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GUIDANCE MATERIAL DEVELOPMENT FOR THE TOPIC OF EVAPORATION AND BOILING AND STUDENTS' VIEWS[1]

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ABSTRACT

This study aims to develop guidance materials on the topic of evaporation and boiling within the Science course, to use the materials with 5th grade students, and to find out the students' opinions about the implementation of these materials. The participants consist of 10 students studying in a public middle school in the 2020-2021 academic year. The development and implementation processes of the guidance materials are described in detail in the article. A semi-structured interview consisting of 5 questions was conducted with 5 students to get their opinions about the implementation process. Descriptive analysis was used to analyze the interviews. The students expressed the view that the guidance materials were helpful in learning the topic, associating it with daily life, and increasing the teacher-student and student-student relationships. The researchers suggest that similar materials should be developed to teach different science topics.
Keywords: 5E learning cycle model, material development, evaporation, boiling.

BUHARLAŞMA VE KAYNAMA KONUSUNA YÖNELİK REHBER MATERYAL GELİŞTİRME VE ÖĞRENCİ GÖRÜŞLERİ

ÖZ

Bu araştırmanın amacı, fen bilimleri dersi "Buharlaşma ve Kaynama" konusunda rehber materyaller geliştirmek, materyalleri 5. sınıf öğrencileri ile uygulamak ve materyaller ve uygulama ile ilgili öğrenci görüşlerini almaktır. Çalışmanın katılımcılarını 2020-2021 öğretim yılında Milli Eğitim Bakanlığına bağlı bir devlet ortaokulu 5. sınıfında öğrenim gören 10 öğrenci oluşturmuştur. Çalışmada, kullanılan rehber materyallerin geliştirilme ve uygulama süreçlerine ayrıntılı şekilde yer verilmiştir. Uygulama süreci ile ilgili öğrenci görüşlerini almak amacıyla, 5 öğrenciye 5 sorudan oluşan görüşme formu uygulanmıştır. Görüşme formunun analizinde betimsel analiz kullanılmıştır. Araştırma sonucunda; öğrenciler rehber materyallerin konunun öğrenilmesinde ve günlük hayatla ilişkilendirilmesinde yardımcı olduğunu, öğretmen-öğrenci ve öğrenci-öğrenci ilişkilerini olumlu olarak arttırdığını ifade etmişlerdir. Buradan hareketle, araştırmacılar fen bilimleri derslerinin farklı konularına yönelik uygulanabilecek rehber materyallerin hazırlanması önerisinde bulunmuşlardır.
Anahtar kelimeler: 5E öğrenme döngüsü modeli, rehber materyal geliştirme, buharlaşma, kaynama.

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INTRODUCTION

According to the constructivist approach, learning is an individual process in which students associate what they already know with new ideas and experiences. This is also a process in which learners develop scientific understanding by interacting with their physical and social environments (Liang & Gabel, 2005). In this process, learning environments are prepared for students to solve and explore problems on their own (Matthews, 1993).

Constructivism proposes learning approaches in which students will be active and take more responsibility. The 5E learning cycle model developed by Bybee et al. (2006) is one of these approaches. The 5E learning cycle model is a linear process for learning new concepts by building upon prior knowledge, for identifying misconceptions, and for providing conceptual change (Bybee et al., 2009; Duit & Treagust, 2003; Wilder & Shuttleworth, 2005).

According to Bybee et al. (2006), the linear process of the 5E learning cycle model consists of the stages of engagement, exploration, explanation, elaboration, and evaluation. Guidance materials can be used to implement each stage of the 5E learning cycle model in the classroom. Guidance materials increase student interest and achievement in the course (Töman et al., 2013). In addition, guidance materials embody abstract concepts, promote permanent learning, and effectively identify and eliminate misconceptions (Chong et al., 2013; Hasja et al., 2020; Kolomuc et al., 2012).

The 5E learning cycle model has greatly impacted science learning and has become the basis for the development of a variety of guidance materials used in science lessons (Bybee et al., 2006). This model increases student science achievement when the guidance materials are used effectively (Bybee et al. 2006; Coulson, 2002; Harrison & Treagust, 2001). When these materials are used in science lessons, the 5E learning cycle model is also effective at attracting student interest, providing them with additional motivation (Boddy et al., 2003; Bybee et al., 2006; Tinnin, 2001), and increasing their scientific reasoning (Boddy et al., 2003).

The activities designed in the exploration and elaboration stages of the 5E learning cycle model contribute to students' acquisition of scientific process and inquiry skills (Bybee et al., 2006). In these stages, guidance materials enable students to learn concepts by associating them with daily life (Guzzetti et al., 1997).

In the literature, many researchers have conducted studies on the topic of evaporation and boiling. These researchers have studied students' misconceptions about this topic. (Buluş Kırıkkaya & Güllü, 2008; Coştu et al., 2007; Demircioğlu et al., 2016; Karslı & Ayas, 2017; Lemma, 2013; Paik, 2015; Papageorgiou et al., 2008; Stein et al., 2008). However, no study has yet to develop guidance materials on this topic for teachers. The current study is important in terms of detecting and eliminating misconceptions by developing guidance materials on evaporation and boiling. Thus, the study will fill this gap in the related literature.

"The Matter and Change/The Nature of the Matter" unit and its content have been updated with the new science curriculum in 2018. Few studies are found in Turkey on the updated unit (Akar, 2019; Bakır, 2019; Kurt, 2018; Sarıkaya, 2019; Usta Yılmaz, 2018). The concepts of evaporation and boiling are widely used in daily life, but students still have difficulties in understanding these concepts. These difficulties are due to the close connection between evaporation and boiling concepts and the relatively abstract concepts of heat and temperature (Hasja et al., 2020). Learning materials containing experiments should be developed so that students can embody these concepts (Halim et al., 2018).

In this article, we share learning activities that use guidance materials with science teachers and educators. We also elaborate on the material development stages in detail as an example for researchers who will work on material development.

Purpose of the Study

This study aims to develop guidance materials using the 5E learning cycle model, use the materials with fifth-grade students, and get their opinions about the materials and the implementation process.

ACTIVITY PLANNING and IMPLEMENTATION

This study follows the guidance material development stages as suggested by Güngör Akgün (2018). Each stage is explained below:

1. Literature review: The first and second authors reviewed the literature on the 5E learning cycle model and material development as well as examples of science lesson plans (Ajaja et al., 2012; Özsevgeç, 2006; Wilder & & Shuttleworth, 2005). As a result of the literature review, we decided to develop materials on the concepts of evaporation and boiling because these are concepts that require abstract thinking and, students tend to confuse the two concepts (Hasja et al., 2020).

2. Examining the objectives of the "Matter and Change" unit: The Science Curriculum recommends 2-lesson hours for the topic of evaporation and boiling. However, the class duration has been reduced to 30 minutes due to the pandemic. Therefore, the authors revised the implementation to take place in 3-lesson hours. The learning objectives for the topic is as follows: "*Students should be able to deduce that substances can change phase through the effect of heat based on the data they obtain from their experiments."* and *"Students should be able to discover that evaporating liquids absorb heat from their surroundings and that this causes the substance to be cooled."* In addition to these general learning objectives, the authors added the following other objectives: "*Students should be able to discover that evaporating liquids take heat from their surroundings and the exothermic substance cools down*", "*Students should be able to infer based on their experimental data that liquid substances can evaporate at any temperature with the effect of heat.*", "*Students should be able to discover that liquid substances may boil at a certain temperature under the effect of heat.*" and "*Students should be able to compare and discuss the main differences between evaporation and boiling.*"

3. Developing the guidance materials: The material was developed based on the above objectives. The engagement stage involves preparatory questions and a story activity (15 minutes), the exploration stage involves the experiment of exploring through activity (40 minutes), the explanation stage involves a definition and differences table regarding the concepts of evaporation and boiling (10 minutes), the elaboration stage involves a concept cartoon activity (15 minutes), and the evaluation stage involves various questions for assessing academic achievement (10 minutes). Appendix 1 provides the designed guidance materials.

4. Finalizing the guidance materials: To establish content validity, we asked two science teachers, two science educators, and a Turkish language teacher to evaluate the prepared guidance materials. In this process, we ensured the readability of the material and made corrections on the sentences based on the feedback that we received. For example, the phrase "Boiling is the temperature at which a liquid's vapor pressure equals the pressure exerted on the liquid by the surrounding atmosphere" was adapted for fifth graders and changed to the simpler definition: "Boiling is the rapid vaporization of a liquid."

We decided to start the activity with questions from daily life and an interesting and intriguing story. We added various questions based on Bloom's (1956) taxonomy levels during the evaluation phase. For example, one question for the analysis level was: "Which phase changes take place in the last days of the summer months when drying peppers and making tomato paste? Indicate the similarities between these changes and the activity Sude completed." For the knowledge level, a sample question is: "What is the transition of a liquid substance into a gas by heating called?"

5. Implementing the guidance materials: For implementing the guidance materials, participants were selected using purposive sampling. Purposeful sampling enables in-depth examination of a situation (Patton, 1987, as cited in Yıldırım & Şimşek, 2013). The study group consists of 10 fifth-grade students (nine girls, one boy) studying at a public middle school located in Central Anatolia.

Before the implementation, permission was obtained from the Ethics Committee (approval #187 dated April 27, 2021). The research process and publication ethics were followed. The first researcher is a science teacher and carried out the guidance material activities.

6. Piloting the guidance materials: The first author piloted the guidance materials online with 12 fifth graders. He prepared the presentation of the activities using the H5P application. Students accessed the presentation using Zoom. The students used the materials and engaged in discussions during the online lesson. The first author identified the issues regarding the activity and materials, then we revised these deficiencies.

Accordingly, we extended the duration of the exploring through activity experiment from 20 minutes to 40 minutes. Students were neither able to access the materials in this activity nor clearly were able to show their experiments on their webcams. They also had trouble using their computers. Therefore, we decided to implement the study in face-to-face education.

7. Implementation: The first author implemented the guidance materials over 3-lesson hours and distributed the activities as written materials to the students. Students also followed these materials on the smartboard. The first author arranged the classroom environment before the implementation of the materials. In addition, he prepared the tools and materials used in the lesson and took the necessary safety precautions. The activity stages involve engagement, exploration, explanation, exploration, and evaluation, as discussed in detail below.

Engagement

At the beginning of the lesson, the teacher asked questions to keep the students curious and motivated. The guidance materials have a picture of steam coming out from a teapot spout (see Appendix 1). The teacher asked the students to examine this picture briefly and to write their ideas on the worksheet. He also asked the students what they thought. A dialogue from this stage is as follows:

Teacher: What do you see in this picture on the worksheet?
Ceren: A picture of steam coming out while the water boils in a teapot.
Teacher: Do you think the water is boiling in this picture?
Ceren: Well (hesitantly), yes.
Teacher: Well, have you ever witnessed the image in this picture in your daily life?
Ceren: Yeah, while boiling water in the kitchen.
Teacher: What do you think is the cause of the steam coming out of the teapot's mouth?
Ceren: As the water heats up, steam comes out, teacher.
Teacher: Can you tell me in what other situations you see steam in your daily life?
Ceren: I see steam when my mother irons.

The teacher wanted to enable the students to put forth their ideas about the subject. By asking questions such as "Do you think the water is boiling in this picture?", he created question marks in the students' minds and prepared them to explore. The teacher tried to identify students' possible misconceptions during the engagement phase, as seen in the given dialogue. In this phase, the teacher received answers from several students and examined the worksheets of the students whose answers he could not get to identify possible misconceptions or alternative conceptions (Recommended time: 5 minutes).

The teacher asked the students to read the story on evaporation given in Appendix 1. According to the dialogues in the story, the teacher asked the students to write on their worksheet which character was telling the truth.

Photograph 1. The Participation Process During the Story Activity

After a few minutes, the students wrote their answers, and some students were given the chance to speak (see Photograph 1). The teacher asked the students what they thought about the ideas of different characters. At this stage, the following dialogue took place:

Teacher: Sude asked why cooling happens in watermelon. Who do you think gave the most correct answer to Sude's question?
Banu: I think her brother.
Teacher: Why do you think it's her brother?

Banu: Because the sun is hot, it heats the watermelon. The watermelon evaporates. Therefore, her brother is telling the truth.
Sena: I think it's her brother. Because in this event, evaporation was explained, and his brother said it correctly.
Teacher: All right, guys, does anyone find Sude's mother or sister correct?
Class: No, teacher.

The students designed experiments to prove their views. They wrote their design on the worksheet. A few students spoke about their design. The dialogue at this stage occurred as follows:

Teacher: Well, if you were Sude, what experiment would you do to support the explanations you chose?
Banu: I would put the water on the stove and start watching the evaporation thing.
Ayça: I would do the evaporation experiment. To prove it, I would have the water receive solar energy.
Elif: I would experiment with boiling water in a kettle.
Teacher: Let's do a similar activity related to what happened in Sude's story.
Class: Hurray!!!

The exploration was started using the experiment the students designed. Thus, a connection was established between the story and the experiment. The teacher identified common misconceptions found in the related literature with both the introductory questions and the written and oral answers to the story. For example, Ceren had the misconception of every drop of steam coming out of the teapot is proof that the water is boiling.

The teacher used stories and questions in the engagement. Thus, the teacher aimed to establish a link between the new concepts that students will learn and their pre-existing concepts (Recommended time: 10 minutes).

Exploration

The teacher had the students conduct an experiment to discover the difference between boiling and evaporation. The students were divided into five groups of two for this activity. The teacher gave each group a beaker, water, a metal stand, a spirit stove, a thermometer, and a glass lid. The teacher gave the following instructions for the experiment to the students:

- Fill a beaker with water.
- Place the beaker filled with water on the metal stand.
- Put the thermometer in the beaker.
- Light the spirit stove and place it under the beaker.
- Observe the water movements in the beaker at certain time intervals.
- Place the glass lid on the mouth of the beaker and remove it after a short while.

The teacher instructed them to begin the experiment as follows: "Dear friends, please check your watch. Measure the temperature every 3 minutes. Note the value you have measured in the table on the worksheet." The teacher encouraged the students to explain their observations and to exchange ideas between groups. Some groups asked the teacher for help overcoming their problems. The teacher had each student participate in the experiment (Photograph 2). Some of the dialogue during the experiment was as follows:

Teacher: What was the final state of the water being heated? Is any water left in the beaker?
Group 1: That's it! All the water in our beaker evaporated, teacher. Ours finished first!
Group 2: Look! The steam that came out started to increase, teacher, the beaker has barely any water left.

Photograph 2. The Thermometer Reading

According to Bybee et al. (2006), students discover concepts when they experiment concretely. With this activity, students were also expected to gain scientific process skills. After the experiment, the students were asked the following:

Teacher: What changes did you observe while heating the beaker?

Cem: As the heat increased, the temperature of the beaker increased and steam began to exit.
Ceren: There was a heat exchange. Evaporation took place. The evaporation increased in the last few minutes.
Sena: The temperature went up.
Nil: Bubbles came out and the temperature went up.
Ayça: I observed evaporation, the red line went up, and the water boiled.
Teacher: What is the name of the phenomenon of steam coming out as the beaker heats up?
Naz: Evaporation and boiling.
Cem: Evaporation.
Banu: Boiling.
Teacher: Did you observe steam for all temperatures? Can we call it all boiling?
Naz: There is something strange about this task, teacher. Then, I guess we can call it evaporation, not boiling.
Banu: So, what is boiling, teacher?
Teacher: We are getting to that soon.

The student with the misconception was confused by the observations and the teacher's guiding questions. She discovered the truth about the concept on her own. Some of the dialogue in the classroom activity process is presented as follows:

Teacher: Based on the experiment and your observations, what is the relationship between evaporation and rises in temperature?
Sena: I took notes on the paper, teacher. I observed the temperature rises as it warms up.
Teacher: How did you establish this relationship?
Sena: I saw the steam increase as the temperature increased. If it goes on like this, as the temperature rises, evaporation increases.
Teacher: Well, done. Let's move on to the next question.
Teacher: What is it called when all the water is vaporized in the final stage?
Cem: The evaporation of water indicates boiling.
Teacher: Well, isn't it is evaporating?
Banu: No, teacher. Evaporation happens all along at any temperature.
Teacher: So, you're saying evaporation and boiling are different things?
Banu: It was different. That's what I thought. I was calling every evaporation thing as boiling.
Teacher: What differences did you discover?
Banu: Evaporation occurs at any temperature, but above 95˚C there was bubbling and the water in the vessel quickly turned into gas. I call that boiling. I was surprised because I used to say "it boils" every time steam comes out of the teapot at home.

Using the questions, the teacher allowed the students to explore the differences between evaporation and boiling (Recommended time: 40 minutes). The students acquired the learning objective: "Students should be able to discover that evaporating liquids absorb heat from their surroundings and that this causes the substance to be cooled."

Explanation

At this stage, the students were asked to explain in their own words the knowledge they'd discovered in the previous stage. The teacher encouraged the students to explain the results of the experiment and allowed them to make scientific explanations. The teacher asked the students to review the answers other students gave to the questions asked in the story and to express the implications of the experiment activity in the exploration stage.

Teacher: At the beginning of the last lesson, I showed you a picture of steam coming out. Afterward, we read a story about Sude. Then, you observed evaporation and boiling by conducting an experiment. You collected and examined data. What conclusions did you draw from the experiment findings?
Ceren: Evaporation and boiling are very similar, teacher. In both, the water in the beaker changed from liquid to a gas. However, there are some differences. While evaporation always takes place between the temperatures we measure; boiling happened at the very end, all of a sudden.
Banu: The last part, in particular, was much more fun, teacher. I can explain boiling as the evaporation of all the water in the beaker at the end of the experiment.
Teacher: Well, you have defined boiling as the instantaneous transition of water from its liquid to the gaseous phase by

evaporating completely all at once. Did steam come out as the water in the beaker was heated?
Cem: Yes, teacher, steam came out all the time.
Teacher: Do we define this phenomenon as evaporation?
Cem: Evaporation occurred as the liquid was heated.
Teacher: So, did Sude's story involve evaporation?
Cem: Yes, teacher. The water in the watermelon exposed to the sun had evaporated.
Teacher: Can we say that evaporation then occurs in liquids at all temperatures?
Cem: Yeah. It happened at any temperature. For example, the first temperature we measured was 20˚C. From that moment on, steam began to come out as it was heated.
Teacher: According to your observations, do you think evaporation increases as the temperature increases?
Nil: Yes, it will, teacher. As the water was heated, it increased more, especially at the end.
Teacher: Is every event of steam coming out boiling then?
Banu: No, teacher. Boiling is the evaporation of all water at a certain temperature at once.
Teacher: How do we know when boiling has started?
Ceren: When bubbling or bubbles occur.
Teacher: Does anyone else want to explain the difference between evaporation and boiling?...

The teacher scaffolded the conceptual change in students. In addition, he stated that they should benefit from the notes on the worksheet on evaporation, boiling, and their differences (see Photograph 3; Recommended time: 10 minutes).

Photograph 3. Reading the Explanations

Thus, the students acquired the following objectives: Discover that evaporating liquids absorb heat from their surroundings, which causes the substance to cool; deduce based on experimental data that liquid substances can evaporate at any temperature with the effect of heat, and deduce based on experimental data that liquid substances can boil at a certain temperature under the influence of heat.

Elaboration: A Concept Cartoon

The teacher asked the students to examine the cartoon titled "Concept Cartoon: When the Water in the Teapot Boils" to enable students to access more information through new experiences. The students studied the cartoon for a while (See Appendix 1).

The teacher asked, "Which character in the cartoon do you think answered his mother's question correctly and why?" He created an environment for scientific discussion by asking questions. The five heterogeneous groups first had a small intergroup discussion and then a large intragroup discussion took place (see Photograph 4).

Photograph 4. Small-group Discussion

The students were instructed as follows: "During the discussion, let's follow the rules regarding showing respect and speaking by asking permission. I also want each group to choose a spokesperson to speak on your behalf to prevent a noisy classroom." While forming their arguments, the teacher emphasized that the groups could use the data they obtained in the previous stages, create justifications, and even refute the claims of other groups. Here is an excerpt of the dialogue that took place during the discussion:

Teacher: Which character in the cartoon do you think gave the correct answer to his mother's question and why?

Group 1: We think Mete's statement is correct: "I think it's enough for a bubble to form on the surface for it to boil."
Group 2: Yıldız's statement is correct: "If there are bubbles in the water, it will start to boil."
Teacher: What do other groups think?
Group 3: According to our group, Yıldız.
Groups 4 and 5: Yıldız.
Teacher: Group 1, you chose Mete. Why?
Group 1: Because if bubbles appear on the surface, it means boiling, and if steam comes out, it means evaporation.
Teacher: Group 2, why did you choose Yıldız?
Group 2: Because if there are bubbles in the water, it starts to boil.
Teacher: Group 3, why not Mete?
Group 3: Teacher, we think the same as group 2. It is not enough to form bubbles on the surface for it to boil. Although the experiment we did had bubbles, the boiling had not been completed. Bubble formation is the initial sign of boiling.
Teacher: Group 1, Is there anything you would like to say in response to Group 3's statements?
Group 1: We realized our mistake. We chose Mete because bubbles signal boiling.
Teacher: As a result, everyone agrees that Yıldız was telling the truth. Yıldız gave the correct answer. Because the formation of bubbles signals the start of boiling. In the previous experiment, boiling started when bubbles began to form.
Groups 2, 3, 4, and 5: (happily) Let's do an activity again, teacher.

As seen in the dialogues, the large group discussion was completed with the participation of all students (Recommended time: 15 minutes). The structured knowledge became more robust through this stage (Bybee et al., 2006), and the students acquired the objective "compare and discuss the main differences between evaporation and boiling."

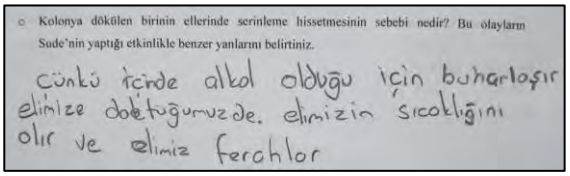
Evaluation

At this stage, the authors aimed to determine whether the students acquired the learning objectives and corrected their misconceptions or not. Accordingly, the authors prepared questions (open-ended, multiple-choice, true-false, and fill-in-the-blank) using the related literature (Saraç, 2018) and the question pool of Ministry of National Education (MoNE) of Turkey (MoNE General Directorate of Assessment, Evaluation and Examination Services Support Material, 2021). They assessed the students' knowledge with these questions (see Photograph 5).

Photograph 5. Evaluation Process

Take the following learning objective as an example: Students should be able to discover that evaporating liquids take heat from their surroundings and the exothermic substance cools down. To assess this objective, the authors asked the open-ended question shown in Photograph 6: "Why does someone who pours cologne feel cooling on their hands? Indicate the similarity of this event with what Sude experienced." Some of the students answered the question as follows:

Naz: When our hands are sweaty or we pour cologne, evaporation occurs and cools our hands.
Elif: In the summer, evaporation usually helps us.
Cem: When cologne is poured on our hands, the liquid in the cologne evaporates by taking heat from our hands. Our bodies cool like the watermelon in the story.



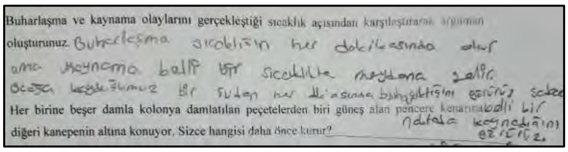
Photograph 6. One Student's Answer to the Open-ended Question on the Worksheet

The analysis of the student answers written on the worksheets revealed that all students stated the evaporation event to have an effect. Some students gave superficial answers like Naz and Elif, while others gave detailed reasons like Cem.

For the learning objective "*Students should be able to infer based on their experimental data that liquid substances can evaporate at any temperature with the effect of heat*," the authors used the true-false question, "*Evaporation takes place at a certain temperature, and boiling occurs at every temperature*." All the students answered this question as false, and one student shared an explanation as, "Evaporation can occur in liquids at any temperature, while boiling occurs at a certain temperature for a pure substance," of which the whole class approved.

For the learning objective "*Students should be able to discover that liquid substances may boil at a certain temperature under the effect of heat*," the authors used the following multiple-choice question "*I. Liquids evaporate at any temperature, II. Boiling occurs at a certain temperature, III. Evaporation occurs throughout the liquid: Which of the above is/are correct?*" Only one student marked option D (I, II, and III) and made a mistake. All the other students correctly marked option B (I and II) on the worksheet.

For the learning objective "*Students should be able to compare and discuss the main differences between evaporation and boiling*," the authors asked the following open-ended question: "*Develop an argument to compare evaporation and boiling events in terms of the temperature at which they occur*." (see Photograph 7).



Photograph 7. An Answer to the Open-ended Question on the Worksheet

The analysis of the students' answers to the written questions on the worksheets revealed that the students answered the majority of the questions correctly. The entire class participated in the evaluation process. The authors requested that the experiment report and worksheets be included in the students' portfolios (Recommended time: 10 minutes).

EVALUATING THE ACTIVITY

Five open-ended questions were directed to five volunteer students to determine their views on the implementation process. The authors prepared the questions and obtained feedback from a science teacher and two science educators about the content and readability of the questions. The interview form was analyzed using descriptive analysis, with the steps being followed and presented in tables (e.g., transcribing students' views, confirming the text by comparing to video recordings, coding the data, creating categories, and getting expert opinions; Corbin & Strauss, 2007).

The first open-ended question posed to the students was "Do you think that the activities helped you distinguish between evaporation and boiling?" All the participants stated that the activities allowed them to distinguish between evaporation and boiling. Nil stated, "Yes, now I can distinguish better" and Naz said, "Yes, sir. I made a mistake in a question about boiling in the activity. I answered by saying that bubbles forming at the top surface indicate boiling, but in fact, boiling starts when bubbles form on the surface."

The second open-ended question was "Which activity grabbed your attention the most and why?" As seen in Table 1, three participants chose the concept cartoon as the most striking activity, three chose the story, while two selected the experiment. Cem explained why he found the concept cartoon to be the most remarkable, saying, "Because it explains by showing cartoons." Ayça expressed, "I liked the thermometer experiment the most. I remember the concepts better."

Table 1. Codes Related to the "Most Remarkable Activity" Category

Participant	Codes
Naz	Story
Ayça	Experiment, story
Elif	Concept cartoon, experiment,
Nil	Concept cartoon
Cem	Concept cartoon, story

The third open-ended question was "Do you think the activities relate science concepts to daily life?" The participants stated that the activities related the science subjects to daily life (see Table 2). For example, Nil said, "Yes, I can relate the examples there to daily life."

Table 2. Codes Related to the "Associating Science Subjects with Daily Life" Category

Participant	Codes
Naz	Cooking
Ayça	Brewing tea
Elif	Cooling of watermelon
Nil	Pouring cologne
Cem	Brewing tea

The fourth and the fifth questions asked the participants to share their views on the positive and negative aspects of the activities. As can be seen in Table 3, one participant had nothing, positive or negative, to comment on the activities, while four participants shared positive features, and one participant expressed a negative feature. Cem stated the negative feature and suggested, "It could be a little more cartoony. It should have more pictures and fewer questions."

Table 3. Codes Related to the "Positive and Negative Features" Category

Participant	Positive	Negative
Naz	Learning by experiencing	-
Ayça	Effective	-
Elif	-	-
Nil	Fun, better for understanding	-
Cem	Being active and persistent	Too many questions, too few pictures

CONCLUSION and SUGGESTIONS

This study has developed guidance materials for the topic of evaporation and boiling using the 5E learning cycle model. The 5E learning cycle model was chosen because of its usefulness in learning new concepts as well as in understanding known concepts in depth (Bybee et al., 2006).

The research studies on material development in the related literature typically introduce the methods and techniques used and provide example activities to make the concepts meaningful and concrete (Şaşmaz Ören et al., 2011; Ürek, 2020). The materials developed in this study follow the 5E learning cycle model and include discussions, a concept cartoon, a story, and an experimental activity, with the concepts being embodied in different parts of the activities. In this sense, the current material development study can be useful resource for students, teachers, and researchers. These materials were prepared using simple tools and examples from daily life so that they can be used in various socio-cultural and geographical conditions.

According to the students' opinions, the guidance materials designed and used in this study helped them learn scientific concepts meaningfully, related science concepts to daily life, and increased teacher-student and student-student interactions as well as academic achievement. Similarly, the results from many studies have emphasized guidance materials to facilitate learning a subject (Appleton, 2002; Ürek, 2020).

The 5E learning cycle model should be included in the curriculum and used by teachers in lesson planning (MoNE, 2018). The literature needs more studies on this model (Wilder & Shuttleworth, 2005). At this point, the authors suggest guidance materials be developed based on the 5E learning cycle model for different topics in the science course. In addition, an experimental study can be conducted to determine whether the developed materials are effective at eliminating students' misconceptions. The developed guidance materials were simplified as much as possible for the fifth-grade level. Guidance materials for higher grade levels can be developed by considering the narration and difficulty levels.

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Appendix 1

The Guidance Materials

Grade Level: 5th Grade

Unit Name: Matter and Change

Topic: Evaporation and Boiling

Objectives: Students should be able to

- ✓ Discover that evaporating liquids take heat from their surroundings and the exothermic substance cools down.
- ✓ Infer based on their experimental data that liquid substances can evaporate at any temperature with the effect of heat.
- ✓ Discover that liquid substances may boil at a certain temperature under the effect of heat.
- ✓ Compare and discuss the main differences between evaporation and boiling.

Preparation: Before using the material, the teacher should ensure that the science lab, workshop, or classroom is suitable. The required tools and equipment should be available in sufficient numbers. Safety measures must be taken. Form heterogeneous groups at the start of the lesson.

Duration: 30+30+30 minutes

EVAPORATION AND BOILING

Have you ever witnessed the image in the picture on the right in your life? If yes, give examples.

How does the steam coming out of the teapot's spout form?

Give examples of other situations in your daily life when you saw steam and explain how it formed.

STORY

Sude heard on the forecast that the weather in Kayseri will be very hot and clear for the weekend. When Sude learned the weather would be hot, she said, “It would be nice if we went on a picnic this weekend!” She convinced her parents. Her older sister and younger brother were also very happy about it. Sude is in the fourth grade, her sister is in the fifth grade, and her younger brother is in the first grade. Sude and her family had a picnic that weekend and found a nice place to put their belongings. While the siblings played together, her mother prepared the table. After getting hungry in the open air, Sude’s mother handed out the watermelon. She had cut it up and left it in the sun, then hand it out to everyone before starting the meal. Sude had a confused face while eating the watermelon and her mother asked what happened. Sude shared the surprise of the cooling that occurred in the watermelon by saying “Mom, look at this watermelon! Something happened to it! It's cold. It's not hot even under the sun!!!” Upon hearing this, her mother smiled and tried to explain the situation saying, “It’s because most of the watermelon consists of water. The watermelon may have less water content now, my daughter.” Sude's younger brother interpreted the situation as, “I think the watermelon doesn’t get cool when left in the sun because the sun is hot.” Sude’s sister who is in the fifth grade stated that they had studied this subject in the science class and explained it saying, “Watermelon juices get warm from the sun and evaporate, and as they evaporate, the watermelon gets cold because the juices took the heat from the watermelon to evaporate.” Confused about this, Sude began to think about which of the things everyone said was true.

Who do you think gave the most correct answer to Sude’s question about why the watermelon was cooling?

If your answer is her mother, why?

If your answer is her brother, why?

If your answer is her older sister, why?

Well, if you were Sude, what experiment would you try to support the explanations you chose?

Let's Explore with an Experiment: Evaporation/Boiling

Sude decided to conduct an experiment to better understand and justify this event. Sude did this experiment at home with a teapot and a glass. You can also do it with a beaker in the laboratory. Perform this experiment in groups of 3-4 people.

Tools and Equipment: Beaker, water, wire stand, spirit stove, thermometer, glass lid, stopwatch

Procedure:

- Fill a beaker with 250 mL of water.
- Put the beaker filled with water on the wire stand.
- Put the thermometer in the beaker.
- Light the spirit stove and place it underneath the beaker.
- Observe the water movements in the beaker at specific time intervals.
- Place the glass lid on the mouth of the beaker and remove it after a short while.

  What was the last phase of the water? Is there any water left in the beaker? Fill in the fields below.

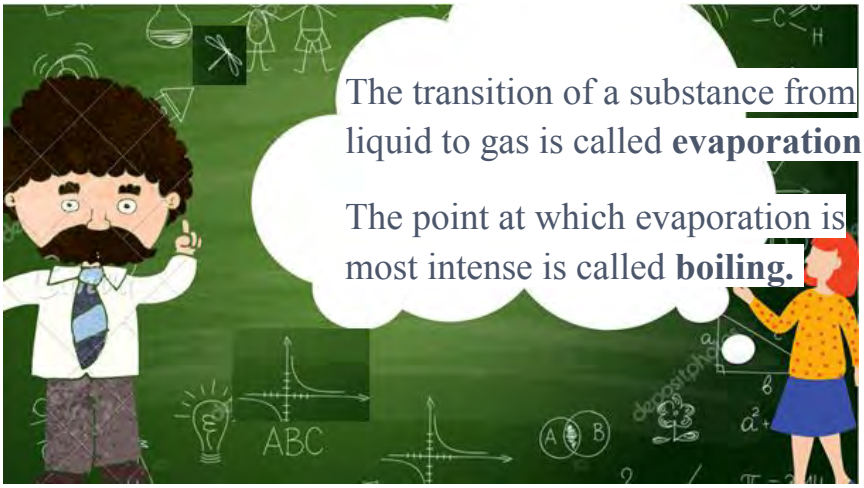
Time (min.)	Temperature (°C)	Is there steam?		Are there any bubbles?	
		Yes	No	Yes	No
Beginning					

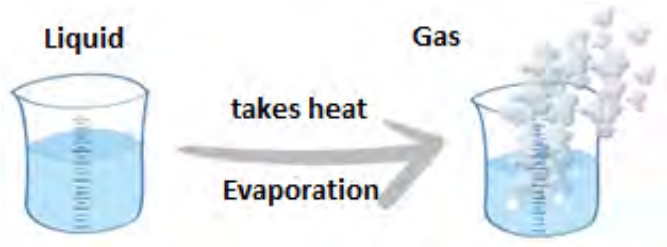
What changes did you observe as the beaker heated?

What is the name of the phenomenon of steam coming out during the heating of the beaker??

Based on your experiment and observations, what is the relationship between evaporation and a rise in temperature? Please explain.

What is it called when all the water becomes steam in the final stage of heating the beaker?





The concepts of evaporation and boiling are used interchangeably in daily life. However, the following scientific differences do exist between boiling and evaporation:

Evaporation	**Boiling**
No bubbles form in the liquid	Bubbles form
Occurs only on the exposed surface of the liquid	Boiling occurs throughout the liquid, both on and below the surface.
Occurs at any temperature	Boiling only happens at a certain temperature: the boiling point
Energy is taken from the environment	Boiling requires constant heat from outside
Evaporation is silent	Boiling makes noise and causes bubbling
Increases with air current (wind)	Unaffected by airflow
Increases with temperature increases	The temperature remains constant
Evaporation has a cooling effect on the liquid	The liquid does not cool in boiling

Example cases where only evaporation occurs with no boiling:

→ Drying the laundry by evaporation,

→ Hands feel cool by evaporation when pouring cologne on them.

Evaporation cools the remaining liquid. Therefore, if you cut a watermelon and leave it in the sun, you will notice that the watermelon has cooled after a while. This is because liquid particles get some of the energy they need to evaporate from the other particles in the liquid. The internal energy of the remaining liquid particles thus reduces: They move more slowly, and as a result, their temperature also decreases.

Similarly, if you wrap a cloth around a plastic bottle with water and wet the cloth, the temperature of the water in the plastic bottle will decrease after a while. This is because the liquid water particles in the cloth transfer some of their energy to the particles on the surface of the cloth. Particles on the surface separate from the liquid and evaporate. The energy of the particles remaining in the cloth decreases and so does their temperature.

Concept Cartoon: When Does the Water Boil in the Teapot?

Which character do you think gave the correct answer to his mother's question?

Why do you think so?

Evaluation Questions

For the following statements, write T in the parentheses if the statement is true or F if the statement is false. Write the true form of the statement in the space below the false statements.

( ) Evaporation takes place at a certain temperature, while boiling occurs at any temperature.

( ) Evaporation is effective for obtaining salt.

( ) Evaporation and boiling can be used interchangeably.

Fill in the blanks below with appropriate words.

The transformation of a liquid substance into a gas state by being heated is called ….....

Answer the multiple-choice questions regarding the following statements:

Which of the following statements are true?

I. Liquids evaporate at any temperature.

II. Boiling occurs at a certain temperature.

III. Evaporation happens all over the liquid.

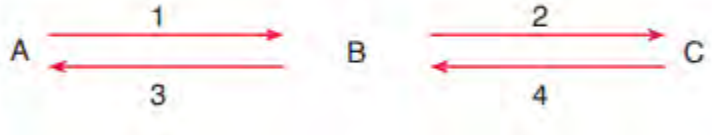
(A) Only II; (B) I and II; (C) II and III; (D) I, II, and III

Which of the following is characteristic of evaporation?

A) Happens at any temperature. B) Happens all over the liquid.

C) Occurs at a certain temperature. D) Transition from gas to liquid.

Different physical phases of a pure substance are shown as A, B, and C.



Of the phase changes 1, 2, 3, and 4, which shows evaporation?

A)1 B)2 C)3 D)4

Which of the following options are grouped correctly under boiling and evaporation?

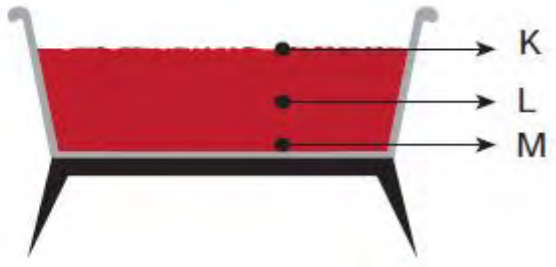
1) Occurs at any temperature of the liquid.
2) Occurs only on the surface of the liquid.
3) Occurs only at certain temperatures.
4) Occurs throughout the liquid.
5) The temperature does not change while forming.
6) Temperature may vary while forming.

	Boiling	**Evaporation**
A)	3, 4, 5	1, 2, 6
B)	1, 2, 3	4, 5, 6
C)	3, 4, 6	1, 2, 5
D)	1, 2, 4	3, 5, 6

Which of the following statements is a *result* of evaporation?

A) The weather is warm when it snows.
B) Water boils as its temperature increases.
C) Ice cream taken out of the fridge melts after a while.
D) Clothes dry faster in windy weather.

While making tomato paste, crushed tomatoes are boiled and the water is evaporated. A photo and drawing of the boiling process while making tomato paste are given.



At which respective points of the tomato paste container does evaporation occur?

A) Only K B) K and L C) L and M D) K, L and M

Answer the following open-ended questions clearly and precisely based on what you have learned.

- In the last days of summer, what phase change or changes take place when drying bell peppers or when making tomato paste? Indicate the similarities these events have with what Sude experienced.

- Why does the hand feel cool when cologne is poured into it? Indicate the similarities this event has with what Sude experienced.

- Write an argument by comparing what happens in evaporation and in boiling in terms of the temperature at which they occur.

- There are two napkins, and both have five drops of cologne placed on them. One is placed by a sunlit window and the other under the sofa. Which one do you think dries first?