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SCIENCE TEACHER CANDIDATES' MISCONCEPTIONS AND LACK OF KNOWLEDGE ABOUT THE RELATION BETWEEN BOILING POINT AND VAPOR PRESSURE

ABSTRACT

This study aims at identifying misconceptions and lack of knowledge among science teacher candidates, about the relation between boiling point and vapor pressure. A worksheet containing open-ended questions was used to determine the misconceptions and lack of knowledge among students. The responses given to the questions on the worksheet were grouped together according to their similarities and evaluated. The assessment of the responses indicated that the teacher candidates had certain misconceptions and lack of knowledge about issues such as the heat exchanges during evaporation process, the physical conditions which effect boiling point, and the relation between boiling point and vapor pressure.

Keywords: Boiling, Vaporization, Vapor Pressure, Boiling Point, Physical Education

FEN ÖĞRETMEN ADAYLARININ BUHAR BASINCI VE KAYNAMA NOKTASI ARASINDAKİ İLİŞKİ İLE İLGİLİ BİLGİ EKSİKLİKLERİ VE KAVRAM YANILGILARI

ÖZET

Bu çalışmanın amacı, fen öğretmen adaylarının buhar basıncı ve kaynama noktası arasındaki ilişki ile ilgili kavram yanılgılarını ve bilgi eksikliklerini belirlemektir. Öğrencilerin kavram yanılgılarını ve bilgi eksikliklerini belirlemek için açık uçlu sorular içeren bir çalışma yaprağı kullanıldı. Çalışma yaprağındaki sorulara verilen cevaplar benzerliklerine göre gruplandırılarak değerlendirildi. Sorulara verilen cevapların değerlendirilmesi, fen öğretmen adaylarının buhar basıncı ve kaynama noktası arasındaki ilişki, kaynama noktasını etkileyen fiziksel koşullar, buharlaşma süresince ısı değişimleri gibi konularda kavram yanılgıları ve bilgi eksikliklerinin olduğunu gösterdi.

Anahtar Kelimeler: Kaynama, Buharlaşma, Buhar Basıncı, Kaynama Noktası, Fen Eğitimi

1. INTRODUCTION (GİRİŞ)

Most of the work on misconceptions in chemistry has been done relatively recently - in the 1980's. Misconceptions in physics and biology have been more extensively studied. Thus, misconceptions in chemistry represent a fertile field for investigation [1]. The students' perceptions have been referred to different terms such as misconceptions, preconceptions alternative frameworks, children's science, naive conceptions and so forth in the related literature [1, 2 and 3]. Students' misunderstanding and misconceptions in school sciences at all levels cause a major problem for science educators, scientists-researchers, teachers, and of course students [1, 4 and 5]. Throughout this article, the term 'misconception' will be used to refer to students' conceptions that are different from scientific conceptions.

To date, many studies have investigated students' understanding of chemistry concepts: physical and chemical change [6, 7, 8 and 9], evaporation, condensation and vapor pressure [10 and 11], dissolution [6, 12, 13 and 14]. Many of these topics about which students hold misconceptions are basics of chemistry knowledge and are interrelated. Boiling point and vapor pressure are examples of such concepts about which students hold misconceptions. For example, Osborne and Cosgrove [15] stated that understanding of the change of states (evaporation, boiling, condensation, freezing etc.) is necessary to grasp and comprehend many aspects of chemistry, physics, earth sciences and biology. Moreover, this concept is not only related to our daily life but also provides an important basis on which to understand the cycle of matter, the conservation of matter, the particulate model, attraction forces between particles and kinetic gas theory [15, 16, 17, 18 ve 19]. Bar and Travis [20] have shown that children have difficulty understanding that water vapor and air exist all around us. This again requires a high level of abstraction. This seems to be echoed by Chang [18] because even teacher candidates referred to air rather than water vapor, as the substance that condenses. Furthermore, Gopal et al.[10] identified many second-year engineering students in South Africa might have an inadequate understanding of the basic physical chemistry concepts of evaporation and condensation. Most students also struggled with the concept of vapor pressure, although quite e few were able to formulate their own useful definition using data and physical evidence provided.

Vapor pressure and boiling point are among the fundamental concepts of science taught from the primary school onwards. A thorough understanding of these concepts is a prerequisite for comprehending many science concepts taught in the later stages of schooling, as the topic is covered in the school curriculum. Both primary and secondary curricula aim to represent this topic for students. The aim of this paper is to draw attention to the existence of such misconceptions. Boiling point and vapor pressure were selected as the concepts on which to illustrate the case, due to their importance in sciences (physics and chemistry).

As future teachers, providing a significant comprehension level of a concept for the students is of utmost importance, especially when the relation of the topic with daily life and other scientific areas such as biology and physics is considered. Topics like matter and its states, boiling, evaporation, freezing, pressure and sublimation may even be difficult for students at university level to explain. Determination of the relevant misconceptions among university students is the goal of the study.

2. RESEARCH SIGNIFICANCE (ÇALIŞMANIN ÖNEMİ)

It is revealed from many studies that classroom teachers have significant role regarding students' misconceptions about science concepts. Thus, identification and understanding of prospective science teachers' misconceptions and lack of knowledge through the use of appropriate measurement and evaluation tools is very important.

The main purpose of this study was to determine the level of understanding of scientific concepts such as boiling point and vapor pressure among future teachers attending to the Science Teacher Training Program of Dicle University's Ziya Gokalp Education Faculty. The research question is: What are the students' levels of understanding and misconceptions about vapor pressure and boiling point?

3. METHOD (YÖNTEM)

3.1. Sample (Örneklem)

This study was carried out on 43 students of the Science Teacher Training Program of Dicle Universirty's Ziya Gokalp Education Faculty, located in the Diyarbakir Province of Turkey.

3.2. Instruments (Araçlar)

In this study, a questionnaire was used to collect data. In line with Constructivist Model the unified teaching model, four staged teaching strategy was used in the development of the questionnaire [21]. The questionnaire consisted of three parts. The first part contained questions to attract attention of the target students (drawing attention). The second part consisted of questions related to the group activities (leading). The third part contained questions about the students' reactions and explanations to these in view of the new experiences, based on the their past observations and experience (discussion). A copy of the questionnaire used in the study can be obtained from the authors. All questions were pilot tested and the required modifications were made prior to the implementation of the open-ended test. The content validity of the test questions were assessed by a group of experts in chemistry, chemistry teachers, and by the instructor.

3.3. Process and Data Analysis (Süreç ve Veri Analizi)

Before the questionnaires were distributed, in view of the laboratory setting, the students were organized into 11 groups containing 4 students each. The work commenced following an explanation about the study and the content of the questionnaire. 120 minutes where given to students to carry out the experiment and complete the questionnaire. Each student was requested to provide answers based entirely on their individual observations and knowledge. To eliminate the hesitation for sharing personal knowledge, students were provided with the option of not writing their names on the questionnaire.

The students' level of understanding for open-ended questions was assessed using a concept evaluation technique used by Abraham et al. [7]. The open-ended questions were analyzed under the following categories:

- **Sound Understanding (SA):** Responses that included all components of scientific conceptions.
- **Specific Misconception (SM):** Responses that included illogical or incorrect information.
- **No Understanding (NU):** Repeated the question; contained irrelevant information or an unclear response; left the response blank.
- **No Response (NR):** "No answer; I don't know; I have no idea".

4. FINDINGS AND DISCUSSION (BULGULAR VE TARTIŞMA)

The data collected during this study is presented under the subtitles of "drawing attention, leading, and discussion".
Data collected in the section of "drawing attention"
To attract their attentions, the students were asked why our hands feel cooler when some eau de cologne is poured on them. The erroneous beliefs conveyed though the responses provided to this question are given in Table 1.

Table 1. Percentages of the students who gave responses in different levels of understanding
(Tablo 1. Farklı anlama seviyelerinde verilen cevaplara göre öğrenci yüzdeleri)

Item 1: What is the reason for feeling cool when cologne is poured into your hands?	f	%
SU: When cologne is poured into our hands, it takes heat from our hands and evaporates. This is why we feel cooler.	38	88
SM: The heat in our hands evaporate due to the alcohol	5	12

Item 1

88% of the students answered this question correctly. The answer of 12% of the students, stating that the heat in their hands evaporated due to the alcohol is assessed as a serious misunderstanding. Regarding the question given in the "drawing attention" section; cologne evaporates by taking on heat from our body. As a result of this, our body looses heat and we feel cooler. This is a physical process. In general, evaporating liquids take away heat from their surroundings. 12% of the students stated that the heat in their hands evaporated due to alcohol. This is assessed as a serious misconception. This may be due to the students' perception of heat as a fluid. The students' misconceptions may have various reasons behind them. For instance, the training programs may be inadequate in terms of being informative and examplatory, or, the teachers may not be utilizing their training strategies and methods properly when teaching the subjects
Data collected under "leading" subtitle:

The data related to misconception and erroneous concepts in connection with each question under the "leading" subtitle is listed in Table 2.

Table 2. Percentages of the students who gave responses in different levels of understanding
(Tablo 2 Farklı anlama seviyelerinde verilen cevaplara göre öğrenci yüzdeleri)

Item 1: Fill an erlenmeyer approximately half way with water, heat it until the water boils and write down your observations.	f	%
SA: When the liquid is heated, the evaporation rate accelerates. The temperature of the liquid rises and after a while, bubbles form at the surface of the water, the temperature which the thermometer shows stays stable and the volume of the water in the cup starts to decrease.	42	98
SM: Boiling is the evaporation of water.	1	2
Item 2: Take the erlenmeyer away from the heat source and carefully cover it with a cap. Place the erlenmeyer upside down, and put it inside the circle. Then, put a pack of ice at the bottom of the erlenmeyer and observe the changes. Write down your observations.		
SA: When the erlenmeyer is turned upside down and ice is placed on top of it, water gives away a certain part of its heat to the ice. As a result of this, the vapor pressure of the water decreases and after a while, water starts to boil again.	33	77
SM: When ice is placed on the erlenmeyer, the vapor pressure of water decreases, consequently, the boiling point increases.	6	14
NU: We saw that the water was boiling again because the ice transmitted heat to the container.	4	9
Item 3: After filling two equally sized beakers completely with water, cover one of the beakers with watch glass, keep the other one open and heat them. Observe the difference. Write down your observations.		
SU: The water inside the beaker which is covered with glass boiled faster than the water inside the non-covered beaker. This is because the water inside the non-covered beaker loses heat.	24	56
SM: The reason why the water inside the non-covered beaker boiled late is because it has more pressure on it.	12	28
NU: Water in both of the beakers should be boiling at the same time.	7	16
Item 4: Fill two beakers with equal volumes of water and olive oil. Heat both of them at the same temperature for 15 minutes and observe the changes which occur.		
SU: The boiling point of water is higher than the boiling point of olive oil. Besides, the evaporation pressure of olive oil is higher than the evaporation pressure of water. This is why olive oil boils earlier than water when they are equally heated.	19	44
SM: Olive oil boiled before the water did. This is due to the fact that olive oil is less dense than water.	24	56

Item 1

98% of the students answered this question correctly. However, 2% of the students answered this question thinking that boiling and evaporation of water are actually the same process.

The students' answers to the first question in the guideline section show that 2% of the students perceive boiling and evaporation of water as the same process. This may be because of the misunderstandings which the students acquired during their previous training. Similar misunderstandings concerning evaporation and boiling have also been identified by Tytler [22]. Whereas evaporation may occur at all temperatures, boiling only occurs when the vapor pressure of the liquid is equal to the external pressure.

Item 2

The ratio of the students who answered this question correctly is 77%. 14% of the students have misunderstandings concerning the issue, because they do not understand the relation between boiling point and vapor pressure. The answers of 9% of the students show that they did not understand the question.

The students' answers to the second question show that 14% of the students believe that when we place ice on the erlenmeyer, the pressure of the water will decrease; therefore the boiling point will increase. This shows that students do not have a thorough comprehension of the relation between boiling point and vapor pressure. The studies carried out by Bar and Galili [23] and Johnson [24] indicate that students of all training levels have different ideas about these concepts. Besides, these studies determine that the misconceptions decrease as the level of training increases.

It should not be disregarded that there is a possibility that these students who will become science teachers in the future may convey their misconceptions to the students they will train. It is noted in [25] that the teachers' spoken language, the environment, the books, individual characteristics and prior knowledge of the students may cause misconceptions. 9% of the students stated that ice transmits heat to water, causing water to boil. This shows that the students have a lack of knowledge about the direction of the heat flow.

Item 3

56% of the students comprehend the relation between boiling point and vapor pressure properly. 28% of the students, however, have incorrect understandings about this relation. 16% of the students gave irrelevant answers to this question. The answers given to the third question in this section indicate that 28% of the students believe the water inside the non-covered cup boils later because it has more pressure on it. This may be the result of the students' misconception about the existence of a relation between time to boiling and boiling temperature. 16% of the students, on the other hand, believe that water in both cups should be boiling at the same time. It may be concluded that students who have such beliefs do not comprehend the relation between boiling point and vapor pressure. The fact that these mistakes may be resulting from the students' trainings in the past is also expressed by other researchers [26, 27 and 28].

Item 4

44% of the students are aware that boiling points and vapor pressures of different liquids are different. However, more that half of the students (56%) has misconceptions about this issue.

Answers given to the fourth question show that 56% of the students believe that olive oil boils earlier than water due to the difference of their densities. The fact that students have such misconceptions is assessed as an important problem for the science education. This result shows that the students not only have misconceptions about this specific subject in the area of science, they have misconceptions about other science subjects as well. Misconceptions among students are addressed by many researchers such as [8, 9, 29, 30, 31, 32, 33 and 34].

Data collected under "discussion" subtitle:

Table 3. Percentages of the students who gave responses in different levels of understanding
(Tablo 3. Farklı anlama seviyelerinde verilen cevaplara göre öğrenci yüzdeleri)

Item 1: Explain the changes that occur during heating	f	%
SU: The volume and mass of the liquid which is heated decreases by evaporation, vapor pressure rises as temperature increases.	37	86
SM: Water gives out air bubbles during heating. This is because the solubility of air in water decreases under high temperatures.	3	7
NU: No changes were observed in the liquid during heating. However, bubbles rising out of the liquid were observed during boiling.	3	7
Item 2: What happens if the energy which the liquid takes from its environment is less than the energy taken away by the evaporating particles?		
SU: Condensation occurs. The amount of evaporation decrease.	37	86
SM: If the energy which the liquid takes from its environment is less than the energy taken away by the evaporating particles, the boiling point increases.	2	5
Item 3: Explain the reason why water boils away before the olive oil does, when one of two cups having equal volume is filled with water and the other one is filled with olive oil.		
SU: The water boils away first because its evaporation rate is higher.	38	88
NU: Boiling point of olive oil is lower. This is why it starts boiling faster, evaporates and boils away before water does.	3	7
Item 4: Define boiling point based on your observations regarding the experiments carried out.		
SU: It is the temperature at which the vapor pressure of a liquid is equal to the external pressure.	38	88
SM: Boiling point is heating the liquid up to the temperature which is needed for it to evaporate.	3	7
NU: All liquids have their own boiling points and these vary.	1	2
Item 5: Under which conditions does the boiling point of a liquid change?		
SU: Boiling point depends on the purity of a liquid and its external pressure.	24	56
SM: Boiling point of a liquid depends on its density and amount. Boiling point depends on the amount of the liquid and the power of the heater.	15	35
NU: Boiling point of a liquid depends on the power of the heater and the solubility of the liquid.	2	5

Item 1

86% of the students answered this question correctly. 7% of the students have misconceptions. 7% of the students did not answer this question.

Answers given to the first question in the discussion section show that 7% of the students believe that water gives out air bubbles during heating due to the decrease in water's solubility at high temperatures. These results are parallel to those of Canpolat et al., [35]. Vapor bubbles form inside the liquid during boiling and the liquid boils turbulently. Moreover, the solubility of air inside the water occurs under high pressure and low temperature. The students who perceive water vapor molecules as air molecules might be misleaded by their prior training.

To understand the changes in the state of matter is extremely important for students who are trained in science and earth sciences. According to many researchers, the process of change of state is very important for understanding the transformations of matter in our daily lives [15, 16, 17, 18 and 19].

Item 2

86% of the students answered this question correctly, 5% of the students have misconceptions and 9% of the students did not answer this question.

Answers given to the second question indicate that 5% of the students believe that the boiling point will increase if the energy which the liquid takes on from its surroundings is less than the energy which the vapor particles take away. This is a serious problem as far as science education is concerned. It shows that the students do not comprehend the relation between the energy of the particles, the vapor pressure and the boiling point. The fact that 9% of the future science teachers did not express an opinion on this subject is found to be worth considering.

Item 3

88% of the students answered this question correctly. The answers of these students are consistent with scientific knowledge. While 7% of the students have misconceptions, 5% of the students did not answer this question.

Answers given to the third question in this section indicate that 7% of the students believe that olive oil will start boiling and diminish by evaporating before water does, since the boiling point of olive oil is less than that of water. This shows that the students have the misconception that a liquid which has a high boiling point will also have a high evaporation rate.

Item 4

88% of the students explained the definition of boiling point scientifically. 2% of the students stated that boiling points vary, rather than defining boiling point and 7% of the students defined boiling point as "the temperature needed for a liquid to boil", in their answers to the fourth question. This may be because of the students' perception of boiling and evaporation processes as identical. The definition given by the students is assessed as a misconception. Although concepts of evaporation and boiling are related, they are two different concepts. While evaporation occurs at all temperatures, boiling occurs only when the vapor pressure of the liquid is equal to the external pressure. This is the most important difference between boiling and evaporation. If the students are unaware of this, they may think that the concept of evaporation is the same as boiling temperature. Similar results have also been expressed by researchers working on the subject such as [14, 19, 20 and 33].

Item 5

56% of the students stated that boiling point is related to the purity of a liquid and external pressure. This is consistent with scientific views. However, 35% of the students have misconceptions regarding the factors which affect boiling point. 5% of the students stated that boiling point depends on the power of the heater and the solubility of the liquid. This shows that they do not understand the factors effecting boiling point.

Answers given to the fifth question indicate that 35% of the students believe that the boiling point of a liquid depends on the density and the amount of the liquid as well as the power of the heater. This is a serious misunderstanding as far as science education is concerned. Moreover, when one considers that those who are making these statements are the science teachers of the future, he or she can have a better understanding of the possible effects of such misunderstandings on younger generations.

5. CONCLUSION AND IMPLICATIONS (SONUÇ VE ÖNERİLER)

In the present research, a worksheet which consisted of 3 sections was used in order to identify and better understand prospective science teachers' misconceptions and lack of knowledge about the relationship between boiling point and vapor pressure. Upon the evaluation of the students' answers given to the questions on the worksheet, following student misconceptions, which were not came across in the existing literature, about the relationship between boiling point and vapor pressure have found.

- When we pour cologne in our hand, our hand is getting cooler because cologne absorbs the heat from the hand.
- Boiling points of the lower density liquids are also lower (The lower the density, the lower the boiling point that liquid has).
- Pressure upon the liquid which is in the open containers is higher.
- When the temperature of the water gets higher, solubility of the air also gets bigger. This makes water boiling.
- Boiling point is the increasing temperature of the heated liquid.
- Boiling points of the liquids depend on the amount of the liquid and the power of the heater (source of heat).

It seems a quite serious problem that prospective science teachers, who will be the actual science teachers in classrooms upon their graduation, have these kind of misconceptions listed above. Since all of the students seeking degrees in science education programs in universities are accepted according the scores, which are very close to each other in all universities, obtained from the same examination in Turkey, it is very reasonable to think that other prospective science teachers have probably the same kind of misconceptions mentioned above.

Therefore, in their pre-service education, misconceptions of science teachers' and teachers in other fields should be identified by preparing appropriate study sheets control lists in the classrooms and laboratories in order to eliminate these misconceptions through the use of appropriate materials, experiments and observations.

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