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Prospective Chemistry Teachers' Awareness of Students' Alternative Conceptions

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ABSTRACT

The aim of this study is to investigate prospective chemistry teachers' awareness of students' alternative conceptions, one of the components of pedagogical content knowledge, regarding the particulate nature of matter. An open-ended questionnaire was distributed to a class of 22 prospective teachers. In addition, semi-structured interviews were carried out with five students chosen according to their responses in the questionnaire. The questionnaire and interview results suggested that the majority of prospective teachers could reason about students' possible difficulties about the particulate theory in the context of phase changes. Their general pedagogical knowledge and learning experiences were influential for this awareness. This study has some implications for teacher education programs.

Keywords: Pedagogical Content Knowledge; Particulate Nature of Matter; Alternative Conceptions.

INTRODUCTION

In this article, we discuss the results of a research concerning prospective chemistry teachers' awareness of students' alternative conceptions about the particulate nature of matter in the context of phase changes. This discussion is broken down into three main sections. Firstly, we present an evaluation of the research reports and theoretical papers that deal with subject matter knowledge, pedagogical content knowledge and students' alternative conceptions about particulate theory. Secondly, research methods we used in this study are explained. Finally, we discuss our research findings and make some recommendations in the light of these findings.

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a) Students' Alternative Conceptions about the Particulate Nature of Matter

Particulate nature of matter is one of the basic topics in chemistry. It is commonly agreed that other chemistry topics can be explained by the use of particulate nature of matter. Several studies have been carried out to find out pupils' views about the particulate theory at primary and secondary levels (Novick & Nussbaum, 1981; Brook, Briggs & Driver, 1984; Pereira & Pestana, 1991; Griffiths & Preston, 1992**;** Abraham, Williamson & Westbrook, 1994**;** De Vos & Verdonk, 1996**;** Harrison & Treagust, 1996**;** Nakhleh & Samarapungavan, 1999; Boz, 2006; Özmen & Kenan, 2007; Ayas, Özmen & Çalık, 2010); and at tertiary levels with prospective science teachers (Gabel, Samuel & Hunn, 1987; Kruger & Summers, 1989; Ayas, Özmen & Çalık, 2010).

These research findings revealed the difficulty of many primary and secondary school students in understanding the term "particles". It was found that students used the word "particles" to indicate small pieces rather than atoms, ions or molecules in science classes (Brook, Briggs & Driver, 1984; Boz, 2006). Furthermore, research findings showed that students had alternative views about the particulate nature of matter such as the application of macroscopic ideas to the particles, arrangement of particles in solids, liquids and gases such as non-existence of forces between particles in the solid state, and lack of comprehension of the intrinsic motion of particles (Brook, Briggs & Driver, 1984; Gabel, Samuel & Hunn, 1987; Griffiths & Preston, 1992**;** Abraham, Williamson & Westbrook, 1994**;** De Vos & Verdonk, 1996**;** Harrison & Treagust, 1996; Boz, 2006; Özmen & Kenan, 2007; Ayas, Özmen & Çalık, 2010; Adadan, Irving & Trundle, 2009; Adbo & Taber, 2009; Tsitsipis, Stamovlasis, & Papageorgiou, in press). Moreover, many students were found to hold the view of change in sizes of molecules across different phases (Gabel, Samuel & Hunn, 1987; Pereira & Pestana, 1991; Griffiths & Preston, 1992; Valanides, 2000; Özmen & Kenan, 2007).

In addition, research findings indicated that many students were hesitant to use the particulate theory to explain phase changes, solutions etc. (Abraham, Williamson & Westbrook, 1994; Brook, Briggs & Driver, 1984; Haidar & Abraham, 1991; Boz, 2006; Ayas, Özmen & Çalık, 2010). For example, Abraham, Williamson and Westbrook (1994), who examined 9th, 11th and 12th grade students' explanations about the reason for the constant temperature of ice during melting, found that only 2% of 9th, 5% of 11th and 6% of 12th grade students referred to the particulate nature of matter in their explanations.

To sum up, it can be said that students at various ages find it difficult to understand the particulate nature of matter. In particular, they have difficulties in understanding even the term "particles", the nature of the space between particles, applying the particulate theory to explain macroscopic concepts.

b) Subject Matter Knowledge

Subject matter knowledge is defined as the knowledge necessary to understand facts, ideas, theorems, scientific definitions, concepts, procedures and connections among them in a discipline. As Ball (1988) points out it also refers to "the nature of knowledge in the discipline— where it comes from, how it changes and how truth is established…" (p. 4).

Shulman (1986) states that teachers need to have two kinds of understanding of the subject-matter, which are "*knowing that*" and "*knowing why*".

> We expect that the subject-matter content understanding of the teacher be at least equal to that of his or her lay colleague, the mere subject-matter major. The teacher need not only understand *that* something is so; the teacher must further understand *why* it is so (Shulman, 1986, p.9).

"Knowing that" is the most basic level of subject matter knowledge. "Knowing why", on the other hand, refers to the knowledge which is related to the underlying meaning and understanding of why things are the way they are.

c) Subject Matter Knowledge in the Context of This Study

We want to define the subject matter knowledge of the particulate nature of matter in the context of phase changes considering two levels of Shulman's distinction. The first one constitutes 'knowing that' level and it is a combination of the following aspects:

- knowing the term "particle",
- knowing the arrangement and behavior of particles in three different states of matter, and
- knowing the change in the arrangement of particles during temperature rise and phase changes.

The above list may not be complete; however, it could give an answer to the question what we mean by 'knowing that' level of subject matter knowledge in this context. The 'knowing why' level, on the other hand, is the knowledge that explains the underlying reasons of the aspects listed above. For example, if we took out some ice from the refrigerator, and record the temperature every minute, we would observe that the temperature of ice increases from -10^{0}C to 0^{0}C, and that the temperature remains constant for a while at 0^{0}C. The underlying reasons for this constant temperature can be explained as a combination of different kinds of knowledge.

First of all, if we know that matters are composed of particles, which can be considered as 'knowing that' type of knowledge, then we can use such knowledge to explain the reasons for constant temperature at 0 ^{0}C. For example, as the temperature rises, the ice begins to melt. The amount of heat required to melt the ice is called the *latent heat of fusion.* Until all the ice melts, the temperature remains constant at 0^{0}C. At this point, we can make use of the knowledge that says matters are composed of particles and the arrangement and behaviors of these particles change while the matter enters into a new phase: During phase change process, the bonds between the particles are beginning to break, when the ice begins to become water. The process of breaking the bonds requires large amounts of heat. The reason that the temperature remains constant at 0^{0}C is because all the heat goes to break the bonds, neither to increase the movement of the molecules nor to increase the temperature of the system. Once all the bonds are broken and the particles are now free to move, further addition of temperature rise, continues to increase the motion of water molecules. Giving such explains in a way reveals also the ability to apply the knowledge in the 'knowing that' level in order to explain the phenomena in real world. Therefore, 'knowing why' is important to reason about the events that take place around us.

To sum up, in this study we used Shulman's definition of SMK which includes both knowing facts, procedures, rules and also the reasons that explain the knowledge in 'knowing that' level.

d) Pedagogical Content Knowledge

PCK is defined as a "special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding" (Shulman, 1987, p. 8). This amalgamation is revealed by Shulman (1986) as "in a word, the ways of representing and formulating the subject that makes it comprehensible to others" (p.9), and he goes on to write that it includes:

> Pedagogical content knowledge also includes an understanding of what makes the learning of specific topics easy or difficult; the conceptions and preconceptions that

> students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons (p. 9).

This definition suggests that the awareness of students' conceptions and difficulties is included in the definition of PCK. In other words, teachers should be aware of students' difficulties in order to make the subject matter more comprehensible for students. This is also supported by the study of Van Driel, Verloop, and De Vos (1998), who examined the effect of in-service workshop on chemistry teachers' development of their PCK. The aim of the workshop was to provide chemistry teachers with an understanding of students' difficulties and alternative conceptions about the chemical equilibrium topic. It was found that chemistry teachers' awareness of students' difficulties led to the development of their PCK into a more communicative way for students.

Various studies also supported the effect of teachers' awareness of students' conceptions and their reasoning on the improvement of their PCK (Lederman, Gess-Newsome, & Latz, 1994; Geddis, 1993; Boz & Boz, 2008). However, it should be noted that PCK was not developed among the teachers in the same way since various factors, e.g., teachers' beliefs about the nature of teaching/learning science, their subject matter knowledge influenced this development. To clarify, differences in subject matter knowledge that teachers possess led to differences in PCK (Van Driel, De Jong & Verloop, 2002; Grossman, 1990).

In the literature, many factors, such as a teacher's past learning experiences as a student as well as teaching experiences as a teacher (Grossman, 1990; Van Driel, Verloop & De Vos, 1998; Van Driel, De Jong & Verloop, 2002; Boz & Boz, 2008), and their subject matter knowledge related to the subject they teach (Van Driel, Verloop & De Vos, 1998; Rollnick, Bennett, Rhemtula, Dharsey, Ndlovu, 2008; Kaya, 2009; Aydin, Boz & Boz, 2010; Karakulak & Tekkaya, 2010) were found to be influential in teachers' pedagogical content knowledge. Smith and Neale (1989) indicated the necessity of a coherent content knowledge for an effective PCK. Moreover, general pedagogical knowledge was found to influence teachers' PCK (Sanders, Borko, & Lockard, 1993; Boz & Boz, 2008; Nilsson, 2008). General pedagogical knowledge involves knowledge about learning theories, instructional principles, how students learn, how to motivate students, how to provide classroom management (Morine-Dershimer & Kent, 1999). As inferred from the definition, teachers who have deficient general pedagogical knowledge, e.g. how to motivate students, provide classroom management, would not probably be so successful in order to make the subject matter more comprehensible for students. In other words, their PCK would be inadequate (Smith & Neale, 1989; Marek, Eubanks & Gallaher, 1990).

All the above discussions indicate that there are various factors affecting the PCK, one of which is the knowledge of students' conceptions. Though various studies were conducted about students' and teachers' conceptions of different chemical concepts (Haidar & Abraham, 1991; Griffiths & Preston, 1992; Garnett & Treagust, 1992; Schmidt; 1991; Hackling & Garnett, 1985; Banerjee, 1995; Coll & Treagust, 2003), few studies exist about prospective teachers' awareness of students' conceptions about different chemistry concepts, such as chemical equilibrium (Van Driel, Verloop & De Vos, 1998), macroscopic and microscopic, combustion (De Jong et al, 1999), and separation of mixtures (Aydin et al, 2010).

The purpose of this study is; firstly, to investigate prospective chemistry teachers` subject matter knowledge related to particulate nature of matter in the context of phase changes, secondly examine pedagogical content knowledge as well as the sources of PCK in the context of awareness of students' conceptions and difficulties. Research questions for this aim are as follows:

a) What is the prospective chemistry teachers' subject matter knowledge about particulate theory in the context of phase changes?
b) What is the prospective chemistry teachers' awareness of students' alternative conceptions about particulate theory in the context of phase changes?
c) Which factors may influence the prospective chemistry teachers' awareness of students' alternative conceptions?

METHODOLOGY

a) Sample

The data were collected from 22 prospective teachers attending the fifth year of a chemistry education program of a university in Turkey. Of 22 students, 13 were female; nine were male. Since they were in their final year of their program, most of the students took pedagogical courses such as Introduction to Teaching Profession, Development and Learning, Instructional planning and Evaluation in Teaching, Methods of Science Teaching, Instructional Technology and Material Development, Classroom Management, School Experience I, and School Experience II. In the school experience I and II courses, students made some observations and group activities at schools in order to gain field experience and teaching practice. They were taking Teaching Practice course where they were supposed to teach for about 20 hours in high schools at the time of this study was carried out. After graduation, these prospective chemistry teachers were supposed to teach chemistry in high schools in Turkey.

b) Instruments

An open-ended questionnaire was distributed to prospective chemistry teachers. The questionnaire involved four questions about the particulate nature of matter within phase changes. Two of these questions were asked to measure prospective teachers` subject-matter knowledge, whereas two questions were asked to understand prospective teachers` awareness of students` alternative conceptions, which is one of the components of PCK.

c) Questions

Consider that you asked the following questions to the high school students. You noticed that some students had some alternative conceptions even though they have already learnt the subject. Please indicate your response as well as your students' possible alternative conceptions for the following questions.

1. Ayşe heated the ice with the initial temperature of -10^0C, taken from the refrigerator and she took the temperature every minute. Then she plotted the graph below.

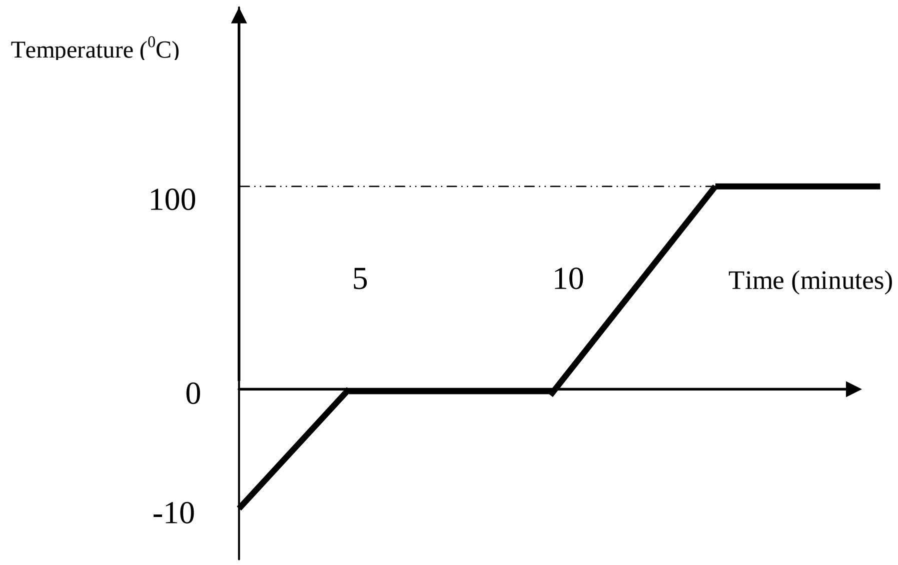

Figure 1. *Ayşe's Temperature-Time Graph for Melting Ice*

a) What do you think what will happen to the particles of the ice as the temperature increases from –10 ^{0}C to 0 ^{0}C?
   - What kind of possible alternative conceptions would you expect students to have about this question?

b) What may be the reason of constant temperature at 0 ^{0}C?
   - What kind of possible alternative conceptions would you expect students to have about this question?

In addition to questionnaires, semi-structured interviews were carried out with five prospective teachers. The aim of the interviews was to obtain deeper understanding of prospective chemistry teachers' written responses in the questionnaire. Therefore, interview questions were based on participants' written responses and involved questions as "Why did you think like that?", "Could you please explain your reasons?"

FINDINGS

a) Analysis of the Questionnaires

In terms of questions related to subject matter knowledge, analysis of the prospective chemistry teachers` responses in the questionnaire indicated that all prospective teachers correctly explained the arrangement of particles when temperature is raised from -10 ^{0}C to 0 ^{0}C. All prospective teachers mentioned that space between particles of ice or the speed of particles would begin to increase when the temperature increased from –10 ^{0}C to 0 ^{0}C. Moreover, nineteen prospective teachers considered the particulate nature of matter to explain the reason for constant temperature at 0 ^{0}C during melting of ice. To clarify, nineteen prospective chemistry teachers considered the bonds between particles of ice to explain the reason of constant temperature at 0 ^{0}C during ice melting. On the other hand, three prospective chemistry teachers told that ice would begin to melt to explain the constant temperature.

For the analysis of questions related to PCK, specifically, knowledge of students' difficulties, fourteen prospective chemistry teachers wrote that students could not think about particles of the ice in order to explain the arrangement of particles of ice during temperature rise from 10 ^{0}C to 0 ^{0}C. The rest of them (8) thought that students could explain the ice particles would melt during the increase of temperature from –10 ^{0}C to 0 ^{0}C. On the other hand, for the explanation of the reason for constant temperature during melting ice, twenty of the prospective teachers mentioned that students could say that heat given was decreased or finished whereas two prospective teachers did not give any response to this question. As can be understood, most prospective teachers thought that students could not consider the particulate nature of matter and would give macroscopic explanations.

For reliability of the study, one of the authors and a chemistry educator categorized prospective teachers' written responses independently. Afterwards, two colleagues came together and compared their categories. It was found that there was a complete match between these, indicating the high reliability.

In addition to written responses, five prospective teachers were interviewed individually. Interviewees were selected in order to represent the participants, whose written responses were under different categories. In this article, we will focus on the interview results of two prospective chemistry teachers, Ceren and Deniz. Ceren is one of the student teachers, who represent the majority of responses given in the questionnaire. Deniz is the prospective teacher who gave macroscopic explanations for the constant temperature at 0^{0}C during ice melting; she told that ice began to melt therefore the temperature was constant. Similarly, Deniz thought that students would mention melting of ice particles when the temperature of ice was increased from 0^{0}C to -10^{0}C. It can be said that Deniz represents other responses given in the questionnaire rather than Ceren does.

b) Analysis of Interview Data

i) The Case of Ceren

Ceren is one of the prospective teachers in her final semester of the chemistry education programme. She completed her chemistry courses and took some pedagogical courses such as 'Introduction to Teaching Profession', 'Development and Learning', 'Instructional planning and Evaluation in Teaching', 'Methods of Science Teaching', 'Instructional Technology and Material Development', 'Classroom Management', 'School Experience I', and School Experience II. Her grades were above BB, which is above average. Ceren made double in Chemistry department; that is, she took more chemistry courses than most participants did. She was more interested in chemistry rather than chemistry education. However, her grades in pedagogical courses were about average. She mentioned in classes that she wanted to get involved in chemistry rather than being a teacher.

For the question 1a, Ceren mentioned an increase in the movement of particles as well as an increase of space between particles in ice as the temperature of ice increases from –10 ^{0}C to 0 ^{0}C. She wrote in the questionnaire that most students could not think of particles in ice and probably would write that ice would melt when the temperature of ice increased from –10 ^{0}C to 0 ^{0}C. When asked the reason of her thought, she gave the following explanations;

> Students would think of ice instead of particles in ice, since in high schools, I know from myself as a student, phase changes topic is usually mentioned in terms of macroscopic properties, particles are not mentioned. Therefore, students understand the macro level of chemistry.

Her experiences as a student in high school helped her have an opinion about the way phase changes topic is taught in high schools. The way phase changes topic was taught in high schools was influential in analyzing the reasons for students' difficulties. Ceren also mentioned another alternative conception that students might have was that ice would melt completely when the temperature increased from –10 ^{0}C to, and at 0 ^{0}C ice was completely liquid. Ice would immediately melt when the temperature increases to 0 ^{0}C".

When asked what would happen if the temperature increased to -5^{0}C instead of 0 ^{0}C, Ceren mentioned that students would not think that ice would melt in this case.

> R: why do students think like that?
> H: Since melting point of ice is 0 ^{0}C, they think that ice will melt when temperature increased to 0 ^{0}C. I used to think like that in high school. Students do not understand that there will be some ice at 0 ^{0}C.

This transcript indicates that herown thinking as a student in high school was influential in analyzing students` alternative conceptions. This finding adds support to the claim that a teacher's own experiences, both as a learner and as a teacher, influence PCK (Even & Tirosh, 1995; Wilson *et al*, 1987).

For the question 1b, Ceren wrote that heat energy would be used to break the bonds between particles of ice to explain the constant temperature at 0^{0}C. When asked about the possible mistakes students could make for the explanation of constant temperature at 0^{0}C, Ceren mentioned that students would assume the finish or decrease of heat. She explained her reasons for this:

> R: why do you think students will probably mention the finish or decrease of heat?
> H: this concept is too abstract for students. They cannot visualize particles to explain this. Instead, they look at the graph and may tell that heat is finished.

The above transcript indicates that Ceren uses her general pedagogical knowledge which is that the abstract concepts are difficult to visualize in order to reason about students' difficulties in learning particulate theory. In addition, she comments on students' ways of thinking, their difficulties in interpreting graphs. This shows that Ceren knows about possible difficulties of students in their journey to learn particulate theory. Some of this knowledge is produced from her learning experiences, and some of them from her general pedagogical knowledge. She amalgamates all these types of knowledge to develop her PCK.

ii) The Case of Deniz

Deniz was the classmate of Ceren. Like Ceren, she took the same pedagogical courses. However, she took less chemistry courses than Ceren did. Deniz can be considered as an average student both in terms of her grades in these courses and her performance in classes.

Deniz told that the distance between particles of ice would increase when we asked her what would happen to the particles of ice when temperature increased from -10^{0}C to 0^{0}C. Like some prospective chemistry teachers, she had similar thoughts about students` possible explanations for this question and her general pedagogical knowledge stating the difficulty of students in visualizing abstract concepts was one of the sources for her knowledge about students' conceptions:

> Students will say that ice particles will melt as soon as the temperature increases. Students cannot think of particles as inner structure of matter since it is abstract topic, instead they perceive that they are part of ice. Therefore, when ice melts, students think particles melt as well.

Deniz also mentioned that students' daily life experiences would cause them think that rise in temperature causes melting.

R: What would students think would happen to ice when the temperature increases to -5^0C instead of 0^0C?
D: They will still think of melting. When there is temperature raise, students will think that ice will melt. Because they see that when ice is taken from refrigerator, it melts.

For the question 1b, she explained the reason of constant temperature during melting by giving macroscopic explanations such as ice begins to melt at 0^0C. When we gave her clue about the usage of particulate theory in her explanations, she could not explain the reason for constant temperature; instead, she only described the arrangement of particles during melting ice.

R: you wrote that ice changes phase at 0^0C and begins to melt. Therefore, temperature is constant at 0^0C. Could you please explain the reason for constant temperature by considering the particles?
D: at 0^0C, ice starts to change phase and due to phase changes, temperature does not increase. Distance between particles increases during melting. Temperature does not increase, distance between particles increases. I cannot think now why distance between particles increases.

Interview with Deniz indicates that her subject matter knowledge is at *knowing that* level. She cannot relate the microscopic properties of matter to explain the reason for constant temperature during melting of ice.

On the other hand, she did not believe the use of particulate nature of matter to explain events related to phase changes; “I think it is not necessary to use the particulate theory to explain phase changes since it may confuse students` minds since it is too abstract and difficult to visualize” Her general pedagogical knowledge, which is that abstract concepts are difficult for students to visualize, affects her belief about the usage of particulate theory in phase changes. We may suggest that she did not give importance to use particulate theory to explain macroscopic events since she, herself, does not believe the necessity of it. This may imply that one’s beliefs have an influential effect on the development of their subject matter knowledge.

As possible explanations of students for the explanation of constant temperature at 0^0C, Deniz mentioned that most students would probably think that no heat was given any more:

Students will probably explain the reason for constant temperature in terms of no heat given. They will seek for relationship between heat and temperature. No heat, then constant temperature, they would think. I have a sister and I teach her and I know from her, she thinks like that.

This indicates that her sister’s reasoning for the constant temperature at 0^0C influenced her decision about students` possible explanations for this question. This is another evidence to teacher’s own experiences is one of the factors influencing PCK.

The interview data presented so far shows that different kinds of knowledge would be influential to reason about students’ difficulties and alternative conceptions about a topic. It was also inferred that personal beliefs, in this study, not believing the necessity of particulate nature of matter, may also have an affect on both prospective teachers’ subject matter knowledge and pedagogical content knowledge, since such feelings affect the way teachers teach.

DISCUSSION

In this paper, prospective chemistry teachers' subject matter knowledge and their awareness of students' difficulties in understanding the particulate nature of matter within phase changes were investigated. It was found that most prospective teachers' subject matter knowledge was sufficient. However, approximately 14% of the participants (three out of 22) still had difficulties in applying the particulate theory for the explanation of constant temperature during melting. This means that their subject matter knowledge is still at *knowing that* level.

Moreover, the questionnaire and interview results suggest that the majority of prospective teachers could reason about students' possible difficulties about the particulate theory in the context of phase changes. Most prospective teachers told that students would give macroscopic explanations such as 'Heat is not given any more' rather than using particulate theory to explain the reason for the constant temperature at 0^0C. In addition, most prospective teachers mentioned the difficulty of students to visualize ice particles as inner structure of ice. For this reason, prospective teachers told that students would not think of particles at all or apply macroscopic properties to ice particles, e.g. 'ice particles melted' to explain what would happen to ice particles when temperature is increased from -10^0C to 0^0C. The attribution of the macroscopic properties of substances to the particles by children have also been documented by Brook, Briggs, and Driver (1984); Novick and Nussbaum (1981); Andersson (1990); Griffiths and Preston (1992), Boz (2006); Özmen and Kenan (2007); Ayas, Özmen and Çalık (2010) and Tsitsipis, Stamovlasis and Papageorgiou (in press). Similarly, most prospective teachers mentioned that students would think that heat is not given any more or heat is finished off. Similar conceptions (finish or decrease of heat given) are found by Abraham, Williamson and Westbrook (1994).

When we elaborate on the underlying reasons of prospective teachers' awareness of students' difficulties during interviews, we find that, mostly, teaching/learning experiences are the main factors for this awareness. For example, Deniz was aware of students' possible difficulties and tutoring students about particulate theory was influential to obtain such kinds of knowledge. On the other hand, Ceren's learning experiences as a student generally formed the source for her knowledge about students' conceptions. These findings support the claims that are put forward in the literature (Even & Tirosh, 1995; Wilson *et al*, 1987). In addition to teaching/learning experiences, general pedagogical knowledge was found as another source for prospective teachers' knowledge about students' difficulties. As the general pedagogical knowledge, both Deniz and Ceren mentioned that intangible concepts are difficult to learn. Moreover, our findings also showed the importance of personal beliefs on PCK. For example, Deniz, who does not believe the necessity of using particulate theory in explaining macroscopic events, did not refer to the particulate theory while explaining the reason for constant temperature during melting of ice. Her belief may have influenced her subject matter knowledge, and as a teacher, in the future, she would not encourage students to use particulate nature of matter, so we can say that personal beliefs would influence in shaping up teachers' PCK, which is also supported by literature (Morine-Dershimer & Kent, 1999).

CONCLUSION and RECOMMENDATIONS

In the light of the findings, we could recommend that students' possible alternative conceptions should be discussed in teacher education programs as well as prospective teachers should be given enough teaching experiences since one of the factors affecting PCK was found to be teaching/learning experiences. Moreover, since some prospective teachers' subject matter knowledge was found to be insufficient, another implication may be that prospective teachers should graduate the faculty with sound subject matter knowledge. In this respect, subject matter knowledge should be taught in a way to enhance prospective teachers' conceptual understanding in teacher education programs. This study revealed the prospective teachers' knowledge about students' difficulties. However, the important thing here is whether one uses such knowledge in helping students to learn the concept. If so, it is crucial to identify whether that person knows the ways of using such knowledge to foster students' learning. Therefore, we recommend a study which examines how 'knowledge about students' component of PCK is made of use by teachers; when and where they use it. Furthermore, are there any other factors in using such knowledge to foster pupils' learning? For example, what is the influence of pedagogical reasoning in using 'knowledge about students' component of PCK at some point of the lesson?

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