets, the use of the time devoted to the activity, guidance and orientation) and the researcher recorded the observations. In this research, human behavior and actions formed the basis of the observations. The research carefully reviewed the observation form entries and the film that had recorded the PBL activity. The general findings were the following: In an examination of the participation in the activities, it was observed that the participating teachers were in full attendance at the PBL activity, that they worked in cooperation and shared information with each other. They referred to the computer and the Internet when they needed help. It was also observed that the PBL scenario whetted the curiosity of the teachers and that they tried to predict the end of the scenario, being thoroughly entertained by the activity in the meantime. The teachers exhibited the need for guidance in places where they got stuck. In general, the time allotted for the activity was seen to be adequate for each group. It was particularly noticed that at the end of the final part of the scenario, the members of the groups showed considerable excitement and enjoyment when they were asked to explain the scenario they produced to the group.

Examples of the some sentences from the observer's (O) notes on the observation form are presented below:

***O:*** *I can see that there is continuous communication at each table and everyone is actively participating. All of the teachers are at their own desks and I didn't see anyone working on anything else. The scenario really interested them... There is some serious cooperation and collaboration in the groups. They are working as a team; I did not see any individualization... They were a little challenged in the parts of the scenario that involved numerical calculations, but then they asked for help from the advisers... The time allotted was enough for them. They completed the tasks on time and none of the groups asked for an extension.*

## Findings regarding the Interview Recordings

Following the PBL activity, face-to-face interviews were conducted with 11 volunteering teachers and their voices were recorded during the interviews. The themes resulting from the content analysis of the interview records are as follows: (a) finding the implementation of the method effective and beneficial from a professional standpoint (b) implementing the method in their own classes.

In the face-to-face interviews, all of the teachers (n=11) said that they had theoretical knowledge of PBL but that they did not know about its practical application, further explaining that the implementation of PBL that they had experienced in this training had been very beneficial for them. Examples of the thoughts on PBL of the teachers recorded in the interviews, in the words of a female teacher using the code name "Sun," a female teacher using the code name "Entertaining Physics," and of a male teacher using the code name "Virus," are as follows:

***Sun:*** *"...We learned by actively doing, one-on-one. The PBL method allowed us to look at a real problem and so we were able to internalize the situation because we were personally involved."*

***Virus:*** *"When we saw the PBL process in written form, it was useful to see the steps leading from one to another."*

***Entertaining Physics:*** *Carrying out a method in real time, doing something I know the theory of but have never tried on my own, was very useful...*

Some teachers mentioned that they would be open to trying this method that they learned how to implement in their classrooms. The comments of the teachers coded Pehlevan and Maroonfive are as follows:

***Pehlevan:*** *I found the implementation of the PBL method very satisfactory and useful. I can use this method in my class next term and I'm thinking of getting some help on this.*

***Maroonfive:*** *I can use this PBL method in my classes. For example, I have a class called, "Science Applications." I can use it there.*

When the teachers' comments were evaluated in general, the conclusion was drawn that the teachers benefited professionally from the PBL implementation and were interested in applying it in their classes.

## Comments and Questions from the Teachers at the End of the Activity

At the end of the activity, one of the teachers related the story that a problem similar to the one in the scenario had been experienced with repairs on the teacher's car and that from now on, the teacher would look at problems differently. Furthermore, many other teachers at the end of the activity voiced their opinion that the real-life problem in the activity took them back to their school years and that before, they had looked at activities in the classroom from an educator's point of view but that after this instruction, they would not neglect to look at everything from the student's viewpoint. Some teachers said that such a comprehensive scenario could not be written by one person and asked about a way of handling this. As a solution, the researcher made two suggestions. The first of these was, depending upon the subject that was going to be taught, to keep the scenario to a single day (single session) or to make it longer (2 or 3 sessions). The second suggestion was to ask for the group teachers' opinions after the scenario was set up or to write up the scenario in cooperation with the group teachers. This type of an effort to develop the needed materials will create synergy between professionals and also reinforce the sharing of information.

## Implications for Practice

This article presented a problem-based learning (PBL) scenario that can be used for the in-service training of middle school science teachers. The scenario was drawn up on the subjects of heat, temperature and thermal expansion within the scope of the 5th and 6th grade science syllabi and was designed to represent the stage-by-stage solution of a real life problem. The scenario was tried out in 2014 as a research project funded by Scientific and Technological Research Council of Turkey (TÜBİTAK) in different geographical regions and provinces of Turkey with elementary school science teachers. Throughout the PBL session, the unstructured notes taken by one of the observers showed that (a) all of the teachers had actively participated in the teaching process; (b) the group collaborated and worked together as a team, and (c) the participants found the application entertaining. The face-to-face interviews conducted with 11 participating teachers and the unstructured observations made throughout the PBL scenario that was introduced in this article reveal that such a scenario is an effective and useful teaching tool and can be used in a program of in-service teacher training. It is believed that the PBL scenario and the PBL implementation presented here will be a guide to research and to the practice of active learning methods in in-service teacher training. A review of the literature on PBL reveals many studies conducted at various class levels (middle school, high school, university). As mentioned in the Introduction to this article, studies on the use of the PBL method in teachers education are few and these are generally related to pre-service teacher training. Only one study (Gertzman & Kolodner, 1996) appears about PBL in the education of in-service middle school science teachers; this is a research project that was sponsored by the EduTech Institute at Georgia Tech. The results of the scan of the literature on the subject indicate that there is a need for more studies on the use of PBL methodology in in-service teacher training. Researchers who will be working in this area might be advised to undertake studies on applications of PBL in the various topics of middle school science classes (biology, chemistry, earth sciences and other science courses).

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