Research Article

CHANGE! PHYSICAL OR CHEMICAL? PHENOMENOLOGICAL ANALYSIS OF SECONDARY SCHOOL 7TH GRADE STUDENTS' STRUCTURE OF KNOWLEDGE RELATED TO THE CONCEPTS OF PHYSICAL AND CHEMICAL CHANGE

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ABSTRACT

The purpose of this study is to determine knowledge structure, justification skills and misconceptions of participating students related to the concepts of physical and chemical change. Being a qualitative study, phenomenological approach was used. The study was conducted in 2015, in a middle-scale province located at Black Sea Region. Participants consisted of a total of 21 (11 males, 10 females) 7th grade students from different schools. Data was collected using semi-structured interview technique accompanied by experimental activity samples prepared by the researchers. Obtained raw data was decoded by the researchers. Following the transcription, data analysis stage was initiated and the data was analyzed according to descriptive data analysis. The frequency of the data under pre-established concepts were given. The focus of the data analysis process was the consistency of the answers given throughout the question set. After determining the consistency type of the answers, justification skill was assessed. According to the findings of the research, participants exhibited both consistent and inconsistent cognitive structures. It was found that the justification of the participants varied according to questions, and they had misconceptions related to physical and chemical change.

Keywords: Secondary school students, physical and chemical change, knowledge structure, justification and misconception.

INTRODUCTION

The curriculum of elementary education science course was implemented in 2005, renewed in 2013 and modified in 2017. The new science course curriculum was based on constructivist learning theory that can be placed under cognitive learning theory, rather than behavioral learning theory (Ministry of Education, 2005; 2013). Regarding science course, the relationship between science course curriculum and constructivist learning theory assigns a particular importance to concept learning. Thus, it is a necessity to consider that science curriculum has a content consisted of authentic concepts. Regarding the significance of concept learning, there are many alternative conceptualizations in the literature that students can use, related to basic concepts of different science disciplines (Thompson and Logue, 2006). It should be noted that the review of constructivist learning theory from this aspect revealed that it offers a recipe towards eliminating existing alternative conceptualizations that students have. So that students learn the concepts that constitutes the content of sciences in a way fitting their scientific meanings. In the light of pointed conceptual explanations, this study is based on theory-like knowledge structure theory (synthetic meaning theory), which is directly associated with constructivist learning theory, and knowledge-in-pieces theory, (diSessa, 2002).

Conceptual Framework

The conceptual framework of this study consists of two dimensions. The first dimension includes theory-like knowledge structure theory and knowledge-in-pieces theory (diSessa,1993; diSessa, 2014; diSessa, 2017; Vosniadou, 1994). The second dimension is formed by the justification based on experimental knowledge and imparted knowledge (Halloun, 2006). Theory-like knowledge structure theory, assumes that the knowledge structured by the students has a certain consistency as the theory established by the scientists. In this regard, the concepts of naïve knowledge are in the form of individual, independent schemes isolated from each other (Ioannides & Vosniadou, 2002; Vosniadou, Ioannides, Dimitrakopoulou & Papademetriou, 2001; Vosniadou, Baltas & Vamvakoussi, 2007). According to this theory, the first stage conceptualization takes place through out of education experiences of the students. The second stage consists of the learning process of formal education system, where the knowledge structures or conceptualizations in the form of preliminary concepts that the student brought to formal education system interact with the new facts or related scientific conceptualizations and synthetic concepts are formed. Synthetic concepts are non-scientific knowledge structures and they have a conceptual framework consistent for specific periods (early childhood, primary school, secondary school, etc.....). In the following cognitive stages (abstract operations and the abstract processes of post-cognitive stages), these synthetic concepts are usually transformed into the concepts that are mostly scientific and new to the students. Based on these statements, the most striking argument of theory-like knowledge structure theory is; preliminary concepts and synthetic concepts also show consistency for a certain period as scientific concepts (for the students learning process and cognitive stages; for the scientists a stable paradigmatic period).

Knowledge-in-pieces theory presented by diSessa (1993) is considerably different that Vosniadou's (1994) theory-like knowledge structure theory. According to diSessa (1993), students' naïve cognitive structure about a science concept is not consistent. In this regard, in the process of inquiry conducted to determine how learning towards any science concept takes place, various small, simple, numerous, interconnected knowledge structures that create a feeling of naturalness interact with each other, letting students to fall into a cognitive instability. According to diSessa's (1993; 2002) knowledge-in-pieces theory, this fact is the justification for the claim that students' naïve cognitive structure is inconsistent.

The concept of justification, which constitutes the second dimension of this study, may be evaluated under two titles as justifications based on experimental knowledge and imparted knowledge. The concept of justifications based on experimental knowledge refers to the events where individuals base their knowledge and justification on direct or indirect facts (physical reality). Accordingly, a new knowledge depends on: individual's existing knowledge, the physical reality with which he/she interacts, sensory and cognitive conditions, the qualifications of the device and tools used. On the other hand, the concept of justifications based on imparted knowledge describes the knowledge that the student obtained from other individuals and printed materials (Halloun, 2006).

There are many national and international works addressing physical and chemical change, which constitutes the subject of this study (Ayvacı and Çoruhlu, 2009; Çayan and Karslı, 2014; Gabel, 1999; Geban and Bayır, 2000; Kariper, 2014; Palmer and Treagust, 1996; Yaşar, Karadaş and Kırkbaşlar, 2013). Some studies in the literature have used qualitative and quantitative research models together and misconceptions have been listed at descriptive level. Whereas some other studies have addressed the efficiency of different teaching techniques in eliminating these misconceptions (Çalık and Ayas, 2005; Harman, 2012; Hesse and Anderson, 1992; Kıngır and Geban, 2014; Sökmen, Bayram and Yılmaz, 2000; Yağbasan and Gülçiçek, 2003; Yıldırım, Nas, Şenel and Ayas, 2007). The main subjects of the studies were misconceptions of the students, who are at different cognitive levels, about concepts and how to teach them. In this regard, Okumuş, Öztürk, Çavdar, Karadeniz and Doymuş (2016) revealed that the majority of the teacher candidates, who were studying in Science Teaching program, could not model their thought about the states of matter by drawing, they have various misconceptions and some of them thought that the structure of the particle changes during the change of state. Ayvacı and Çoruhlu (2009) concluded that descriptive stories are effective on eliminating misconception about physical and chemical changes. Çayan and Karslı (2014) reported that problem-based learning approach eliminates students' misconceptions and leads to positive conceptual changes. In another study conducted with high school students, it was found that students possessed alternative concepts about the concepts of physical and chemical changes (Demircioğlu, Demircioğlu, Ayas and Kongur, 2012). In a similar study, Hesse and Anderson (1992) found that high school students' cognitive challenges related to chemical change were at different epistemological levels. The mentioned study revealed that students failed to use the concepts of atom and molecule to explain chemical change and they referred to superficial analogies instead of chemical theories. Harman (2012) documented that science teacher candidates have mostly defined physical change as the change occurred at the external structure of the matter, and chemical change as the change occurred at the internal structure of the matter. Sağır, Tekin and Karamustafaoğlu (2012) showed that teacher candidates had a problem in understanding physical and chemical change, reaction types and decomposition topics. In another study, Çalık and Ayas (2005) have found that students at secondary school and teacher candidates have similar misconceptions related to chemical change.

The topic of this study consists of cognitive consistency and justification ability of participating students. Accordingly, the data and outcomes obtained from this study are believed to be important in terms of making a new contribution for the causes of the facts pointed above and summarized in the literature, as well as suggesting solutions.

Purpose of the Study

The purpose of the study is to determine 7th grade students' knowledge structure about physical and chemical change concepts, their justification skills and accordingly their misconceptions.

METHOD

Being a qualitative study, a phenomenological approach was adopted in this work. The reason of preferring this approach is phenomenological approach allows in-depth analysis of participants' cognitive structure. According to Yıldırım and Şimşek (2008) phenomenological research provides significant advantages in investigating the phenomena that someone is aware of but lack a deep and detailed understanding. In this way, revealing primary basis of the conceptualizations about the facts and our way of perceiving these facts in our individual cognition get possible (Creswell, 1998).

The study was conducted in a middle-scale province of Black Sea region. Participants consisted of a total of 21 (11 males, 10 females) 7th grade students from different schools. The reason of selecting 7th grade students as participants was physical and chemical change concepts have been taught in 6th grade within Granular Structure of Matter unit, under Matter and Change subject area.

Data Collection Tool

Research data was collected using semi-structured interview technique accompanied by experimental activity samples prepared by the researchers. Each interview lasted approximately twenty minutes; the conversation of the interviewer and the participant took place in a comfortable room where participants would not be disturbed by external noises; they were recorded by a standard recorder, in accordance with qualitative data collection techniques. Obtained raw data was decoded by the researchers. Following the transcription, data analysis stage was initiated and the data was analyzed according to descriptive data analysis. The frequency of the data under preestablished concepts were given (Büyüköztürk, Kılıç Çakmak, Akgün, Karadeniz and Demirel, 2012). The focus of the data analysis process was the consistency of the answers given throughout the question set. After determining the consistency type of the answers, justification skill was assessed.

FINDINGS

The experimental activities used to model physical and chemical change, the types of the changes occurred in the activities and relevant question codes are given in Table 1. The codes given in Table 1 and Table 2 indicate the type of the change in the activity (PC: Physical Change, CC: Chemical Change, PC-CC: Both Physical and Chemical Change) and the sequence number of the experimental activity (like 1, 2, 3…).

Table 1. Experimental activity, Type of the Change in the Activity and Relevant Question Codes

Question Code	Experimental activity	PC	CC	PC-CC
PCQ1	Melting of ice	X		
PCQ2	Evaporation of water	X		
PCQ3	Melting of wax	X		
PC-CCQ4	Melting and burning of the candle			X
CCQ5	Popping corn		X	
PCQ6	Grinding corn	X		
CCQ7	Boiling the egg		X	
PCQ8	Breaking the egg	X		
PCQ9	Heating iodine crystals	X		
PCQ10	Solving iodine in chloroform	X		
PCQ11	Solving iodine in ethyl alcohol	X		
PCQ12	Solving sugar in water	X		
CCQ13	Heating and cooling hygrometric paper		X	

Basic principles and codes of the experimental activities outlined in Table 1 and Table 2 are explained below.

Melting of ice

Interview questions aiming to determine the knowledge structure of the participants about physical and chemical change concepts through the experimental activity based on the melting of ice, where a physical change took place, and qualitative and quantitative results of the obtained data were coded as PCQ1.

Evaporation of water

Interview questions aiming to determine the knowledge structure of the participants about physical and chemical change concepts through the experimental activity based on the evaporation of water, where a physical change took place, and qualitative and quantitative results of the obtained data were coded as PCQ2.

Melting of wax

When wax (paraffin) is heated, it switches from solid phase to liquid phase. In other words, melting which is as change of state where a physical change occurs, takes place. In this study, interview questions aiming to determine the knowledge structure of the participants about physical and chemical change concepts through the experimental activity based on melting of wax, where a physical change took place, and qualitative and quantitative results of the obtained data were coded as PCQ3.

Melting and burning of the candle

While burning a candle (paraffin), it is first melted then start to burn. In this regard, the melting of a wax is a physical change, whereas burning is an event of chemical change. Under the light of this basic knowledge, in this study, interview questions aiming to determine the knowledge structure of the participants about physical and chemical change concepts through the experimental activity based on burning a candle, where a physical change took place first, followed by a chemical change and qualitative and quantitative results of the obtained data were coded as PC-CCQ4.

Popping corn

Interview questions aiming to determine the knowledge structure of the participants about physical and chemical change concepts through the experimental activity based on popping corn in a pan, where a chemical change took place, and qualitative and quantitative results of the obtained data were coded as CCQ5.

Grinding corn

Interview questions aiming to determine the knowledge structure of the participants about physical and chemical change concepts through the experimental activity based on grinding corn, where a physical change took place, and qualitative and quantitative results of the obtained data were coded as PCQ6.

Boiling the egg

Interview questions aiming to determine the knowledge structure of the participants about physical and chemical change concepts through the experimental activity based on boiling a chicken egg, where a chemical change took place, and qualitative and quantitative results of the obtained data were coded as CCQ7.

Breaking the egg

Interview questions aiming to determine the knowledge structure of the participants about physical and chemical change concepts through the experimental activity based on breaking a chicken egg, where a physical change took place, and qualitative and quantitative results of the obtained data were coded as PCQ8.

Solving iodine in ethyl alcohol

When iodine crystals are added into a beaker containing ethyl alcohol, they are dissolved to form a reddish-brown solution. This event is an example of physical change. In this study, interview questions aiming to determine the knowledge structure of the participants about physical and chemical change concepts through an experimental activity (Ergül, 2014 and Ergül, 2014) designed related to the event of dissolution where a physical change took place, and qualitative and quantitative results of the obtained data were coded as PCQ9.

Solving iodine in chloroform

When iodine crystals are added into a beaker containing chloroform, they are dissolved to form a purple-violet solution. This event is an example of physical change. In this study, interview questions aiming to determine the knowledge structure of the participants through an experimental activity (Ergül, 2014 and Ergül, 2014) designed related to the event of dissolution where a physical change took place, and qualitative and quantitative results of the obtained data were coded as PCQ10.

Heating iodine crystals

Iodine crystals are black and in the solid state at room temperature, whereas they are purple-violet in gas state. When heated with a naked flame in the air, iodine crystals are sublimated, and they are deposited when cooled. This is a sublimation-deposition event related to the change of state and representing an example of physical change. In this study, interview questions aiming to determine the knowledge structure of the participants about physical and chemical change concepts through an experimental activity (Ergül, 2014 and Ergül, 2014) designed related to a change of state event (sublimation-deposition) where a physical change took place, and qualitative and quantitative results of the obtained data were coded as PCQ11.

Grinding cube-sugar and solving it in water

Tea sugar (saccharose: $C12H22O11$) can be dissolved in the water at room temperature or hotter and this an example of physical change. In this activity, tea sugar grinded in a mortar with pestle is added to the pure water in a beaker and dissolved by stirring. Interview questions aiming to determine the knowledge structure of the participants about physical and chemical change concepts through this experimental activity, and qualitative and quantitative results of the obtained data were coded as PCQ12.

Hygrometric Paper (Moisture Determination Paper)

In moist environment, Cobalt (II) chloride ($CoCl2$) compound is light pink and it has a structure containing crystal water ($CoCl2x7H2O$). When $CoCl2x7H2O$ is heated, the crystal loses its water and it is transformed into $CoCl2$ chemical compound, which is blue. Hygrometric paper (Moisture determination paper) is prepared based on this basic information, by drying $CoCl2$ absorbed filter paper in an oven. This paper is a measurement tool used to determine the liberation of H_2O in a chemical reaction or to find out if there is moist in the system. If there is moist in the system, the paper will contain $CoCl_2 \times 7H_2O$ compound and it will take the light pink color of the compound, on the other hand, if there is no moist, the paper will contain $CoCl_2$ compound and it will take the blue color of the compound. In this study, interview questions aiming to determine the knowledge structure of the participants about physical and chemical change concepts through an experimental activity based on heating moisture determination paper, where a chemical change took place, and qualitative and quantitative results of the obtained data were coded as CCQ13.

Based on the outcomes of the analysis made on the answers given by the participants, the frequencies (F) related to the consistency of the answers and justification basis of the answers are given in Table 2.

Table 2. Frequencies Regarding the Consistency of Students' Answers and Their Justifications

Question Code	Inconsistent Answer (F)	Consistent Answer (F)	Experimental Justification (F)	Imparted Justification (F)	Overall (F)
PCQ1	0	21	20	1	21
PCQ2	2	19	17	5	21
PCQ3	7	14	15	6	21
PC-CCQ4	17	4	7	15	21
CCQ5	15	6	5	16	21
PCQ6	1	20	19	2	21
CCQ7	11	10	14	7	21
PCQ8	2	19	20	1	21
PCQ9	16	5	4	17	21
PCQ10	1	20	2	19	21
PCQ11	0	21	3	18	21
PCQ12	3	18	9	12	21
CCQ13	13	8	1	20	21

According to knowledge-in-piece theory, each participant in the position of learner has a naïve cognition and they are expected to give inconsistent answers to different questions (different contexts) related to the same physical facts. On the other hand, according to theory-like knowledge structure theory, the naïve cognition structure of the students is similar to those of the scientists, thus they are expected to give consistent answers to each question (diSessa, 1993; 2002). Regarding the answers related to consistency in Table 2, the answers given to 6 of the 13 questions (PCQ1, PCQ2, PCQ3, PCQ6, PCQ8 and PCQ12) are positive-consistent answers (repeating right answer); 2 of them (PCQ10 and PCQ11) are negative-consistent answers (repeating wrong answer); whereas 5 of them (PC-CCQ4, CCQ5, CCQ7, PCQ9 and CCQ13) are inconsistent answers.

Regarding the evaluation of the answers according to justification; it was found that experimental justification frequency of 5 of the 8 answers, which were suitable for theory-like knowledge structure theory was high and correct. For the remaining 3 answers, imparted justification was found to be high; where 2 answers were wrong (PCQ10 and PCQ11) and one answer is right (PCQ12). It was observed that participants who answered in accordance with knowledge-in-piece theory have answered 4 questions with the answers that are in line with imparted justification, whereas they have answered 1 question with the answers that fits experimental justification.

The data displayed in Table 2 shows that participants have given answers that are suitable for theory-like knowledge structure theory and knowledge-in-piece theory.

In the following paragraphs, the data are examined in the context of each question, respectively,

Quotation from PCQ1 (Melting of Ice)

Regarding the consistency of the answers given to the question related to experiment PCQ1, all 21 participants gave a consistent answer. Regarding the answers in terms of justification, 20 participants answered through experimental justification, whereas 1 participant answered based on imparted justification. This fact means that students that answered according to theory-like knowledge structure mostly prefer experimental justification. Two quotations are given in Example 1 and Example 2 for this question.

Example 1. The quotation for PCQ1 containing a consistent answer with experimental justification.

R: We put ice into the beaker … We heat it from the bottom, what do you think happening now?

S: … It is like heating by radiation... Ice is transformed into water.

R: What king of change is it? … Physical change, or chemical?

S: Physical?

R: Why? ...

S: Because it doesn't lose its impact. (Participant referred that the structure of the substance did not changed, which constitutes a proof for physical change).

R: What do you mean by not losing its impact …?

S: Yes… Hmm… Him…

R: … You are observing, what happened?

S: It became water, yes water…. Physical (The justification was experimental because the participant built his/her answer based on his/her own experiment, based on direct observation).

R: … Ok why do you think so?

S: …. Because ice is made of water … Water, eee I don't see anything to say. (Since the participant answered as physical change during the whole interview, he/she showed cognitive consistency).

Example 2. The quotation for PCQ1 containing a consistent answer with imparted justification.

R: … Here we added some ice, did you notice it? ...

S: Hmm Hmm

R: We will heat it from the bottom…

S: It will melt.

R: Yes. What is the new phase?

S: Liquid.

R: … OK, what kind of change we have here?

S: Physical.

R: Why?

S: Eee, because it receives heat … The particles of the substance get away from each other when heated. (Since the participant explained based on theoretical knowledge beside his observation, the justification was imparted).

R: Hmm

S: It became liquid because they move more.

R: … So…?

*S: Physical… As I said it receives heat there and in fact it only changes its state. it isn't transformed into another substance. It is not lost with fire (*The participant was cognitively consistent because he referred to physical change during the whole interview).

Quotation from PCQ2 (Evaporation of Water)

Regarding the consistency of the answers given to the question related to experiment PCQ2, 19 participants gave a consistent answer, whereas 2 participants gave inconsistent answer. Regarding the answers in terms of justification, 17 participants answered through experimental justification, whereas 5 participants answered based on imparted justification. The answers given to this question are also the evidence that students that answered according to theory-like knowledge structure theory mostly refer to experimental justification. Two quotations are given in Example 3 and Example 4 for this question.

Example 3. The quotation for PCQ2 containing a consistent answer with experimental justification.

R: ... At the moment it is completely in the water form and we continue to heat. What will happen in a moment or what do you see happening here?

S: Gas.

R: Is there a change here?

S: There is a physical change here. Gas was formed from water.

R: There is a physical change. It was shifted from water to gas. Can you explain a bit, what does it mean to shift from water to gas and being a physical change?

S: Now, ee shifting from water ee, liquid matter shift to gas phase by heating ee how can I explain, I cannot explain it (Participant referred to physical change, showed cognitive consistency by making explanations. Based on his explanation, it can be said that the answer was more suitable for experimental justification).

Example 4. The quotation for PCQ2 containing an inconsistent answer with imparted justification.

R: OK, we continue heating from the bottom. We still continue heating. Yes, we continue. What is happening at the moment?

S: It is boiling.

R: It is boiling. Eee, is there any change here?

S: Hmm Hmm.

R: What kind of change is it?

S: I think chemical.

R: Why?

S: There are drops formed. While boiling there, some heat spread from there and …

R: Hmm Hmm.

S: And with spreading, how to say, eee a chemical change occurs with air.

R: We see it now. It's boiling, you see the flames.

S: I see.

R: Eee let's look at once more if you want.

S: I don't know exactly. Or I couldn't explain.

R: But you say there is a change.

S: There is.

R: What kind of change is it?

S: I think its chemical. This is I mean, a different result than evaporation there because it's boiling, I don't know well. Eee it seems like chemical.

R: Hmm. OK, is there evaporation at the same time?

S: Yes.

R: OK, is this a change?

S: Yes.

R: What kind of change is it?

S: Physical. I think evaporation is a physical change. (Participant used to refer chemical change at the beginning of the interview, whereas he/she used physical change expression at this stage of the interview, which was an indicator of cognitive inconsistency on the answers).

R: Hmm. why?

S: Hmm, eee it gets lower if the atoms get away from each other. In fact, there is physical change in the displacement or divergence of the atoms. Eee, I think a chemical change doesn't occur. (Since the participant made an explanation based on theoretical information rather than his/her own observation, its justification was imparted.)

Quotation from PCQ3 (Melting of wax)

Regarding the consistency of the answers given to the question related to experiment PCQ3, 14 participants gave a consistent answer, whereas 7 participants gave inconsistent answer. Regarding the answers in terms of justification, 15 participants answered through experimental justification, whereas 6 participants answered based on imparted justification. This fact confirms that students that answered according to theory-like knowledge structure theory mostly refer to experimental justification. One quotation for this question is given in Example 5.

Example 5. The quotation for PCQ3 containing a consistent answer with experimental justification.

R: You see the particles. We will start to heat. We started. Let's continue in this way, it is not very clear but focus on the particles of wax... Is there a differentiation on the particles? … What do you think? Can you see particles now?

R: We heat from the bottom.

S: Yes...

R: Look, there are particles here now, did you see them?

S: Yes.

R: You saw the particles.

S: Hmm.

R: We heated from the bottom.

S: Yes.

R: We heated … We heated from the bottom, we gave heat… Now, we will check if we can see the particles or not.... When we heat the wax, what do you think of happening to these particles?

S: The wax is melted.

R: Hmm. Is there any change here?

S: It is melted and there is a physical change.

R: Why?

S: It was only melted… (Participant referred to the event of melting based on the observation made. Thus, it was accepted as an experimental justification).

R: Hmm. Then?

S: Physical... It became liquid. (He/she referred to the liquidation of the wax, he/she still implied that it was still wax).

R: Hmm.

S: Therefore, it is physical... Because its appearance changes here... (Participant exhibited a consistent cognitive structure by insisting on physical change during the interview).

Quotation from PC-CCQ4 (Melting and burning of solid candle)

Regarding the consistency of the answers given to the question related to experiment PC-CCQ4, 4 participants gave a consistent answer, whereas 17 participants gave inconsistent answer. Regarding the answers in terms of justification, 7 participants answered through experimental justification, whereas 15 participants answered based on imparted justification. One quotation for this question is given in Example 6.

Example 6. The quotation for PC-CCQ4 containing an inconsistent answer with imparted justification.

R: I get it, OK. Let's continue now. Now, there is something here, which we see all the time. What is it?

S: Hmm…

R: A candle.

S: A candle, yes.

R: It's burning. Now, shall we have a change in the candle while it is burning, what's happening?

S: Yes. The candle is burning.

R: OK…

S: But the thread in the candle can be seen.

R: OK, what kind of change do we have here? What kind of change do we have?

S: In my opinion, the melting of the wax is physical, and the burning of the thread is chemical change. (Even though the participant made observation [such as melting, burning phenomenon], his/her justification implicitly [In my opinion expression] referred to school knowledge).

R: Hmm. A chemical change. Is the candle melting?

S: It is melting.

R: Does it burn, is it burning?

S: It is burning...

S: It is melting.

R: Melting or burning?

R: What do you mean by melting or burning?

S: If it is melting, it is physical, if it is burning it is chemical... Hmm I don't know. (It can be seen that the participant decided again according to the knowledge learned from the book. Therefore, participant made an imparted justification).

S: It's burning. Due to the heat, they are slowly melting from the thread there.

R: I see it. Thus, the change here is…

S: Chemical.

R: Chemical or physical?

S: It may be physical too.

R: Hmm?

S: I don't know, I guess.

R: OK. Either physical or chemical, what if both …

S: It may be both. Yes, I will say both, is it OK? It is both.

R: Why both of them?

S: Ya, I don't know. It may be one of them or both. (Participant exhibited cognitive inconsistency related to physical and chemical change concepts).

Quotation from CCQ5 (Popping corn)

Regarding the consistency of the answers given to the question related to experiment CCQ5, 6 participants gave a consistent answer, whereas 15 participants gave inconsistent answer. Regarding the answers in terms of justification, 5 participants answered through experimental justification, whereas 16 participants answered based on imparted justification. It was found that most of the participants gave inconsistent answers and referred to imparted justification. One quotation is given in Example 7 for this question.

Example 7. The quotation for CCQ5 containing an inconsistent answer with imparted justification.

R: Did you see the ickers? It is corn, right?

S: Yes.

R: OK, we pop corns, what do you think about the change occurring here, is it a physical change or a chemical change? What's happening? We heat from the bottom, what happens? You should know this; corns, what are they doing now?

S: They are popping.

R: Haa. What's happening? Is it a physical change or a chemical change?

S: In fact, it seems to both but it is supposed to be chemical?

R: Why?

S: Because we heat from the bottom and they are popping (With "heating from the bottom" expression participant referred to heat energy and the fact of burning, which was an indicator that he referred to printed course material and the teacher, therefore to imparted justification).

R: Hmm… Yes.

S: In fact, it may be physical as well.

R: Why?

S: Because the shell enters into it.

R: Hmm…

S: Eee, but chemical.

R: Why?

S: Because all of them were popped because of the heat that we gave.

R: Yes.

S: It changed their shapes.

R: You say it changed their shapes. And therefore…

S: Chemical (Participant referred both physical and chemical change concepts during the interview, thus he/she exhibited cognitive inconsistency).

Quotation from PCQ6 (Grinding Corn)

Regarding the consistency of the answers given to the question related to experiment PCQ6, 20 participants gave a consistent answer, whereas 1 participant gave inconsistent answer. Regarding the answers in terms of justification, 19 participants answered through experimental justification, whereas 2 participants answered based on imparted justification. This fact supports the relationship between theory-like knowledge structure, theory-based conceptualization and experimental justification. One quotation is given in Example 8 for this question.

Example 8. The quotation for PCQ6 containing a consistent answer with experimental justification.

R: OK, OK. OK, look, did you see the ickers? Now we will take the ickers and let's see where to put them. We took the ickers and placed them. What are we doing now?

S: We are crashing.

R: We are crashing. What happens when we crash?

S: Physical change.

R: What is it, did any change took place here?

S: Something happened.

R: What happened?

S: Physical.

R: Why physical?

S: Because it is divided into pieces. I mean it is still the same substance.

R: Hmm.

S: Thus, it is physical change (Participant decided that the change occurred was physical based on the observation that he/she made during the experimental activity where the corn was crashed, in other words grinded with the applied force. Therefore he/she answered the asked questions through experimental justification. Regarding the type of the change, he/she gave the same answers repeatedly, thus he/she exhibited cognitive consistency).

Quotation from CCQ7 (Boiling an Egg)

Regarding the consistency of the answers given to the question related to experiment CCQ7, 10 participants gave a consistent answer, whereas 11 participants gave inconsistent answer. Regarding the answers in terms of justification, 14 participants answered through experimental justification, whereas 7 participants answered based on imparted justification. Two quotations from this question are given in Example 9 and Example 10.

Example 9. The quotation for CCQ7 containing a consistent answer with experimental justification.

R: OK, let's continue. We look at the egg that we put into water. Now, you see the egg, the egg that we heated, the egg that we boiled. OK, is this egg different than this egg?

S: Different.

R: OK, after boiling this egg, did any change occurred in the egg?

S: It did.

R: OK, regarding the change here, is it a physical change, or a chemical change?

S: Physical.

R: Why?

S: It is still the same egg.

R: How, can you clarify a bit? ...

S: Eeeee... The egg is the same, only it is solid not liquid.... (Participant saw that there is a change on the transformation of a raw egg into a boiled egg and expressed this change as physical through a very simple experimentation, from this point of view the justification was experimental. Participant exhibited cognitive consistency because he/she was consistent during the interview).

R: How...?

S: I don't know ...

Example 10. The quotation for CCQ7 containing an inconsistent answer with imparted justification.

R: Hmm. OK, now the egg, the egg that we heated as we said... Now we cut it, divided into two. Did any change occurred in the egg?

S: This one, right?

R: Hmm.

S: There is a physical change.

R: Why?

S: Because it is divided into two. This egg is the same egg …

R: No, no. Compared to the one before boiling …

S: Haa!

R: Think of the egg before boiling and the egg after boiling, compare them. Is there any change here?

S: It may be chemical change.

R: Why?

S: Because it was boiled. In chemical change, events like cooking, boiling happens. (Participant referred to printed or teacher knowledge. Therefore, it can be said that it was imparted justification).

R: Hmm.

S: But it may be physical change as well... only the shape might have been changed.

R: Hmm. So?

S: So ee chemical change occurs (It was observed that the participant was reluctant whether the change occurred in the egg heated in the water bath, in other words while boiling an egg, is physical or chemical, and referred to both changes. Therefore he/she was cognitively inconsistent).

Quotation from PCQ8 (Breaking an Egg)

Regarding the consistency of the answers given to the question related to experiment PCQ8, 19 participants gave a consistent answer, whereas 2 participants gave inconsistent answer. Regarding the answers in terms of justification, 20 participants answered through experimental justification, whereas 1 participant answered based on imparted justification. One quotation is given in Example 11 for this question.

Example 11. The quotation for PCQ8 containing a consistent answer with experimental justification.

R: ... OK, what kind of change happened here? We put it out of the shell, we broke it into the plate.

S: Do you ask for this egg?

R: Hmm.

S: I mean breaking the shell is again a physical change.

R: Hmm.

S: ????

R: At the moment we put it out of the shell, we broke it into the plate.

S: Yes.

R: Now it is a broken egg.

S: Yes.

R: Is this a change?

S: Ee it is a physical change.

R: Why physical, why a physical change?

S: Ee it was inside the shell, we broke the shell... (Participant expressed that the change was physical for the question asked at two different points of the interview. Therefore, he/she was cognitively consistent. In this context, the justification for the change was a descriptive justification based on direct observation, thus it was experimental).

Quotation from PCQ9 (Sublimation of Iodine)

Regarding the consistency of the answers given to the question related to experiment PCQ9, 5 participants gave a consistent answer, whereas 16 participants gave inconsistent answer. Regarding the answers in terms of justification, 4 participants answered through experimental justification, whereas 17 participants answered based on imparted justification. One quotation is given in Example 12 for this question.

Example 12. The quotation for PCQ9 containing an inconsistent answer with imparted justification.

R: ... Now... I'm just completing. Do you know what it is? Iodine, iodine particles. Now, the researchers will take these iodine particles and will put them into a beaker.

S: Hmm.

R: OK? She takes iodine particles, put them into a beaker, there are iodine particles at the bottom of the tube, can you see them?

S: Yes.

R: Now, she will show this part. She will turn it. Turn it a bit more, researcher... Now... Look, do you see the pinkness?

S: Yes.

R: Yes. What is happening? Does any change occur? ....

R: Interesting, isn't it?

S: To be clear, I see this for the first time.

R: OK, do you think there is a change here?

S: Yes, there is.

R: What kind of change is it?

S: I think it is chemical change.

R: Why?

S: ???? (Silence)

R: Hmm.

S: ... I think it is chemical change. It might have been entered into a reaction ("Reaction" expression of the participant can be considered as a typical imparted justification).

R: I see. Why it may be entered into a reaction …

S: I don't know.

R: What is your opinion…

S: I just thought like this.

R: Hmm. I get it, I get it. OK, eee OK let's continue. Let's continue. We are at the stage of cooling here. In your opinion, what is happening now...?

S: It takes its previous form... it takes, it takes.

R: Do you see such a thing?

S: Ee, Yes…

R: Hmm?

S: Not so much, but it seems to shift back to its previous form. Its blackness like this.

R: OK, what king of change is this change?

S: I guess physical.

R: Which one?

S: Getting its previous form seems like that. I mean it shifts.

R: That change, that one.

S: Hmm.

R: Let me restart.

S: I cannot know. I don't know.

R: What you think it is closer to?

S: I think as chemical. (Participant has first described it as chemical change, then physical change and finally turned back to chemical change decision and exhibited cognitive inconsistency. In the answers, he/she stated that he/she has observed a change in the color and interpreted this change as a chemical change. Observing the previous color after the cooling operation created a cognitive inconsistency, thus he/she used physical change expression, but at the end he/she tended towards chemical change. Thus, due to the misconception that color change should be a chemical change, he decided based on imparted justification).

R: Why?

*S: I mean, maybe a change occurred there. It seems that it was burned there. (*Participant decided that a substance heated by naked flame in open air may potentially burn and it will undergo a chemical change based on imparted justification again).

R: Hmm…

S: This is why.

Quotation from PCQ10 (Solving iodine in chloroform)

Regarding the consistency of the answers given to the question related to experiment PCQ10, 20 participants gave a consistent answer, whereas 1 participant gave inconsistent answer. Regarding the answers in terms of justification, 2 participants answered through experimental justification, whereas 19 participants answered based on imparted justification. Two quotations are given in Example 13 and Example 14 for this question.

Example 13. The quotation for PCQ10 containing a consistent answer with imparted justification (An example of participant having a misconception).

R: OK, now we put these iodine pieces into a chemical solution. It is called chloroform, a solution like water. OK?

S: OK.

R: A solution called chloroform... We put them into a solution. Look, eee we mixed these iodine pieces and that solution. Yes, did any change occurred? ...

S: Yes, it occurred.

R: OK, this change is it physical or chemical?

S: Eee, Chemical.

R: Why?... Why?

S: Eee…

R: I ask again; Physical or Chemical? Or is there a change?

S: Yes, there is.

R: Yes.

S: But I couldn't find what kind of change it is.

R: What change do you think?

S: I think it is a bit like chemical.

R: Why? Tell me what you think.

*S: Eee, because those two are combined with each other… (*Referred to a reaction, imparted justification*)*

S: These two are mixed together.

R: Hmm…

R: Yes.

*S: Chemical. (*During the interview performed with the participant, he/she expressed in two different times that there will be chemical change when iodine crystals are added into chloroform, therefore he/she exhibited consistency. In this decision, he/she referred to a theoretical knowledge such as "two substances are combined or mixed with each other", coming from a book or teacher while justifying. Thus, the answer indicating that the change was chemical was based on an imparted justification. The dissolution of iodine crystals into chloroform is a physical change, rather than chemical. Thus, the participant had a misconception …. Although the training of physical and chemical change concepts has been given to the participants in the 6th grade, he couldn't distinguish physical change and chemical change concepts through an experimental activity.*)*

Example 14. The quotation for PCQ10 containing an inconsistent answer with experimental and imparted justification.

R: We put this chloroform into this bottle. Chloroform, is a kind of chemical liquid. Now, remember the iodine shown a while ago …

S: Yes.

R: I showed you just a while ago, it's the same, look how clear we draw it.

S: Hmm.

R: We put is inside this again.

S: Yes.

R: We add a certain amount of this liquid into it, or we put it into the liquid. It doesn't matter. I mean these two are…

S: We mix them.

R: Let's see what will happen. Dou you see any change?

S: Yes.

R: What, what happened?

S: It may be physical change.

R: Why?

S: Because they are mixed each other.

R: OK.

S: It became a mixture. (He/she referred to the theoretical knowledge of mixture. Imparted justification)

R: Hmm.

S: Thus, a physical change might have been happened.... That's how we learned at school (Imparted justification)

R: You said a physical change might have been happened.

S: Hmm.

R: That's how you explain it.

S: Hmm.

R: Is there any change, such a change?

S: There is, Yes. Iodine cannot be seen now. In fact, it was dissolved… (Participant expressed that iodine crystals were not seen and referred to the concept of dissolution based on this, which mostly referred to experimental justification).

R: OK. Ee do you see any other change?...

S: The color of the liquid was changed.

R: Yes. Change of color... how we can interpret it?

S: We can say chemical. Change of color is chemical... (Imparted justification)

R: How?

S: Ultimately the color was changed and??? Something might have been happened. A chemical reaction.

R: You accept it as chemical... (Participant explained as "change of color is chemical" and "Chemical reaction", which indicated that he/she used "change of color is a chemical change" knowledge that he has get at school. In this case justification was imparted. At the beginning, participant stated that the change was physical, whereas he stated that the change was chemical when an alternative question concerning the change of color was asked. In this case he/she was cognitively inconsistent).

Quotation from PCQ11 (Solving iodine in ethyl alcohol)

Regarding the consistency of the answers given to the question related to experiment PCQ11, all of the participants (21 people) gave a consistent answer. Regarding the answers in terms of justification, 3 participants answered through experimental justification, whereas 18 participants answered based on imparted justification. One quotation is given in Example 15 for this question.

Example 15. The quotation for PCQ11 containing a consistent answer with imparted justification (An example of participant having a misconception).

A. Now, we put it into another liquid. This is alcohol, ethyl alcohol. You should have heard about ethyl alcohol, we have it at the laboratory.

S: I guess.

R: Look at inside the ethyl alcohol, it is here, do you see it?

S: I see.

R: We have seen these iodine pieces before, you see them now too. These are iodine pieces, iodine. She took iodine and put into the tube. She added ethyl alcohol into the tube. Let's see what will happen when we add ethyl alcohol? Let's see what will happen? Ah, she is adding now. She added iodine in ethyl alcohol. Did any change occurred?

S: It occurred.

R: OK, what kind of change is it?

S: Chemical.

R: Why? ... Why?

S: Eee, why …

R: Why do you suppose?

S: Because… the color of the liquid was changed. (Participant referred that change of color occurs in case of a chemical change. This fact was a knowledge acquired from the teacher or reference books, thus it was imparted justification. He/she assumed that "Chemical change occurs if the color changes" hypothesis was correct; however, this hypothesis doesn't validate this experimental activity...).

R: Hmm… What is the reason of the color change in the liquid?

S: Because we added ethyl alcohol. Because ethyl alcohol is available in the laboratories (Imparted justification/"ethyl alcohol is a chemical" statement may be considered as a proof of being imparted school knowledge … "The chemical substances available in the laboratory will cause chemical change" is a significant education problem …).

S: .... Chemical

..

R: OK, this is also ethyl alcohol. We are adding ethyl alcohol.

S: Hmm.

R: You should have heard about ethyl alcohol.

S: Hmm, I heard.

R: OK. Now we will put some iodine, our famous iodine, into the ethyl alcohol. You see its granulose form, you see it in the form of granules. What happened? Did you see anything? Did any change occurred?

S: Yes.

R: What happened?

S: A chemical change occurred.

R: Why?

S: Ee the color changes and it seems something different happens inside it. (When black iodine crystal is added to ethyl alcohol, which is a colorless liquid, it becomes reddish-brown. The change of color makes think that there will be a change "inside" the substance, in the internal structure of the substance, in other words it will cause a chemical change. This phenomenon, which was coming from a text book or from the teacher of the participant, was not valid for this activity. Thus, the justification was imparted.)

Quotation from PCQ12 (Grinding sugar in the mortar and solving it in water)

Regarding the consistency of the answers given to the question related to experiment PCQ12, 18 participants gave a consistent answer, whereas 3 participants gave inconsistent answer. Regarding the answers in terms of justification, 1 participant answered through both imparted and experimental justification, 8 participants answered through experimental justification, whereas 12 participants answered based on imparted justification. The quotation is given in Example 16 for this question.

Example 16. The quotation for PCQ12 containing a consistent answer with imparted and experimental justification.

R: ... we have a cube-sugar at hand.

S: Yes.

R: Remember the mortar that we previously had, we put it into the mortar, crashed, put into pieces. Did any change occurred?

S: It occurred.

R: Is this a physical change, or chemical change?

S: Physical change.

R: Why?

S: Why? Because the sugar is still normal.

R: Normal. OK, we put the same sugar into hot water and we stirred. What happens?

S: vapor…

R: Or, we put it into cold water and we stirred. What happens, ee cube sugar? Think, what happen to the sugar when you add it into the tea, at home?

S: Eee they are spread around. (Experimental justification)

R: They are spread. OK, does any change occurs in the sugar, cube sugar?

S: It doesn't occur.

R: Why? We put the cube sugar that was in the form of a cube into the tea.

S: It occurs.

R: OK, what do you think of this change, is it a physical change, or chemical change?

S: Physical.

R: Why?

S: Eee, sugar is scattered around... turned into pieces... the same sugar (Experimental justification)

R: What does scatter means?

S: Dissolved, mixed... the same taste ... dissolving... mixture, from the book... eeee .... I heard from my teacher... it should be physical change (dissolving and especially mixture expressions were school knowledge, and therefore imparted justification; whereas referring to the same taste was an experience from daily life, thus it was experimental justification.)

R: Did you taste it? ... (Participant repeated that the sugar added to water underwent a physical change, therefore he/she was consistent. In addition, he decided based on qualitative data such as scattering of the sugar into water, becoming invisible inside the water and lack of change in its taste, therefore he made the decision based on experimental justification).

S: Yes, at home... Sugared tea...

Quotation from CCQ13 (Heating and cooling hygrometric paper)

Regarding the consistency of the answers given to the question related to experiment CCQ13, 8 participants gave a consistent answer, whereas 13 participants gave inconsistent answer. Regarding the answers in terms of justification, 1 participant answered through experimental justification, whereas 20 participants answered based on imparted justification. One quotation is given in Example 8 for this question.

Example 17. The quotation for CCQ13 containing an inconsistent answer with imparted justification.

R: Ok. Look, there is a paper here. Researcher heats the paper from distance so that it will not burn, turn into ashes … What happened, what color did the paper took?

S: Blue.

R: It became blue-purple. Do you think there is a change here?

S: Yes, there is.

R: What kind of change?

S: Physical change. Lighter fluid ignites it here. The gas of the lighter went, the gas changed its color. Thus, it is a chemical change.

R: Is this a chemical change … Both physical and chemical?

S: Yes. physical because its appearance was changed, chemical because lighter fluid changed the chemistry of the paper.

R: How do we know that its chemistry was changed?

S: Because lighter fluid changed its color there, that's why.

R: Because it became blue?

S: Yes... Participant, 1) had a misconception because he explained the change of color on the paper with CoCl2 with a chemical reaction occurred between lighter fluid and the paper, in other words he stated that it was a chemical change because of the change of color. 2) Participant believed that color is a physical feature, and due to this imparted justification, he thought that the change was physical change. Consequently, the participant exhibited cognitive inconsistency regarding the type of the change, physical or chemical. Regarding the given answer in terms of justification, the participant stated that the lighter fluid that he cannot see caused a chemical reaction, which was an indicator that he employed imparted justification.

DISCUSSION AND CONCLUSION

Within this study, 13 experimental activities have been designed to determine the knowledge structure of 7th grade students related to physical and chemical change concepts, which are among the most basic concepts that they encounter in real life and they were taught at 6th grade. The answers given to the questions related to experimental activities were evaluated in terms of cognitive consistency, justification dimensions and misconceptions.

The consistency of the students' answers referred to theory-like knowledge structure theory; whereas their inconsistency referred to knowledge-in-piece theory (diSessa, 1993; Vosniadou, 1994). The justifications based on the observations made during experimental activities referred to experimental justification; whereas justifications based on the knowledge learned from textbooks and teachers referred to imparted justification (Halloun, 2006).

Discussion of Experimental Activities

According to the data, the activities designed to determine the knowledge structure of participating students may be divided into two groups. First of them (PCQ1, PCQ2, PCQ3, PC-CCQ4, CCQ5, PCQ6, CCQ7, PCQ8, PCQ12) are the activities practiced with the materials that the students know from the daily life and related to the facts that they have already encountered. The second one (PCQ9, PCQ10, PCQ11 and CCQ13), are the activities that students would not observe frequently in real life and in formal education (Table 1).

Regarding the characteristics of the designed experiments, it can be seen that they are easily applicable in the classroom or laboratory environment, doable with simple and easily obtainable materials. Therefore, the activities were preferred because of: being interesting in terms of providing qualitative data, such as change of color, dissolution, change of state; being doable with the materials that don't harm human; and the simplicity of the operations such as heating using a lighter and cooling to room temperature. In this regard, it could be said that the activities are usable to determine knowledge structure of participating students related to physical and chemical change concepts.

Discussing the Answers in terms of Consistency

According to the data, it can be seen that positive-consistency frequency of the answers, in other words the number of correct and consistent answers given to the questions related to 6 activities that participants observe in real life as well (coded as PCQ1, PCQ2, PCQ3, PCQ6, PCQ8 and PCQ12) was higher. On the other hand, it can be seen that negative-consistency frequency of the answers, in other words the number of incorrect and consistent answers, given to the questions related to 2 activities that participants don't observe in real life (PCQ10 and PCQ11) was higher. It can be said that; the activities that are experienced in real life and in formal education, which possess the qualities that can be observed directly and immediately, guide students towards consistent and accurate answers. Regarding the justifications of the questions belonging to PCQ1, PCQ2, PCQ3, PCQ6, and PCQ8, experimental justification frequencies were found to be high. This finding shows that participants justified the activities that they were familiar from daily life and they gave consistent-correct answers using their observational experiences at the moment. This fact can be interpreted as, the examples of descriptive activities that are suitable to the cognitive level of the participants, with which they are familiar, may guide them to perform direct observations and therefore improve their reasoning skills (Table 2).

Regarding the activity coded PCQ12, participating students showed positive and consistent answer in a typical quotation, where they employed both imparted and experimental justification. In a part of the quotation, participant referred to the scattering of solid sugar pieces in the water. He/she referred to the lack of change in the taste of the water based on his/her daily experience, and concluded that the sugar is still there. Since these explanations were the expressions of direct observations, the justification was experimental. The quotation was: "Eee, sugar is scattered around... turned into pieces... the same sugar". At the same time, physical change was also referred in the quotation. In another part of the quotation, explanations were given for the dissolution of the sugar in water and mixture phenomenon, and relevant concepts were stated to have been acquired from the school and teacher. This fact was an indicator that imparted justification was employed. The quotation was: "Dissolved, mixed... the same taste ... dissolving... mixture, from the book... eeee .... I heard from my teacher … it should be physical change."

The examples of the activities, in which students exhibited cognitive inconsistency or had misconceptions (even if they were consistent), are detailed in the following paragraph.

Regarding the sublimation of iodine activity, coded as PCQ9; in a typical answer of participating students, the change of color occurred after heating black iodine crystal was described as; "... I think it is chemical change. It might have been entered into a reaction." And he/she concluded that it was a chemical change. In the relevant activity, the opportunity of observing the heat loss (cooling) process was also provided to the participants. Even though the participant developed an explanation based on physical change after this observation, the concepts of color change and reaction dominated his/her reflection and he/she returned back to the concept of chemical change. With the mentioned activity, it was attempted to raise awareness towards reversibility process that happens in the process of physical change, without requiring high energy. Participants were encouraged to make such an observation. Participants exhibited cognitive inconsistency in their explanations during and after the activity, they employed imparted justification, which was based on a misconception (change of color is chemical, etc.…) and tended not to use reversibility process as a data, which can be interpreted as they have not experienced such integrated activities in the experimental activities performed in the school environment and therefore they couldn't acquire cognitive sufficiency related to physical change concept.

In the two activities where negative-consistency (wrong and consistent answers) frequencies were higher (PCQ10 [Solving iodine in chloroform], PCQ11 [Solving iodine in ethyl alcohol]); it was found that participants exhibited cognitive consistency, adopting “chemical change” concept at the beginning, middle and end of the interview. This may be due to the limited number of activities related to physical and chemical change in the formal education system and the time restriction in the learning-teaching process. On the other hand, the relevant finding refers to a situation where “if the color of a substance change, it should be subject to chemical change” (Ergül,2014) hypothesis, which is mostly considered to be correct by the teachers, should be rejected. In a typical quotation for PCQ10, the participant employed imparted justification based on chemical reaction concept and exhibited cognitive consistency for chemical change. Related typical quotation is: “Eee, Chemical … Eee because those two are combined with each other … chemical". Only 1 participant gave inconsistent answer for PCQ10, however he/she perseveringly accepted the change of color as a chemical change and employed imparted justification for the evaluations in this direction. He/she explained the answer of physical change with the disappearance of iodine pieces into chloroform, therefore with the concepts of dissolution and mixture. Related typical quotation was: “R: Is there any change, such a change? S: There is, Yes. Iodine cannot be seen now. In fact, it was dissolved… (Participant expressed that iodine crystals were not seen and based on this he/she referred to the concept of dissolution, which mostly referred to experimental justification). R: … OK. Ee do you see any other change?... S: The color of the liquid was changed. R: … Yes. Change of color... how we can interpret it? S: We can say chemical… Change of color is chemical... (Imparted justification) R: How? S: Ultimately the color was changed and??? Something might have been happened. A chemical reaction. R: You accept it as chemical...".

The answers given to PCQ11 activity were also similar; most of the participants interpreted the change of color as a chemical change. Relevant quotation; “… OK, what kind of change is it? … Chemical… Why? ... Why? … Because… the color of the liquid was changed.”

In CCQ13 activity, most of the participants gave inconsistent answers and they mostly employed imparted justification. Regarding the relevant quotation, which is “… physical because its appearance was changed, chemical because lighter fluid changed the chemistry of the paper… How do we know that its chemistry was changed? … Because lighter fluid changed its color there, that’s why.”, first the participant interpreted the change of color as a physical appearance change; however, he/she interpreted the change of color as a reaction between the flame of the lighter and hygrometric paper. Therefore, this fact is a proof that the knowledge was based on an imparted knowledge from the school environment.

The consistency and justification categories in Table 2 can be analyzed according to the conceptualization level of the concepts (Lawson, 1995). It can be seen that PCQ1, PCQ2, PCQ3, PCQ6 and PCQ8 questions can be conceptualized at descriptive level. It can be said that regarding the questions with the conceptualizations at descriptive level, most of the participating students exhibited cognitive consistency and their justifications were experimental. Such a finding should be related to the fact that relevant questions have a content that can be faced in real life; they are familiar; and they allow to use direct observation skill. Therefore, it can be concluded that the questions belonging to relevant activities are "within the limits of students' actual cognitive competence". It can be seen that the answers given to activities PCQ10, PCQ11 and PCQ12 were cognitively consistent and imparted in terms of justification. Regarding the answers given to PCQ10 and PCQ11 activities, containing misconceptions, this finding can be interpreted as participating students faced with the substances that they were not familiar and thus they based their justifications on the theoretical knowledge that they have acquired from the school environment. Instead of associating the change of color at descriptive level with physical change, which can be detected through direct observation, they associated it with chemical change that contains theoretical references such as reaction, atomic interaction. Although there is no misconception in PCQ12 activity, the theoretical dimension of dissolving was referred and the justification was performed through imparted school knowledge. The answers given to PC-CCQ4, CCQ5, PCQ9 and CCQ13 activities were seen to be cognitively inconsistent and imparted. The findings related to these activities can be interpreted as the answers were associated with chemical change, which mostly have theoretical references, and therefore the justifications were performed through imparted theoretical school knowledge.

As a result, experimental activities performed with chemical substances that are not frequently seen in real life, in which a change of color occurs, should be included in the formal education and teaching processes during the instruction of physical and chemical change concepts. Moreover, chemical and physical reversibility phenomena should be a topic of observation in the activities featuring chemical and physical change. Regarding this type of activities, making the cyclicality of the process a topic of observation, accompanied with "what/how is the nature of the change" along with the indicators is quite important in terms of running pedagogical content knowledge. For example, using potatoes pieces, which is a natural source of starch, in iodine activities to test the presence of iodine molecule in the environment may be considered to fulfil such a responsibility. In this regard, the answers of the participating students related to the activities with bigger negative-consistency frequency, in other words answered incorrectly and consistently (PCQ10 and PCQ11) were based on the imparted justification implying that "in case of a change of color, chemical change occurs", support that they were referring to the textbooks used in the formal education system and the knowledge imparted by their teacher. The reason of this situation may be limited number of activities related to physical and chemical change and the time restriction in learning-teaching process.

The review of some books approved to be suitable for the science course curriculum proposed by Ministry of Education (MEB, 2013, 2017) in the light of the above discussion showed that all of them provide exercises based on the activities limited by daily life. Relevant textbooks contain physical change examples such as, fragmentation of sugar, cutting paper, melting of wax and ice; however, there is no activity indicating that a change of color may occur in a physical change process (Gökçe and Işık, 2017). Although Gökçe and Işık (2017) provided some examples related to change of color in the unit related to physical and chemical change (3rd Unit, p.104-111), the statements used create the impression that change of color indicates a chemical change. It was also observed that Gökçe and Işık (2017) used a didactic language in 6th grade science textbook. The experimental activities mentioned in the relevant work are still constructivist, close-ended and result-centered. It can be said that students were prevented to refer to micro-world using the evidences of macro-world (non-demonstrative evidence) by frequently referring to the particulate and atomic structure of the matter. The examples of physical change given in the 6th grade science textbook of MEB (2016) were limited with the examples from daily life and a didactic language was used. Some of the activities used in our study, namely the physical change activities concerning the formation of ethyl alcohol-iodine and chloroform-iodine solutions, the sublimation of iodine by heating and chemical change activities concerning the treatment of hygrometric paper with heat, are the activities referring to these shortcomings.

Abovementioned findings and interpretations are in line with the studies reporting that students accept melting and dissolution events as chemical change; it was found that they cannot justify "regaining criteria" of physical changes and "reversibility criteria" of chemical changes through the examples (Uluçınar Sağır, Tekin and Karamustafaoğlu, 2012; Yıldırım, Er Nas, Şenel and Ayas, 2007). These studies found that theoretical knowledge that participants have was not sufficient in explaining the questions or scenarios simulating chemical and physical change phenomenon and students referred to various alternative concepts (Demircioğlu et al., 2012). In a study conducted with primary school students, Kariper (2014) revealed that participants preferred physical change in the answers related to biological putrefaction, with which participants were not familiar, whereas some of them stayed reluctant. Participating students have referred to the change in the appearance of the matter while explaining the relevant finding. In the same study, participants have interpreted the change of color caused by ink drops added to the water as chemical change. The author explained this kind of answers with the low amount of experience that students had related to physical and chemical change and the failure to understand the structure of the matter properly.

Based on these explanations, the following knowledge should be taught in the formal education system related to the concepts of physical and chemical change; "in case of a physical change, when the impact made to a substance is over, the matter will turn to its original state, in other word its molecular structure will not be changed". In this regard, the review of the textbooks revealed that there is no experimental activity or modelling designed for this purpose. It was also seen that activities direct students to one-directional observation and there is no content providing data that the substances undergoing a physical change spontaneously return to their initial positions under the condition of the application (For example; Gökçe and Işık, 2017).

In general terms, it can be said that exemplification of the related changes through the substances like iodine, chloroform, ethyl alcohol and hygrometric paper, which are mostly found in laboratory environment, will make more contribution to increase and differentiate contextual diversity, and the achievement of meaningful learning. The answers of the participating students related to the activities with higher negative-consistency frequency (PCQ10 and PCQ11), in other words having cognitive consistency but giving wrong answers (misconceptions) and the activities with higher cognitive inconsistency frequency (PCQ9 and CCQ13), support the necessity of this regulation.

Another way of eliminating students' misconceptions related physical and chemical change is descriptive stories. Many studies in the literature reported that descriptive stories are effective in eliminating students' misconceptions about physical and chemical change (Ayvacı and Çoruhlu, 2009; Demircioğlu, Özmen and Demircioğlu, 2006). In PCQ10 and PCQ11 activities of the study, students exhibited a consistent cognitive structure and evaluated the change of color as a chemical change, which can be seen as an evidence showing that the activities in the textbooks are insufficient and they don't provide support for observation and data formation that will allow meaningful learning. In PCQ10 and PCQ11 activities students referred to the knowledge originated from the teacher and printed materials as can be seen in the quotations "…the color of the liquid was changed … and … eee the color is changing and it seems that different things happen in it". This knowledge constitutes imparted justification of student's answer. In this case, it can be suggested to develop descriptive stories to eliminate misconceptions. Regarding the effects of the experimental activities covered in our study on the formation of participating students' knowledge structure, it can be said that the activities used as data collection and cognitive analysis material allowed students to involve in the process cognitively, from the beginning to the end, as done by descriptive studies. Since several case studies are obtained from both daily life and laboratory environment through these activities, students encounter factual situations rich in terms of diversity. It can be suggested that relevant activities have a particular importance in terms of the contribution made to the reasoning skill of the students, in addition to guiding towards cognitively right answer.

Discussion of Experimental Activities in terms of Reversibility

Another knowledge that should be taught in the formal education system related to the concepts of physical and chemical change is; "when a substance underwent a physical change, and then the effect causing the change is eliminated, the matter will turn to its original state, in other word the property of "reversibility"". The studies in the literature reported that students at different level have misconceptions about the reversibility of physical and chemical change (Uluçınar Sağır, Tekin and Karamustafaoğlu, 2012). In this study, most of the participants evaluated the change of color as chemical change, which occurred in the activities coded as PCQ9, PCQ10 and PCQ11, executed with the chemical substances in a laboratory and a physical change occurred, which indicates that they were not aware of the "reversibility property of physical change". These findings refer that using both the substances from daily life and chemical substances and materials from the laboratory will be appropriate in teaching reversibility property of physical change. In this regard, it is a necessity to teach physical change in an experimental process where the activities such as PCQ1, PCQ2, PCQ3, PCQ6, PCQ8 and PCQ12, in which examples from daily life were exhibited and the activities such as PCQ9, PCQ10 and PCQ11 (Ergül, 2014), in which samples from the laboratory substances (such as iodine, ethyl alcohol, chloroform) were showed, takes place together. The observation of reversibility property in the relevant activities constitutes the most important dimension. This fact has a special importance in the activities where iodine crystals are used. So that the reversibility of the sublimation process where iodine crystals were heated, can be determined by observing the re-crystallization of the iodine in the tube by getting it to the room temperature. Regarding the activities where a change of color occurred, the presence of the iodine molecules in the environment as dissolved in ethyl alcohol and chloroform can be determined by using potatoes, which contains starch, and observing the indicator interaction of iodine-starch molecules. At this point it should be noted that PCQ9, CCQ13 are quite simple, since they can be practiced with a lighter of candle flame, whereas PCQ10 and PCQ11 can be realized at room temperature, which provides an opportunity suitable for teaching the reversibility property of physical change and chemical change. The reversibility property of physical changes may also be observed in case of chemical change where many dynamic equilibria are established. The discussion of reversibility property in chemical changes was excluded from this study because the cognitive level of 7th grade students was not appropriate according to the education that they have got up to now, as well as it was not included in the curriculum; thus, it will be analyzed in another study.

When a substance is heated, the followings may occur: only physical change, both physical change and chemical change and direct chemical change. In this study, it was found that most of the participants (16) gave inconsistent answers related to the experimental activity coded as PCQ9, in which sublimation and deposition events occurred by heating and cooling iodine consecutively. It was also found that most of the participants (13 people) gave inconsistent answers related to the experimental activity coded as CCQ13, in which heating operation was performed. In both experimental activities, coded as PCQ9 and CCQ13, heating operation took place and a change of color occurred at the end. In this regard getting mostly inconsistent answers for both activities, and basing these inconsistent answers on imparted justification is important and meaningful. According to the answers of the participants, the presence of the negative-consistent and mostly inconsistent answers while determining the type of the change in the activity coded as PCQ9 where physical change occurred in spite of the heating operation and in the activity coded as CCQ13 where chemical change occurred as a result of the heating operation, and imparted justifications are an indicator that the conceptualization process was based on knowledge-in-piece theory for the relevant concepts. As a result, science curriculum and textbooks should include activity examples where only physical change occurred at room temperature (PCQ10, PCQ11), as well as activity examples that both physical change (PCQ9) and chemical change (CCQ13) accompanied with a change of color occurred by heating.

The important factors that affect misconceptions while teaching a knowledge or a concept can be outlined as follows; the role and efficiency of the teacher in the classroom, the sufficiency of the relevant information and the activities in the books and the teaching methods used. In this regard, Kırbaşlar, Özsoy Güneş, Avcı and Atalar (2012), found that there were misconceptions in science textbooks at primary and secondary education levels; the examples were insufficient and even incorrect. They stated that the exemplifications of the source books mostly contained daily language and examples, which has triggered misconceptions. This finding supports the explanation about the misconceptions of the participants in the activities coded as PCQ9, PCQ10, PCQ11 and CCQ13, where they were faced with the examples that they didn't encountered in real life.

SUGGESTIONS

This study was conducted to determine whether 7th grade students' knowledge structure related to physical and chemical change concepts was shaped according to synthetic meaning theory of cognitive learning theory or knowledge-in-pieces theory, as well as the misconceptions. The results and suggestions offered in the light of this study, can be outlined as below:

It can be said that covering qualitative analysis methods and evidence-based activities in the content of the activities prepared for different contexts offered for physical and chemical change events may lead to get more consistent answers in the science education of the students at relevant cognitive level.

It can be said that a large proportion of misconceptions would be eliminated if the experimental activities that are supposed to be executed while teaching relevant concepts are carried out as an exhibition experiment in the classroom or as a hypothesis-testing experiment in the laboratory environment.

The misconceptions of participating students related to physical and chemical change are based on the qualitative knowledge given for the change of color.

The misconceptions of participating students related to physical and chemical change are based on the knowledge given for the impact of heating to the type of the change.

Science curriculum and source books should include at least one activity where only physical change occurs at room temperature, while observing a change of color (as in PCQ10, PCQ11).

Science curriculum and source books should include at least one activity where only chemical change occurs at room temperature, while observing a change of color.

Science curriculum and source books should include at least one activity where a heated substance underwent a physical change while observing a change of color (as in PCQ9).

Science curriculum and source books should include at least one activity where a heated substance underwent both a physical and chemical change (as in PC-CCQ4).

Science curriculum and source books should include at least one activity where only a chemical change occurred in a heated substance, while observing a change of color (as in CCQ13).

Experimental activities coded as PCQ1, PCQ2, PCQ3, PCQ9, PCQ10, PCQ11 and PCQ12 can be used to taught reversibility property of physical change, whereas CCQ13 can be used to taught reversibility property of chemical change within the context of science education.

The textbooks prepared according to science curriculum should be reviewed to eliminate students' misconceptions at relevant grade levels and to increase the diversity of the experimental activities.

New textbooks should be developed, in which the content of experimental activities are formed considering misconceptions and the diversity of the experimental activities is increased.

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