JOURNAL OF BALTIC SCIENCE EDUCATION
ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/

PROMOTING PRE-SERVICE SCIENCE TEACHERS' CONCEPTUAL UNDERSTANDING ABOUT BOILING BY DIALOGIC TEACHING

Mehmet Demirbağ,
Sevgi Kingir

Abstract. *In order to reach students who can efficiently use intended scientific understandings, it is important to have science teachers without conceptual difficulties. The aim of present research is to enhance pre-service science teachers' conceptual understanding about boiling by dialogic teaching. The sample consisted of forty-three pre-service science teachers in their first year of teacher education. Dialog-based instructional activities were conducted in a chemistry laboratory course. Audio recordings of classroom discourse and written texts were used for data collection. Pre-service science teachers' conceptions about boiling identified before and after dialogic teaching were analyzed using content analysis. The findings showed that dialogic teaching efficiently supported pre-service science teachers' understanding about boiling.*

Keywords: *dialogic teaching, conceptual change, boiling topic, pre-service science teachers.*

Mehmet Demirbağ
Uludag University, Turkey
Sevgi Kingir
Hacettepe University, Turkey

Introduction

Conceptual Difficulties in Chemistry

One of the goals of education is to move students away from rote learning to meaningful learning. Meaningful learning requires making connections between newly introduced conceptions (naïve mental structures that represent natural phenomena and processes) and prior knowledge (diSessa & Sherin, 1998; Novak, 1993). It is highly difficult or even impossible to understand conceptions without establishing meaningful relationships between concepts because (a) meaning emerges from such relationships, (b) no concept exists in isolation, and (c) concepts are organized in the conceptual ecology that controls and modifies the conceptual change process (Strike & Posner, 1992).

To create semantically meaningful relationships among conceptions, each conception should first be built on a logical framework (Lemke, 1990). Failure to construct conceptions on a logical framework and to make links among relevant conceptions often result in conceptions that are not consistent with scientific ideas (Zoller, 1996), that is, misconceptions or alternative conceptions (Dykstra, Boyle, & Monorach, 1992; Nakhleh, 1992). One softer version of these conceptions is superficial understandings. In this version, there are (acceptable) limited explanations without thorough understanding (Calık, 2008). These difficulties influence observations and interpretations in class activities and hinder further learning.

Chemistry is one of the scientific branches where students have difficulties in understanding basic scientific mechanisms and relationships. The scholars consider that four common sources are responsible for these difficulties: the nature of chemistry, everyday language, teachers and textbooks. Regarding first, chemistry learning requires connection among macroscopic, microscopic and symbolic levels of representation (Johnstone, cited in Garnett, Garnett, & Hackling, 1995). Macroscopic level includes phenomena that are perceived by the senses, such as changes of color of a solution. Microscopic level refers to explanations on the basis of properties, shape, movement and interaction of particles such as atoms and molecules, which are real but not perceived by the senses. The symbolic level of representations includes formulae and equations. Students' failure to connect macroscopic

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

and symbolic levels with microscopic level of representation may result in alternative conceptions (Unal, Calik, Ayas, & Coll, 2006). Everyday language may also cause alternative conceptions. For example, there is a confusion in the use of 'energy' term which has a specific meaning in chemistry but different meanings in everyday life (e.g., Bond making requires input of energy and bond breaking releases energy) (Boo, 1998). Teachers are one another source of conceptual difficulties (Fisher, 1985). A teacher, for example, can explain his/her understanding of the water molecule by stating that water consists of hydrogen and oxygen. The student who does not have adequate prior knowledge may misinterpret water as a mixture of hydrogen and oxygen (Andersson, 1986). The final source is the textbooks used in the chemistry classes. De Posada (1999), for example, showed that nearly half of the text-books superficially defined the metallic bonding model and the relationships among the model. In addition, these models were metaphorical in nature and they were open to misinterpretations.

Conceptual Difficulties about Boiling

Boiling is a natural phenomenon that occurs in our daily life. It is included in many countries' science curricula as well as the general chemistry courses within pre-service science teacher education programs. It is important for science teachers to have a strong, accurate understanding of basic concepts about boiling because they provide a basis for understanding various chemistry topics including conservation of matter, particulate nature of matter, phase diagrams, and colligative properties of a solution such as boiling point elevation. In addition, to achieve a proper understanding about boiling, one needs to relate it to issues of heat and temperature, heat transfer, pressure, kinetic theory, and the particulate nature of matter. Perhaps because of these multiple relationships, existing literature revealed that boiling was one of the chemistry topics about which many students have conceptual difficulties (e.g., Canpolat, 2006; Canpolat, Pınarbaşı, & Sözbilir; 2006; Chang, 1999; Costu, 2008; Costu, Ayas, & Niaz, 2010; Coştu, Ayas, Niaz, Ünal, & Çalık, 2007; Çalık, 2008; Goodwin, 2003; Johnson, 1998; Kirbulut & Beeth, 2013; Osborne & Cosgrove, 1983; Ozmen, 2011; Paik, 2015; Papageorgiou, Johnson, & Fotiades, 2008; Papageorgiou, Stamovlasis, & Johnson, 2010; Schmidt, Kaufmann, & Treagust, 2009; Şenocak, 2009; Varelas, Pappas, & Rife, 2006). Some of the alternative conceptions identified in these previous studies are summarized in Table 1.

Table 1. Alternative conceptions identified in previous studies.

Boiling events occur only because of heat (Paik, 2015).
Vaporization occurs with boiling (Costu, et al., 2010).
Atmospheric pressure has no influence on boiling events (Costu et al., 2007).
Vaporization does not occur without boiling (Canpolat et al., 2006).
Vapor pressure increases and boiling occurs (Çalık, 2008).
Failure to recognize that the amount of vapor in a closed system diminishes with the effect of cooling and its pressure on the liquid thus decreases (Costu et al., 2007).
Various alternative conceptions about internal pressure, external pressure, and vapor pressure (Çalık, 2008).

Conceptual Change Activities in Chemistry and for Boiling Topic

Conceptual change includes learning pathways from students' pre- and post-instructional conceptions to the intended scientific conceptions (Kilinc et al., 2013) Chemistry educators have focused on changing students' alternative conceptions with scientifically accepted ones using various instructional methods and strategies including case study (Ayyıldız & Tarhan, 2013; Yalçınkaya & Boz, 2015), four-step constructivist instruction (Çalık, 2008), inquiry-based learning (Roehrig & Garrow, 2007), multimodal representations (Adadan, Irving, & Trundle, 2009), predict–observe–explain activities (Costu, Ayas, & Niaz, 2012), computer support learning (Papageorgiou et al., 2008), and analogy (Şendur, Toprak, & Pekmez, 2008). In the case of boiling, Çalık (2008), for example, used four-step, constructivism-based teaching to eliminate pre-service science teachers' alternative conceptions about the boiling point. Similarly, Costu et al. (2007) applied a conceptual change approach to address pre-service science teachers' alternative conceptions of boiling.

Dialogic Teaching and Conceptual Change in Science Education

Students' construction of science concepts cannot be considered as separate from linguistic processes (Lemke, 1990). Students are constantly in interaction with activities, books, gestures, conversations, and mathematical symbols while learning concepts (Airey & Linder, 2008). Language acts as a tool in meaning-making processes. Students use language to think about their own and peers' ideas and to talk about and discuss science concepts. In other words, students construct scientific knowledge using various forms of language. Hence, some researchers (e.g., Scott, Mortimer, & Aguiar, 2006) have offered suggestions about the use of language in the scientific knowledge-construction process. This use can take on the form of either a monolog or a dialog. In a monolog, the teacher is dominant and knowledge is transmitted from the teacher to students, resulting in rote memorization. In a dialogic environment, authority is shared between the teacher and students, and both teacher–student and student–student interactions result in the construction of meaning (Alexander, 2008; Reznitskaya, 2012).

The scholars consider that students' explanations about chemistry phenomena can be transformed into scientific explanations via small-group and whole-class discourse (e.g., Varelas et al., 2006). In such dialogic environments, students can benefit from argumentative virtues and structures (claims, justifications, rebuttals, etc.) in order to collaboratively build scientific meanings (Erduran & Jimenez-Aleixandre, 2008; Kilinc et al., in press). The trade-offs of justifications among the students and between the teacher and students have the potential to ease conceptual change because such interactions are a natural part of construction of meanings about everyday life (Tytler & Peterson, 2000).

Purpose and Research Questions

The aim of this research is to promote pre-service science teachers' understandings about boiling by dialogic teaching. The research aims to answer the following research questions:

1. What are the conceptual difficulties of pre-service science teachers about boiling?
2. Do dialogic interventions lead to conceptual change about boiling?

Methodology of Research

General Background

The research was conducted in the second semester of 2015-2016 academic term. Case study design was used in this research. 'Case study is used in many situations, to contribute our knowledge of individual, group, organizational, social, political, and related phenomena' (Yin, 2014, p. 4). In addition, a case can be an event or an entity; a community's decision and specific event can be included in a case study. However, boundaries should be definite in order to consider something as a case. In this sense, the whole class, in which dialogic intervention was conducted, was selected as the case. Another important point following the boundaries in case study is the identification of units of analysis within cases such as topics, programs, and specific events (Yin, 2014). To this end, the students' explanations in the class where dialogic intervention was conducted were selected as the unit of analysis. Because the context is unique and there is a single unit of analysis in this study, type of case study design is a holistic single case study (Yin, 2014).

Context, Teacher and Participants

The research was conducted in a Turkish context with pre-service science teachers (PSTs). Looking at Turkish context, those who want to become a science teacher need to apply to Faculties of Education at many universities and complete four-year education covering subject-matter courses (e.g., Physics), pedagogy courses (e.g., Educational Psychology) and subject-matter education courses (e.g., Science Teaching Methods). They complete a two-step national examination and Turkish Higher Education Council (THEC) (2010) appoint them into the universities according to their examination scores. In addition, even though there is no any structured centralized system for the content of university courses in Turkey, THEC (2010) has ascertained basic components of teacher education courses in order to match this education with state school programs. However, teacher educators are free to organize their own programs and course plans.

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

A teacher education course was first selected in which a dialogic intervention can be applied on boiling topic. The course 'The Laboratory of Fundamentals of Chemistry (LFC)' that was offered in the first year of all science teacher education programs and that covered the unit of pressure and boiling was selected. This course is offered in two classroom hours (1 classroom hour is 45 minutes) each week at one semester and used for helping PSTs to better understand fundamental mechanisms and conceptions presented in one another course 'The Fundamentals of Chemistry (FC)'.

The convenience sampling that is one of the types of purposeful sampling was used in the present study (Creswell, 2012). After designing the dialogic intervention by a structured course plan, the possible sample alternatives within the researchers' universities were considered. Even though both of the universities (Uludag and Hacettepe) possessed similar infra structures and syllabuses, it was decided to select the sample from Uludag University because first researcher was the teacher of the selected course and because he has taught same course for four years. In addition, both Uludag (8th) and Hacettepe (7th) were in top 10 selected universities for the candidates of teacher education.

Looking at the nature of science teacher education at Uludag University, consistent with constructivist approaches that were suggested by the THEC and adopted by the Turkish Ministry of Education, particularly science teacher educators organize their courses based on conceptual development of PSTs and dialogic interactions among them. At this point, first researcher is a research assistant who is about to complete his Ph D. His Ph D focuses on science teachers' belief systems regarding technology integration and he uses teachers' classroom discourse as the main data. In addition, first researcher participated in a nation-wide project focusing on the development of argumentation skills of teachers and students. He applied many dialogic interventions in the course of LFC before present study because he believed that dialogic interactions were crucial channels where conceptual problems could be determined and corrected. In addition, the course covered the topics such as 'Laboratory safety', 'Techniques in Chemistry Lab.', 'Separation of Homogeneous Mixtures', 'Crystallization', 'Determination of a solution's concentration', 'Heat relations', 'Melting Point', 'Boiling Point', 'Dissolution' 'Resolution', 'Acids and Bases'. The course was conducted in the Chemistry Laboratory, where there were eight experiment desks surrounded by eight chairs in each.

The participants included 43 first-year PSTs (35 males and 8 females, aged 18 to 21 years) attending the course of LFC organized by first researcher. The intervention was conducted in the topic 'Boiling Point' that was offered in the seventh and eighth weeks of the semester (covering 14 weeks). Before beginning the intervention, the nature of research and purpose was clearly explained and volunteer participation was emphasized. It was also stressed that unless any participant wanted to join the study, it was considered to group them in one another laboratory and continue routine teaching program with the help of one another research assistant. All of the participants attending the course signed ethical approval documents and were willing to join the study.

Regarding the relationships between first researcher and the participants through the semester, first researcher considered that he had good relations with PSTs. He tried to produce an interactive environment, where PSTs could ask their questions at any time they wanted and they could interact with the others. Consistent with the records of our intervention, first researcher also did not possess an authoritative identity and tried to ask open-ended questions that were not closely related to course content so the PSTs experienced cognitive conflicts and used their critical thinking abilities. First researcher was also supporter of constructivist teaching because he believed that these methodologies eased PSTs to connect their daily-life experiences with scientific mechanisms. In addition, first researcher argued that he tried to uncover PSTs' prior conceptions about any topic he taught and used these conceptions as starting points for his further dialogic interactions.

Procedures

This research was carried out during regular classroom hours over a 2-week period. The classroom instruction included two 45-min periods per week. A Prediction-Observation-Explanation activity, which has frequently been used in previous conceptual change studies focusing on boiling topic (Costu, Ayas, & Niaz, 2012), was designed using a dialogic teaching approach. Prior to the instruction, the instructor asked pre-service teachers to form their own small groups. There were seven groups and six or seven individuals per group. For the first laboratory class, the instructor chose a demonstration activity (Köseoğlu, Tümay, & Kavak, 2002) concerning the effect of pressure on the boiling point of a liquid. Consistent with conceptual change theory (Strike & Posner, 1992), the purpose of this open-ended activity was to elicit the PSTs' prior conceptions about boiling through prediction and observation. The teacher also used these prior conceptions for the starting points of the whole class discussion. A flask of water is heated until it boils (Figure 1a). After it reaches its boiling point, the flask is stoppered and removed from the heat source. The water vapor is trapped in the flask. When an ice pack is applied to the flask, the water boils (Figure 1b). The cooling effect decreases the frequency of collision of gaseous molecules in the water; therefore, the vapor pressure required to induce boiling is reduced and the water boils.

In the first two classroom hours, the aim was to elicit pre-service science teachers' alternative conceptions regarding boiling through prediction and observation phases of the demonstration activity. The procedure followed in these phases was explained below.

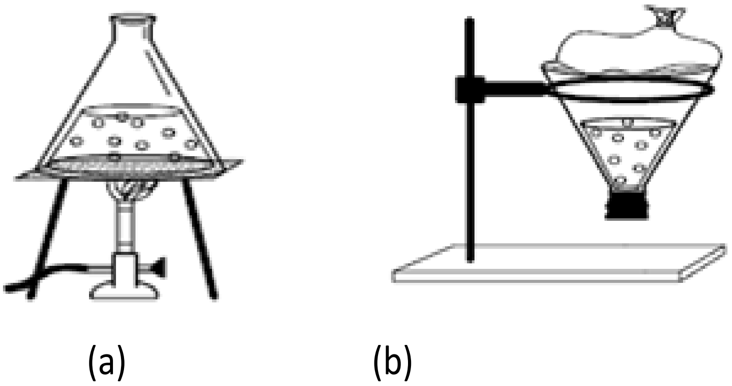

Figure 1: Demonstration activity: (a) heating, (b) cooling.

1. Prediction Phase

The lecturer informed the class about the basic details of demonstration activity. Next, he completed the first half of the demonstration (Figure 1a) described earlier. The lecturer then asked participants to predict what would happen if an ice pack was applied to the flask. Pre-service science teachers discussed the demonstration in their small groups and wrote out their predictions individually. This phase identified their existing conceptions (or alternative conceptions) about boiling.

2. Observation Phase

To test their predictions, each group performed entire demonstration activity with the help of the instructor, repeating the first half of the procedure and then applying an ice pack to the flask. The students observed the changes in the flask. They were surprised when the water inside the flask boiled again perhaps because most of them believed that boiling does not occur without heat. Boiling events are usually related to the heating of a substance. However, in this activity, the water inside the flask begins to boil without the aid of additional heat. They then discussed what they had observed in their small groups. The instructor circulated through the groups, monitored their discussions, and facilitated their thinking through questioning. At this stage, the instructor strived to make participants aware of their conceptions and uncover what they already knew about boiling. In addition, pre-service science teachers wrote their observations with explanations individually.

3. Explanation Phase

Upon the completion of observations, the instructor asked pre-service science teachers write their ideas on the board and he then summarized what had been observed in the classroom. At the end of the class session, the instructor listed and categorized the pre-service science teachers' alternative conceptions about boiling into four groups: pressure, heat and temperature, exothermic reaction, and formation and movement of bubbles. The instructor verified these categories with the participants and then sought to create dialogic learning environments that are specific to these conceptions during the next class hour.

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Based on Resnitskaya's (2012) dialogic inquiry model, the students shared major responsibilities for the process of discussions and the instructor shared his *authority* with them. He dialogically interacted with the students regarding their explanations and conceptual categories so that they can reach intended scientific explanations. In addition, the lecturer began with an *open-ended question*s to engage pre-service science teachers in talking about what they understood and avoided asking questions that could be answered only as "yes" or "no." After asking a high-level question (e.g., Why does the water boil when ice is rubbed on the flask?), for example, he gave participants time to deeply think. When it comes to *feedbacks,* he consistently played with the students' answers in order to inspire further explorations. He spontaneously assessed their claims and justifications and then continued asking challenging questions to refute the alternative conceptions expressed. The instructor used different "moving on" strategies such as restating, rephrasing, and redirecting questions for different purposes.

The lecturer used many argumentative structures such as claims, evidence, justifications and rebuttals and turned them to question forms (what do you think?, how do you support what you have said? Do you have any evidence? Is there anyone considering a limitation in this evidence?, etc.) so the students build strong *explanations and arguments*. In addition, for *connecting students' ideas* and *construction of ideas*, the instructor redirected pre-service science teachers' answers back to the class, asking "Is there any different idea?" or "Do you agree with your classmate"? When the students failed to answer a high-level question or could not agree each other after a period of discussion, the instructor did not reveal the answer but instead offered hints to push the dialogic learning process forward until a consensus was attained. Upon the completion of the dialogic intervention, participants were asked to write down their final explanations.

Data Collection

The data consisted of both written texts and audio recordings. Pre-service science teachers' written texts were obtained from their prediction, observation and explanation phases of the demonstration activity. These texts were used for determination of conceptual difficulties and for pursuing the possible changes after the interventions. In addition, audio recordings of the dialogic interventions were used to better understand the influence of dialogic interventions.

Data Analysis

The pre-service science teachers' written texts were interpreted by content analysis using grounded theory procedures (Patton, 2002). Open, axial and selective codes were used in this analysis (Patton, 2002). The conceptual difficulties that were uncovered were grouped into two categories: superficial understanding (SU) and alternative conception (AC) (Calik, 2008; Zoller, 1996). In addition, we uncovered intended scientific understandings (ISU) in the texts (Ozbas & Kilinc, 2015). Coding categories were both drawn from the related literature deductively (e.g., Asterhan & Schwartz, 2009a; Calık, 2008) and inductively developed by the authors. In addition, because the language is crucial in dialogic interventions and conceptual analyses, we first analyzed PTs' dialogic exchanges and conceptions in Turkish and we then translated our main findings to English. It was also benefited from the suggestions of a bilingual science educator in terms of translation issues.

Trustworthiness

To ensure the trustworthiness of the present research, triangulation and interrater reliability were used (Lincoln & Guba, 1985).

1. Triangulation

Categories were formed using pre-service science teachers' written texts and transcripts of audio recordings. Data from the written texts were mainly used to identify categories while audio recordings were used to confirm the categories. For instance, four categories were identified based on written texts. Using the audio recordings, a review was conducted to reveal whether there was an opinion that was mentioned during the process but was not written. Categorizations were finalized after they were confirmed by the audio recordings.

2. Interrater reliability

Pre-service science teachers' predictions, observations, and explanations were evaluated by two independent researchers in the form of raw data. The researchers assigned independent categories in relation to predictions, observations, and explanations. The overall agreement attained by the researchers was over 90% after coding. The researchers iteratively discussed discrepancies in these categories until they reached consensus.

Results of Research

Conceptual Difficulties about Boiling

Pre-service science teachers' conceptual difficulties about boiling were determined in the phases of prediction and observation. Table 2 shows that participants possessed a range of ACs and SUs about pressure, heat and temperature, exothermic reactions, or the formation and movement of bubbles. In addition, there was not any expected ISU at these stages.

Table 2. Conceptual difficulties about boiling.

Category	Pre-service Teacher
Alternative Conceptions (AC)	
Related to pressure	
• Amount of water vapor increases and water boils	p6, p31
• When the heat increases, the volume of the water increases and pressure decreases	p19, p21, p22, p23
• The water boils when the external pressure increases with the cooling effect	p2, p3, p4, p6, p17, p18, p29, p30
Related to heat and temperature	
• The water boils because of vaporization	p27, p28, p37
• When the vaporized air encounters cold water, it condenses, turns back to water and the water boils	p12, p13
• Boiling does not occur because heat is required for boiling	p14, p15
• Boiling does not occur; the condensed water particles turn back to the surface of the water as it rains	p1, p5, p7, p11
Related to exothermic reaction	
• As water vapor condenses, exothermic reaction takes place and water boils because of the released heat	p36, p38
Related to formation and movement of bubbles	
• In fact, boiling does not occur. Gas molecules condense with cold water and water bubbles in the flask move upward because of an empty space above the liquid	p33, p35
Superficial Understanding(SU) Related to pressure	
• Water boils when internal and external pressures are equal.	p8, p16, p24, p26, p32
• The water boils when the water vapor pressure gets equal to external pressure.	p39, p40, p41, p42, p43

Note: Four participants (p9, p10, p20, p34) did not write anything.

The Impacts of Dialogic Interventions on Conceptual Difficulties

Table 3 displays that most of the conceptual difficulties were treated by dialogic interventions conducted by the instructor. In other words, most of the participants experienced conceptual change from ACs and SUs through ISUs. The percentage for ACs, for example, decreased from 66 % to 7 %. Similarly the percentage for SUs decreased from 24 % to 3 %.

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Table 3. The descriptive changes in PSTs' conceptions before and after dialogic intervention.

Categories	Before Dialogic Intervention		After Dialogic Intervention	
	N	%	N	%
AC	28	66	3	7
SU	10	24	1	3
ISU	-	-	38	90
NA	4	10	-	-
TP	42	100	42	100

** AC: Alternative Conception, SU: Superficial Understanding, ISU: Intended Scientific Understanding, NA: No Answer, TP: Total Population*

As shown in Table 4, even though this type of dialogic interventions was successful in correcting most of the conceptual difficulties, there were several ACs that could not easily be fixed.

Table 4. The changes about conceptual difficulties after dialogic intervention.

Conceptions Before Dialogic Int.	Conceptions After Dialogic Int.
Related to Pressure	
AC. Amount of water vapor pressure increases and water boils (p6, p31) **AC.** When the heat increases, the volume of the water increases and pressure decreases (p19, p21, p22, p23) **AC.** The water boils when the external pressure increases with the cooling effect (p2, p3, p4, p17, p18, p29, p30)	**AC.** I think that boiling point is related to heat and pressure. The pressure is inversely proportional to the temperature. When the internal and external pressures are equal and the temperature is reduced, a boiling event occurs (P6). **ISU.** I thought that boiling was related only to pressure. But, boiling is also related to temperature. When the glass flask was exposed to the cold water, the pressure of water vapor decreased and the water boiled (P31). **SU.** A difference in pressure (water vapor) takes place by heating water, and (we see that water is condensed by reducing the pressure under cold water). We only have confusion about what the pressure is. I confirmed the theoretical part of the experiment (P9). **ISU.** When the glass flask was exposed to the cold water, heat transfer took place. Boiling occurs at the lower temperature because the number of moving particles in the glass flask is reduced. That is, the number of particles impacting the glass flask is reduced). Thus, the pressure decreases and boiling takes place (P2, p3, p30 P4, p18). **ISU.** I thought that boiling was related only to pressure. But, boiling is also related to temperature. when the glass flask was exposed to the cold water, the pressure of water vapor decreased and the water boiled (P17,p29, p19, p20, p21, p22, p23)
Related to heat and temperature	
AC. The water boils because of vaporization (p27, p28, p37) **AC.** When the vaporized air encounters cold water, it condenses, turns back to water and the water boils (p12, p13) **AC.** Boiling does not occur because heat is required for boiling (p14, p15) **AC.** Boiling does not occur; the condensed, water particles turn back to the surface of the water as it rains (p1, p5, p7, p11)	**ISU.** When the glass flask was exposed to the cold water, heat transfer took place. Boiling occurs at the lower temperature because the number of moving particles in the glass flask is reduced. That is, the number of particles impacting the glass flask is reduced. Thus, the pressure decreases, boiling takes place (p27, p15, p1). **ISU.** Pressure effects boiling as well as temperature. As pressure decreases boiling point decreases.(p11, p12, p13, p14,p28,p37) **AC.** I think that boiling point is related to heat and pressure. The pressure is inversely proportional to the temperature). When the internal and external pressures are equal and the temperature is reduced, a boiling event occurs (P5, p7).

Related to exothermic reaction	
AC. As water vapor condenses, exothermic reaction takes place and water boils because of the released heat (p36, p38)	**ISU.** When the glass flask was exposed to the cold water, heat transfer took place. Boiling occurs at the lower temperature because the number of moving particles in the glass flask is reduced. That is, the number of particles impacting the glass flask is reduced). Thus, the pressure decreases and boiling takes place (P36, p25). **ISU.** My argument is refuted. Because water vapor is trapped inside the glass flask when we put a stopper on the end of it. Cooling effect causes water vapor to condense. However, heat released from condensation cannot boil water inside the glass flask because heat can be transferred both into and outside of the glass flask.
Related to formation and movement of bubbles	
AC. In fact, boiling does not occur. Gas molecules condense with cold water and water bubbles in the flask move upward because of an empty space above the liquid (p33, p35)	**ISU**. I recognized that temperature is not sole effect on boiling. When we put a stopper on the end of the glass flask, water vapor pressure occurs inside the flask. When we applied an ice pack to the flask, both temperature and pressure decreased. Water boiled again due to decrease in pressure. In conclusion, water can boil at a lower temperature at lower pressures.
Related to pressure	
SU. Water boils when internal and external pressures are equal (p8, p16, p24, p26, p32) **SU.** Water boils so that the water vapor pressure increases with external pressure (p39, p40, p41, p42, p43)	**ISU.** When the glass flask was exposed to the cold water, heat transfer took place. Boiling occurs at the lower temperature because the number of moving particles in the glass flask is reduced. That is, the number of particles impacting the glass flask is reduced). Thus, the pressure decreases and boiling takes place (p8, p24, p32, p26, p34, p16, p39, p40, p41, p42, p43).

Note: One participant p10 did not write anything.

Because all dialogic interventions that the instructor conducted had a similar nature, an example excerpt was presented in Figure 2 displaying conceptual change for an AC after dialogic intervention. The nature of the impact of dialogic intervention on conceptual change was discussed in the next section.

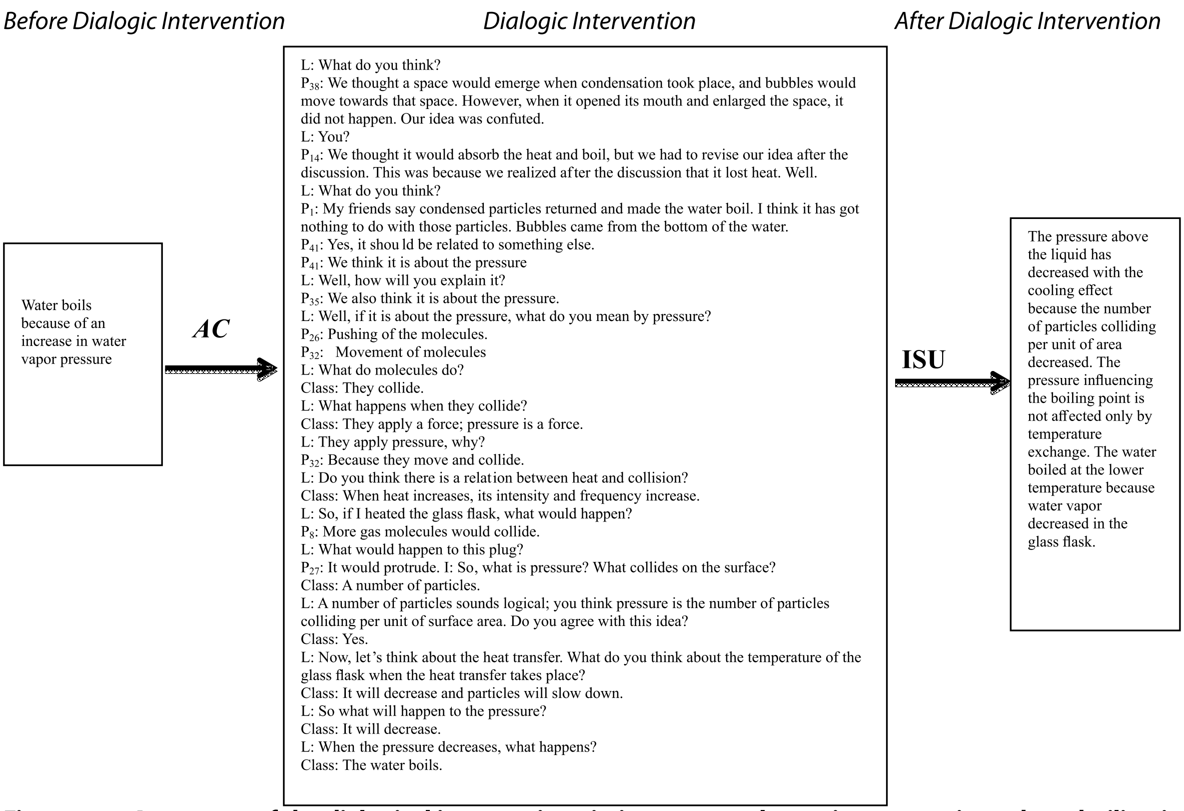

Figure 2: An excerpt of the dialogical intervention aiming to treat alternative conceptions about boiling in relation to pressure.

L = lecturer, P = pre-service teacher, Class: A great majority of the participants reached a consensus.

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Discussion

Conceptual Difficulties about Boiling

Consistent with existent literature (Costu, 2008; Çalık, 2008; Paik, 2015), the present study showed that pre-service science teachers possessed a range of ACs and SUs about boiling. Looking at ACs that are particularly related to macro level (i.e., sensual changes) (Unal, Calik, Ayas, & Coll, 2006), we can argue that most of the participants could easily envisage joint existence of water vapor, heat and boiling and condensing vaporized air when it encounters cold water. Perhaps some hands-on experience at home, school and the nature fosters this conceptual ecology. However, these seemingly correct networks seem to be main sources of certain ACs such as 'amount of water vapor increases and water boils', 'the water boils because of vaporization', 'boiling does not occur because heat is required for boiling', 'boiling does not occur; the condensed water particles turn back to the surface of the water as it rains' and 'boiling does not occur. Gas molecules condense with cold water and water bubbles in the flask move upward because of an empty space above the liquid'. In addition, some participants combined these macro-level images with certain correct reasoning that were learned in classroom environments. The ACs 'As water vapor condenses, exothermic reaction takes place and water boils because of released heat' exemplified this type of combination. Even though they correctly know that exothermic reaction resulted in heat, they benefitted from this reasoning in incorrect place. In addition, we believe that symbolic level interpretations (Unal, Calik, Ayas, & Coll, 2006) may be responsible for certain incorrect conceptual relationships. Ideal gas equation (P.V = n.R.T.) seems to be incorrectly used by some participants. The AC 'when the heat increases, the volume of the water increases and pressure decreases', for example, showed that some participants confused the causation between the components in both sides of the equation.

Some participants had SUs about boiling point and pressure. They stated such ideas as "water boils when internal and external pressures are equal" and "the water boils when the water vapor pressure gets equal to external pressure". These participants did not explain what they meant by internal and external pressure or the relationship between pressure and boiling point. Although they were approaching to the desired answer, they still could not completely grasp the concept (Canpolat & Pınarbaşı, 2012). This finding may imply that these students might mechanically memorize these statements or try to use them as they were included in textbooks (De Posada, 1999) and that they could not transit these conceptual networks to specific cases.

The Impacts of Dialogic Interventions on Conceptual Difficulties

Present study showed that most of the conceptual difficulties were treated by dialogic interventions. This result is consistent with many previous findings (e.g., Asterhan & Schwarz, 2009a, 2009b; Cardetti & Orgnero, 2013; Calık, 2008; Dillon, 2008). For moving this body of knowledge one step further, we took a closer look at the impacts of dialogic interventions on the conceptual difficulties. Figure 2 displays that the pre-service science teachers had an AC (water boils because of an increase in water vapor pressure) due to a wrongly structured justification. When the teacher asked the pre-service science teachers to elicit their justifications, he noticed that some were not aware of the relationships between pressure and boiling point. Therefore, he waited for having a pressure-related answer. He then asked further questions to get a clear description about pressure because he was willing to use it as first justification component (A force exerted on a surface per unit area). After that, he was willing to connect this component molecules' behaviors and asked further questions to get second justification component (Molecules collide once pressure increases). He then hunted for the third component which was the relationship between collision and heat by new questions. After that, he turned back the case (What happens once we heat the flask?) so that pre-service teachers could build a conclusion based on previous three components. He was also willing to use this (fourth) component for the following step. Once pre-service teachers correctly answered the question about the relationship between heat and molecule movements in the flask, he asked them to conclude (or produce an ISU) what happened once heat was transferred between cold water and flask, using previous four components. Looking at ISU emerged from same pre-service science teacher's written text after dialogic teaching, it was clearly seen that the participants used the justification components that were emerged during classroom discussion.

Table 4 shows that dialogic interventions were successful in fixing most of the conceptual difficulties; however, several ACs were resistant to change. Looking at these ACs (Amount of water vapor increases and water boils; Boiling does not occur, the condensed water particles turn back to the surface of the water as it rains) and follow up AC (I think that boiling point is related to heat and pressure. The pressure is inversely proportional to the temperature…) after dialogic intervention (please see Figure 2), we can argue that these pre-service teachers were struggled to understand the relationship between heat and pressure. When we listened to the dialogic interventions after getting this result, we noticed that these sections (or justification component building moments) included limited trade-offs between students and were realized at the end of the course. Perhaps certain pre-service science teachers could not have an opportunity to express these conceptual understandings because the instructor interacted with the whole class at the end.

Conclusions and Implications

The present research showed that dialogic interventions promoted pre-service science teachers' conceptual understandings about boiling point. There are two important implications that present study could suggest. First, dialogic teaching interventions can be a part of science educators' (academics and science teachers) routine teaching because they can ease the conceptual change procedures even in highly misunderstood topics such as boiling. The nature of dialog and dialogic inquiry is crucial at this point. When the teacher is aware of argument structures (justification components and conclusions/claims) and associates these structures with the subject matter, he/she has huge potential to get positive results. Therefore, we suggest program developers and teacher educators to incorporate dialogic teaching procedures into their teacher education programs so that future teachers may have the chance to correct conceptual difficulties of students. Dialogic inquiry components (authority, questions, feedback, connection among students' answers, explanation and collaboration), argument structures (claim, justification, evidence, etc.), speaking moves and discussion culture can be a part of such programs. Second, the dialogic interventions need to be efficiently planned, considering each section of the classroom course. Even though they seem to be successful, the teachers need to be persistent on speaking moves through the whole classroom session.

Limitations and Future Research

Present research included two limitations. First, it is related to generalization of our interpretations based on present findings. Even though the main goal was to contribute to theoretical components (Yin, 2014) regarding the impacts of dialogic intervention on conceptual change process, further studies covering bigger samples with quantitative methodologies may enhance the body of knowledge produced here. Second, the conceptual difficulties before and after the dialogic intervention were compared and it was found a considerable development. The impact of dialogic exchanges on conceptual development was also investigated via a micro-analytic approach. Such research particularly focusing on the conceptual development during dialogic interactions can be repeated in order to enhance the reliability of our interpretations.

References

Adadan, E., Irving, K. E., & Trundle, K. C. (2009). Impacts of multi-representational instruction on high school students' conceptual understandings of the particulate nature of matter. *International Journal of Science Education*, *31* (13), 1743-1775.

Airey, J., & Linder, C. (2009). A disciplinary discourse perspective on university science learning: Achieving fluency in a critical constellation of modes. *Journal of Research in Science Teaching*, *46* (1), 27-49.

Alexander, R. (2008). *Essays on pedagogy.* New York, NY: Routledge.

Andersson, B. (1986). Pupils' explanations of some aspects of chemical reactions. *Science Education, 70* (5), 549-563.

Asterhan, C. S. C., & Schwarz, B. B. (2009a). Argumentation and explanation in conceptual change: Indications from protocol analyses of peer-to-peer dialog. *Cognitive Science*, *33* (3), 374-400.

Asterhan, C. S. C., & Schwarz, B. B. (2009b). Transformation of robust misconceptions through peer argumentation. In B. B. Schwarz, T. Dreyfuss, & R. Hershkowitz (Eds.), *Guided transformation of knowledge in classroom* (pp. 159-172). New York, NY: Routledge.

Ayyıldız, Y., & Tarhan, L. (2013). Case study applications in chemistry lesson: Gases, liquids, and solids. *Chemistry Education Research and Practice*, *14* (4), 408-420.

Boo, H. K. (1998). Students' understandings of chemical bonds and the energetics of chemical reactions. *Journal of Research in Science Teaching*, *35* (5), 569-581.

Calık, M. (2008). Facilitating students' conceptual understanding of boiling using a four-step constructivist teaching method. *Research in Science & Technological Education*, *26* (1), 59-74.

Canpolat, N. (2006). Turkish undergraduates' misconceptions of evaporation, evaporation rate, and vapour pressure. *International Journal of Science Education, 28* (15), 1757-1770.

Canpolat, N., & Pınarbaşı, T. (2012). Kimya öğretmen adaylarının kaynama olayı ile ilgili anlayışları: Bir olgubilim çalışması [Chem-

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

istry teacher candidates boiling event related conceptions: A Phenomenological Study study]. *Erzincan Üniversitesi Eğitim Fakültesi Dergisi, 14* (1), 81-96.

Canpolat, N., Pinarbasi, T., & Sozbilir, M. (2006). Prospective teachers' misconceptions of vaporization and vapor pressure, *Journal of Chemical. Education, 83* (8), 1237-1242.

Cardetti, F. A., & Orgnero, M. C. (2013). Improving teaching practice through interdisciplinary dialog. *Studying Teacher Education*, *9* (3), 251-266.

Chang, J. Y. (1999). Teachers college students' conceptions about evaporation, condensation, and boiling. *Science Education*, *83* (5), 511-526.

Coştu, B. (2008). Learning science through the PDEODE teaching strategy: Helping students make sense of everyday situations. *Eurasia Journal of Mathematics, Science & Technology Education*, *4* (1), 3-9.

Coştu, B., Ayas, A., & Niaz, M. (2010). Promoting conceptual change in first year students' understanding of evaporation. *Chemistry Education Research and Practice*, *11* (1), 5-16.

Coştu, B., Ayas, A., & Niaz, M. (2012). Investigating the effectiveness of a POE-based teaching activity on students' understanding of condensation. *Instructional Science*, *40* (1), 47-67.

Coştu, B., Ayas, A., Niaz, M., Ünal, S., & Calik, M. (2007). Facilitating conceptual change in students' understanding of boiling concept. *Journal of Science Education and Technology*, *16* (6), 524-536.

Creswell, J. W. (2012). Qualitative inquiry and research design: Choosing among five approaches (3rd Ed.). London: Sage Publications.

De Posada, J. M. (1999). The presentation of metallic bonding in high school science textbooks during three decades: science educational reforms and substantive changes of tendencies. *Science Education, 83*, 423-447.

Dillon, J. (2008). Discussion, debate and dialog: Changing minds about conceptual change research in science education. *Cultural Studies of Science Education*, *3* (2), 397-416.

diSessa, A. A., & Sherin, B. L. (1998). What changes in conceptual change. *International Journal of Science Education*, *20* (10), 1155–1191.

Dykstra, D. I., Boyle, C. F., & Monarch, I. A. (1992). Studying conceptual change in learning physics. *Science Education, 76* (6), 615-652.

Erduran, S., & Jiménez-Aleixandre, M. P. (2008). Argumentation in science education. *Perspectives from classroom-Based Research*. Dordrecht: Springer.

Fisher, K. M. (1985). A misconception in biology: amino acids and translation. *Journal of Research in Science Teaching, 22* (1), 53-62.

Garnett, P. J., Garnett, P. J., & Hackling, M. W. (1995). Students' alternative conceptions in chemistry: A review of research and implications for teaching and learning. *Studies in Science Education, 25*, 69–95.

Goodwin, A. (2003). Evaporation and boiling-trainee science teachers' understanding. *School Science Review*, *84*, 131-141.

Johnson, P. (1998). Children's understanding of changes of state involving the gas state, Part 2: Evaporation and condensation below boiling point. *International Journal of Science Education*, *20* (6), 695-709.

Kilinc, A., Demiral, U., & Kartal, T. (2017). Resistance to dialogic discourse in SSI teaching: The effects of an argumentation-based workshop, teaching practicum, and induction on a pre-service science teacher. *Journal of Research in Science Teaching*, *54* (6), 764-789.

Kilinc, A., Yeşiltaş, N. K., Kartal, T., Demiral, Ü., & Eroğlu, B. (2013). School students' conceptions about biodiversity loss: Definitions, Reasons, Results and Solutions. *Research in Science Education*, *43* (6), 2277-2307.

Kirbulut, Z. D., & Beeth, M. E. (2013). Consistency of students' ideas across evaporation, condensation, and boiling. *Research in Science Education*, *43* (1), 209-232.

Köseoğlu, F., Tümay, H., & Kavak, N. (2002, September). Yapılandırıcı öğrenme teorisine dayanan etkili bir öğretim yöntemi –tahmin et, gözle, açıkla- buz ile su kaynatılabilir mi? [An instructional method based on constructivism- predict, observe, explain- can you boil water with ice?] V. Fen Bilimleri ve Matematik Eğitimi Kongresi, Ankara, Turkey.

Lemke, J. L. (1990). *Talking science*: *Language, learning and values,* Norwood, MA: Ablex.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Beverly Hills, CA: SAGE.

Nakhleh, M. B. (1992). Why some students don't learn chemistry. *Journal of Chemical Education, 69* (3), 191-196.

Novak, J. D. (1993). How do we learn our lesson? *Science Teacher*, *60* (3), 50-55.

Osborne, R. J., & Cosgrove, M. M. (1983). Children's conceptions of the changes of state of water. *Journal of Research in Science Teaching*, *20* (9), 825-838.

Ozbas, S., & Kilinc, A. (2015). School students' conceptual patterns about weight gain: A preliminary study for biology teaching focusing on obesity. *Journal of Biological Education*, *49* (4), 339-353.

Ozmen, H. (2011). Turkish primary students' conceptions about the particulate nature of matter. *International Journal of Environmental and Science Education*, *6* (1), 99-121.

Paik, S. H. (2015). Exploring the role of a discrepant event in changing the conceptions of evaporation and boiling in elementary school students. *Chemistry Education Research and Practice*, *16* (3), 670-679.

Papageorgiou, G., Johnson, P., & Fotiades, F. (2008). Explaining melting and evaporation below boiling point. Can software help with particle ideas? *Research in Science & Technological Education*, *26* (2), 165-183.

Papageorgiou, G., Stamovlasis, D., & Johnson, P. M. (2010). Primary teachers' particle ideas and explanations of physical phenomena: Effect of an in-service training course. *International Journal of Science Education*, *32* (5), 629-652.

Patton, M. Q. (2002). *Qualitative research and evaluation methods (3rd Ed.)*. Thousand Oaks, CA: Sage.

Reznitskaya, A. (2012). Dialogic teaching: Rethinking language use during literature discussions. *The Reading Teacher*, *65* (7), 446-456.

Roehrig, G., & Garrow, S. (2007). The impact of teacher classroom practices on student achievement during the implementation of a reform-based chemistry curriculum. *International Journal of Science Education*, *29* (14), 1789-1811.

Schmidt, H. J., Kaufmann, B., & Treagust, D. F. (2009). Students' understanding of boiling points and intermolecular forces. *Chemistry Education Research and Practice*, *10* (4), 265-272.

Scott, P. H., Mortimer, E. F., & Aguiar, O. G. (2006). The tension between authoritative and dialogic discourse: A fundamental characteristic of meaning making interactions in high school science lessons. *Science Education*, *90* (4), 605-631.

Strike, K.A., & Posner, G.J. (1992). A revisionist theory of conceptual change. In R. Duschl & R. Hamilton (Eds.), *Philosophy of science, cognitive psychology, and educational theory and practice* (pp. 147-176). Albany, NY: SUNY Press.

Şendur, G., Toprak, M., & Pekmez, Ş. E. (2008). Buharlaşma ve kaynama konularındaki kavram yanılgılarının önlenmesinde analoji yönteminin etkisi [The effects of using analogies to prevent misconceptions about evaporation and boiling]. *Ege Eğitim Fakültesi Dergisi, 9* (2), 37-58.

Şenocak, E. (2009). Prospective primary school teachers' perceptions on boiling and freezing. *Australian Journal of Teacher Education*, *34* (4), 27-38.

Turkish Higher Education Council (THEC). (2010). *The higher education system in Turkey. Report paper*. Ankara.

Tytler, R., & Peterson, S. (2000). Deconstructing learning in science—Young children's responses to a classroom sequence on evaporation. *Research in Science Education*, *30* (4), 339-355.

Ünal, S., Çalık, M., Ayas, A., & Coll, R. K. (2006). A review of chemical bonding studies: needs, aims, methods of exploring students' conceptions, general knowledge claims and students' alternative conceptions. *Research in Science & Technological Education, 24* (2), 141-172.

Varelas, M., Pappas, C. C., & Rife, A. (2006). Exploring the role of intertextuality in concept construction: Urban second graders make sense of evaporation, boiling, and condensation. *Journal of Research in Science Teaching*, *43* (7), 637-666.

Yalçınkaya, E., & Boz, Y. (2015). The effect of case-based instruction on 10th grade students' understanding of gas concepts. *Chemistry Education Research and Practice*, *16* (1), 104-120.

Yin, R. K. (2014). *Case study research: Design and methods* (5th Ed.). London, UK: SAGE.

Zoller, U. (1996). The use of examinations for revealing and distinguishing between students' misconceptions, misunderstandings and "no conceptions" in college chemistry. *Research in Science Education*, *26* (3), 317-326.

Received: *April 20, 2017*

Accepted: *July 02, 2017*

Mehmet Demirbağ	Uludag University, Faculty of Education, Department of Science Education, Bursa, Turkey E-mail: mtdemirbag@uludag.edu.tr
Sevgi Kıngır	Hacettepe University, Faculty of Education, Department of Elementary Education, Ankara, Turkey. E-mail: ksevgi@hacettepe.edu.tr