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PRE-SERVICE SCIENCE TEACHERS' CONCEPTIONS OF THE "CONDUCTION OF HEAT IN SOLIDS"

Tülay Şenel Çoruhlu

Abstract: *There has been various researchers focus on "heat transfer". "Convection, radiation and conduction" discussed as mere elements of the wider object of analysis in these research. Given the lack of sufficient emphasis on conduction in solids, no cross age research conducted with pre-service science teachers supported by drawings, interviews, and open-ended questions could be found. Employing a cross-age design, this research determined pre-service science teachers' (PSTs') conceptions in the "conduction of heat in solid". The sample group of the research consists of 257 PSTs (first year student-n=55; second year student-n=76, third year student-n=56, and fourth year student-n=70) selected from Department of Science Education in Fatih Faculty of Education at the Karadeniz Technical University in the city of Trabzon in Turkey. Conceptual understanding test and semi-structured interview were used in the data collection process. The test including two questions was administered to 257 PSTs from different years. Semi-structured interview including one question was conducted with 16 voluntary PSTs (4 students from each grade level). The research found that PSTs had difficulties in terms of describing and showing the movement of the particles of solid under the impact of heat. In the light of the findings, it can be suggested that animations should be used to the teaching of the movement of the particles under the impact of heat.*

Keywords: *cross-age study, conduction of heat in solid, pre-service science teachers.*

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Introduction

The exchange of heat through space or material medium is called "heat transfer". Heat transfer can be provided in three ways: conduction, convection and radiation. All these ways need the existence of a temperature difference (Cengel, 2007). Heat transfer is associated with the heat, temperature and energy. A review of the existing literature reveals that there are many studies aiming to identify misconceptions students of various grades may have with respect to the concepts of heat/temperature (i.e., Alwan, 2011; Brook, Bringgs, Bell & Driver, 1984; Carlton, 2000; Harrison, Grayson & Treagust, 1999; Jasien & Oberem, 2002; Kesidou & Duit, 1993; Leong Wong, Chu & Chin Yap, 2016; Thomaz, Malaquas, Valente & Antunes, 1995) and energy (Amettler & Pinto, 2002; Kaper & Goedhart, 2002; Soloman, 1985; Stylianidou, Ormerod & Ogborn, 2002). A prerequisite of teaching the concept of heat transfer to students is an accurate description of the relationships between the concepts of heat, temperature and energy.

An understanding of heat transfer, and particularly conduction, requires insight into the particle-based structure of matter at secondary schools. Yet, in this perspective, one may come across microscopic-level misconceptions of the students from the elementary school to university level, regarding conduction. Against this background the need to identify how PSTs, who are set to play a significant role in science teaching to future generations, imagine conduction at particle level, becomes crucial. A glance at the studies performed at the university level suggests that "convection, radiation, and conduction" as the means of heat transfer have always been discussed en masse. Yet, there are no studies which try and determine the views PSTs in different years of training have with respect to each mode of transfer. According to Lubben, Netshisaulu & Campbell (1999), students believe that the specific modes of heat transfer were essentially similar concepts, and that the atoms comprising the matter would undergo changes such as melting-disintegration and merging during heat transfer. The research also revealed that the students do not have sufficient knowledge about conduction, and that they had misconceptions such as wood would not conduct heat. Brook et al. (1984) found that students confused conductivity of heat and electricity. Jacobi, Martin, Mitchell & Newell (2004), in a research on the modes of heat transfer, found that the students had difficulty comprehending the difference between conduction in metals, and heat transfers involving liquids and gases, and that they believed the dissipation of heat in solids occurred through the

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movement of atoms, as is the case with liquids and gases. Pathare & Pradhan (2010) investigated the misconceptions 57 undergraduate students in India had about the modes of heat transfer and kinetic theory. The research analyzed conduction, convection, and radiation not as distinct objects, but mere elements of a general topic, and reached to general results. Tanahoung, Chitaree and Soankwan (2010) reviewed the conceptual structures first year university students have with respect to the concepts of heat and temperature. Most students were found to fail to define the concepts of temperature, heat, phase transition enthalpy, specific heat capacity, and thermal equivalence in an accurate manner. Moreover, the students were observed to have only an incomplete grasp of heat transfers, and fail to provide accurate descriptions of the matter. All these studies were found to discuss "convection, radiation and conduction" as mere elements of the wider object of analysis, and not as distinct objects of interest. Given the lack of sufficient emphasis on conduction in solids, no developmental studies supported by drawings, interviews, and open-ended questions could be found. This state of affairs once again emphasizes the necessity of the present research.

An understanding of conduction of heat in solids requires insight into the particle-based structure of solids. Existing literature in the field, particularly the one focusing on the particle-based structure of matter, notes various misconceptions on part of the students, with respect to such particle-based structures (Adadan, Trundle & Irving 2010; Adbo & Taber 2009; Ayas & Özmen, 2002; Ayas, Özmen & Çalık, 2010; Johnson 1998; Kokkotas, Vlachos & Koulaidis 1998; Nakhleh, Samarapungavan & Sağlam 2005; Özmen, Ayas & Coştu 2002; Pozo & Gomez Crespo 2005). The samples involved in these studies focus mostly on primary (Johnson 1998; Nakhleh et al., 2005; Özmen, 2011; Pozo & Gomez Crespo, 2005) and secondary (Adadan et al., 2010; Adbo & Taber 2009; Ayas & Özmen, 2002; Ayas et al., 2010; Pozo & Gomez Crespo 2005) education. For instance, Adbo & Taber (2009) carried out a research to understand the mental models 16 years old students have with respect to the particle-based structure of matter. The research found that the students described the inertness of solid objects in connection with the static state of their particles. The studies at the university level, on the other hand, are found to be limited in numbers (i.e. Ayas, Özmen & Çalık, 2010). Özmen (2013) carried out a literature review on 79 studies performed in the last 30 years, on the particle-based structure of matter. The review revealed that open ended and multiple choice questions as well as interviews were the most popular data gathering tools in the literature. The present research enables a detailed analysis at the microscopic level, of the movement of the particles of solids under the impact of heat. The research will investigate the views PSTs at various years of education have with respect to the matter. This is considered as a means for taking concrete steps to eliminate the misconceptions PSTs may have. The aim of this research is to determine PSTs' conceptions of the "conduction of heat in solids". The following research question guides this research: How do the PSTs' conceptions of conduction of heat in solid change over year?

Methodology of Research

General Background of Research

The research is carried out as a cross-age study, which refers to a specific type of developmental research. In developmental research; students' conceptions across time may be investigated in cross-age and longitudinal studies (e.g. Abraham, Williamson & Westbrook, 1994). Longitudinal studies may require a lot of time, since researchers conducted long term study with the same sample group (Çepni, 2010). Cross age studies are preferred option for quick access to data (Babbie, 2009; Cohen, Manion & Morrison, 2007; Jackson, 2009). Cross-age studies allow researchers to use time effectively (Çepni, 2010). Cross-age studies also persuade researchers for describing the understanding about a particular concept held by students from kindergarten until university education (Ruane, 2005). There have been numerous researchers prefer to use cross-age studies in the literature (i.e. Çalık, 2005; Çalık, Turan & Coll, 2014; Çepni & Keleş, 2006; Prokop, Usak, Özel, Fančovičová, 2009; Yen, Yao & Chiu, 2004). In this research; it was preferred a cross-age study to provide insights into 257 pre-service science teachers, at different grade in the university. This research was conducted in the fall semester of the 2014–2015 academic year. Pre-service science teachers take chemistry courses in grade 11 before the university education. When pre-service science students graduate from the university they become science teachers at grades 5-8. They teach "particulate structure of solid", "heat", "energy" and their relationship between each other. Determining the conceptions of the "conduction of heat in solid" held by PSTs' gain importance at this point. With the help of such research, concrete steps will be taken to remedy PSTs' non-scientific concepts.

The Context of the Research

Students firstly introduce the concept of the "solid" within the "Matter and change" unit in grade 4 (Getting to know the matter) curriculums (MoNE, 2004a). Students learn macroscopic structure of the matter. They learn microscopic structure of the matter within the "Particulate structure of matter" unit in grade 6 (Matter and change) curriculum (MoNE, 2004b). Students learn relationship between matter and energy within the "Chemistry and energy" unit in grade 11 (MoNE, 2011). Students learn the concepts "Heat, mechanical work, internal energy, entropy, internal energy, and the laws of thermodynamics" in this unit. The PSTs take the "General Chemistry I-II" and "General Chemistry lab. I-II" course in the fall and spring semester of first year of the university. Students learn 'solid matters' structure in macroscopic and microscopic' in depth with these courses. When they graduate from the university, students take nation-wide exam called 'Public Personnel Selection Exam (Kamu Personeli Seçme Sınavı)' employed in the state schools. They answer questions related to the General Chemistry in the exam.

Participants of the Research

The research was carried out with 257 PSTs (first-year student-n=55; mean age: 19.3; 49 females and 6 males; second-year student-n=76, mean age: 20.2; 50 females and 26 males; third-year student-n=56, mean age: 21.5; 36 females and 20 males; and fourth year student-n=70, mean age: 22.4; 47 females and 23 males) attending the enrolled at department of science education in a city of Trabzon in Turkey. It was decided that participation was based on voluntariness. Pre-service science teachers who did not want to participate in the research were not included in the sample group. Therefore, 257 voluntary PSTs participated in this research. They all took chemistry course in grade 11. The sample of the research socioeconomically came from low and medium income families.

Data Collection

Conceptual understanding test and semi-structured interview were used in data collection process. The test asked students two questions (See Appendix) and developed by the researcher. The first question provided one daily life example regarding the conduction of heat, and asked an explanation for the case thus described, while the second question asked students to draw a figure describing the transfer of heat in solids. The drawings are useful tools to reveal the level of comprehension by not constraining the student's response, in cases where interviews and open ended questions are not helpful (Çepni, 2010). The pilot application of the test was carried out with 8 pre-service science teachers (2 students from each year). The pilot research helped find out how much time to allocate for the test, and assess the comprehensibility of the questions.

The semi-structured interview was carried out with a total of 16 PSTs. 4 PSTs who volunteered for each year of education participated as interviewees. Individual interviews were conducted by the researcher. Semi structured interviews were conducted one-to-one. The interview intended to carry out a detailed review of the conceptual transformation of PSTs. The interview was based on the question *"When you stir your tea for a while using a tea spoon, you would notice your heat getting warmer. How does the tea spoon transfer heat to your hand? What can you say to explain this process?"*. The pilot application of the interview took place with 4 pre-service science teachers (1 PST from each year). The preliminary interview asked two questions: The first question was *"When you stir your tea for a while using a tea spoon, you would notice your heat getting warmer. How does the tea spoon transfer heat to your hand? What can you say to explain this process? Please explain"*. The second one asked "*How does heat transfer in solids take place? Please explain*." As the interviews were observed to give answers similar to those they gave for the first question, the second question was removed in actual application, to eliminate redundancy. The pilot research revealed that each interview took 10-15 minutes. Interviews were recorded by the researcher.

Data Analysis

Content analysis was utilized for the analysis of interview responses. The content analysis is summarized in four stages; (1) encoding of data, (2) finding of, (3) organization of codes and themes, (4) interpretation of findings (Yıldırım & Şimşek, 2013). These stages were taken into consideration of the interview analysis. Individual interviews transcribed and then analyzed. Each PST's responses was evaluated and then compared with each other. 2 main

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codes–macroscopic and microscopic– were developed with reference to the statements PSTs provided in the interview. The examples of the statements PSTs provided, within each 2 codes, are quoted directly in the findings section.

The responses PSTs provided to the first question of the conceptual understanding test were analyzed with reference to Marek's (1986) classification. Complete understanding was letter coded A, while partial understanding was coded B, misconception was coded C, and no response / unrelated response was coded D. The rate of PSTs in each category is presented to the readers in the tables. The categories developed in the literature (Ayas & Özmen, 2002) were utilized for the analysis of the second question of the conceptual understanding test. In this context, the drawings were categorized as "particle-based/accurate", "particle-based/inaccurate", "continuous", and "blank". Furthermore, point-based drawings were also observed in the research, and hence a relevant category was developed. The drawings by PSTs exhibit either one or two stages. Some PSTs draw more than one category. The one and two stage drawings by PSTs were then coded; particle-based/accurate drawings, particle-based/inaccurate drawings, continuous drawings, blank, and point-based drawings. Examples of the drawings are provided in results.

Reliability, Validity and Ethical Issues

Ethical issues have been emphasized in this research. Voluntary pre-service science teachers participated to the research. 257 PSTs answered the conceptual understanding test. Researcher conducted interviews with 16 PSTs. Interviewers choose the place of interviews. PSTs' voices were recorded. Before recording, permissions have been obtained from the PSTs. Due to research ethics considerations; PSTs were assigned codes to identify them. i.e. PST 1 among first year student was coded Fr1, while PST 1 among second year, third year, and fourth year were coded Sn1, Th1, and Ft1 respectively.

Experts' opinions and member checking can be used to ensure internal validity (Yıldırım & Şimşek, 2013). To enhance external reliability of the research, the following criteria were taken into consideration; (1) researcher makes her position clear in the research (2) determining the participants (3) identification of social environments and processes in the research environment (4) defining the conceptual framework used in data analysis. Conceptual understanding test questions were submitted to two experts in the field of science education, for internal validity. The experts verified the validity of the test questions in terms of the objectives of the research. Researchers separately analyzed the conceptual understanding test questions. They analyzed first question according to Marek's (1986) classification. Second question analyzed to the categories developed in the literature (Ayas & Özmen, 2002) by the researchers. The results of the analysis by the researchers were compared by an expert out of the research. Firstly, %90 agreement was checked between two researchers' analysis. After the discussions full agreement was reached. The same process was followed in interviews. Researchers separately analyzed the interview question and determined codes. The results of the analysis by the researchers were compared by an expert out of the research. Firstly %85 agreement was checked between two researchers' analysis. After the discussions full agreement was reached between researchers.

Results of Research

The findings reached through the interviews and conceptual understanding test presented respectively. PSTs' responses to interview are presented in Table 1.

Table 1. PSTs' responses to interview.

Codes	Sub-codes	Sample statements
Mac.	Mode of transfer	"Tea spoon is made of metal. In metals and solids, heat transfer is through conduction." (Fr1)
		PSTs:Fr2, Fr4, Sn2, Sn3, Th1, Th 2, Th3, Ft2, Ft3, Ft4
Mic.	Inter-particle space	"Tea spoon is a solid object. Since the distances between solid molecules are low, heat transfer is through conduction." (Fr3)
		PSTs: Sn1, Sn2, Ft3
	Particle movement	"In solids, particles vibrate. When heated, particles vibrate, and transfer energy to surrounding particles. This leads to the transfer of heat through the vibration of particles." (Ft1).
		PSTs: Sn2, Sn4, Th4

Fr: first year student, Sn: second year student, Th= third year student, Ft= fourth year student Mac.= macroscopic, Mic.=microscopic

As can be seen in Table 1 the macroscopic explanations code, PSTs refer to "mode of transfer", and in the microscopic explanations code they refer to "inter-particle space" and "particle movement", hence providing explanations in two codes. The statements PSTs' provided in response to item 1 in the conceptual understanding test are presented in Table 2.

Table 2. Percentages of the PSTs' responses to item 1 in the conceptual understanding test.

Ct.	Examples of student statements	Fr.(%)	Sn. (%)	Th. (%)	Ft. (%)
A	Tea spoon transfers heat through conduction. In solids, the particles comprising the matter are very close to each other. The heat causes the particles to vibrate and crash into each other.	14,54	26.31	16,07	28,57
B	As the tea spoon is a solid, it transfers heat through conduction.	58.18	59,21	32,14	50
C	The tea spoon transfers heat through convection.	5.45	6.57	5.35	7.14
D	Un-related response-no explanation	21.81	7.89	46.42	14.28

Ct: categories, A:complete understanding, B: partial understanding, C: misconception, D: no response/unrelated response

Table 2 shows that 14.54% of first year student, 26.31% of second year student, 16.07% of third year student, and 28.57% of fourth year student provide microscopic explanations of how heat transfers occur in solids. The distribution of PSTs' drawings provided in response to item 2 in the conceptual understanding test is presented in Figure 1.

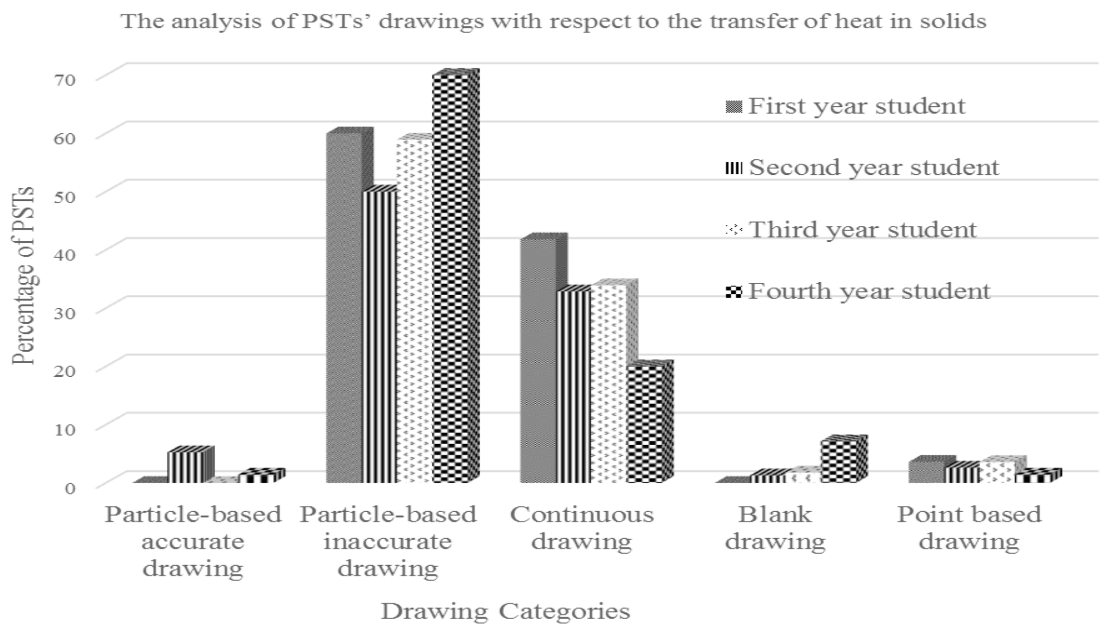

Figure 1: The analysis of PSTs' drawings with respect to the transfer of heat in solids.

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Figure 1 reveals that 5.26% of second year student, and 1.42% of fourth year student made particle-based accurate drawings. Examples of two-stage and one-stage particle-based accurate and particle-based in-accurate drawings provided by PSTs are presented in Figure 2 below.

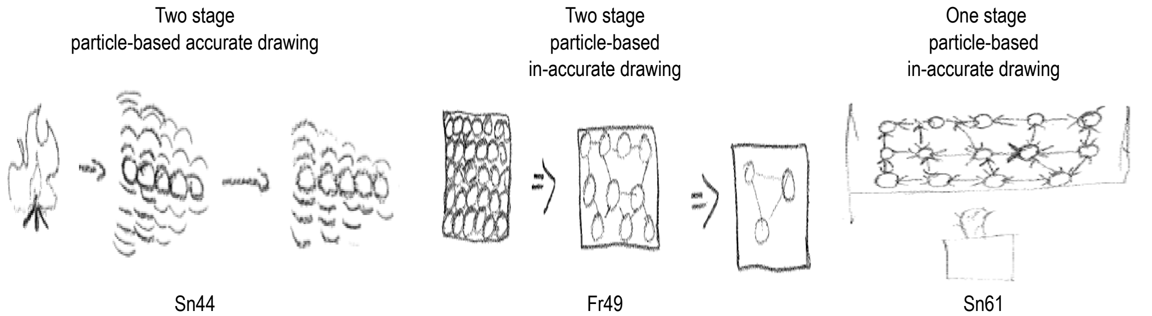

Figure 2: Examples of two-stage and one-stage accurate particle-based and in-accurate particle-based drawings provided by PST.

Figure 2 shows that Sn44 provided a "particle-based accurate" depiction of conduction in solids. Fr49 and Sn61, on the other hand, provided "particle-based inaccurate " depictions. For instance, Sn61's drawing shows a larger than accurate space between the particles of solids. The distribution with reference to year of education, of the drawings coded "continuous", is presented in Figure 3.

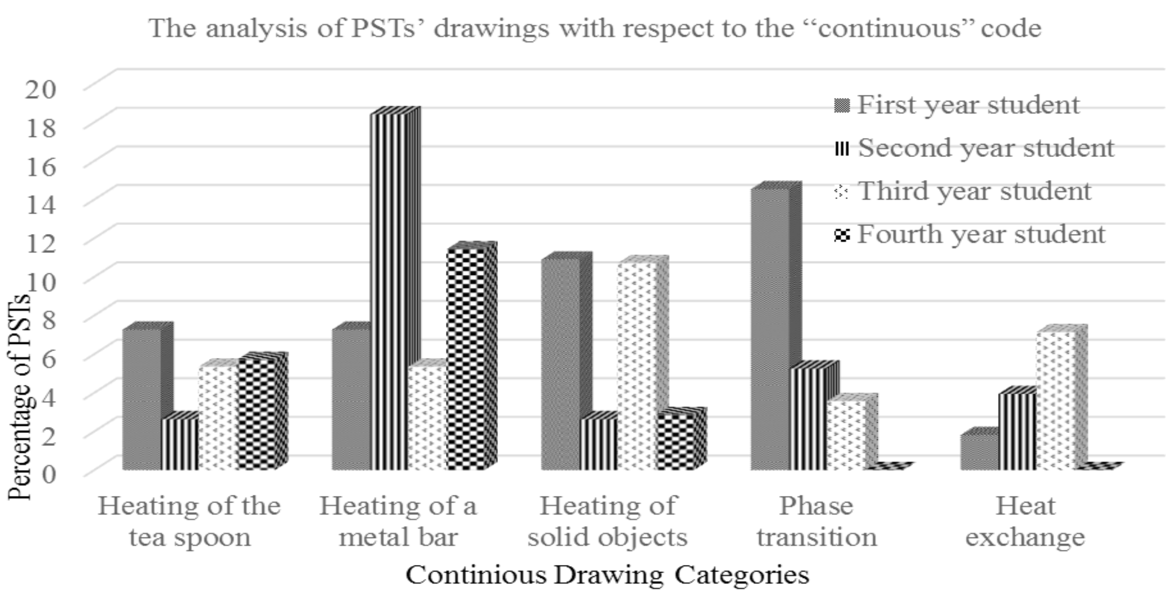

Figure 3: The analysis of PSTs' drawings with respect to the "continuous" code.

Figure 3 suggests that PSTs depict the heating of the tea spoon, heating of a metal bar, and heating of solid objects, phase transition, and heat exchange in their continuous drawings. The examples of continuous drawings and point-based drawings by PSTs are presented in Figure 4.

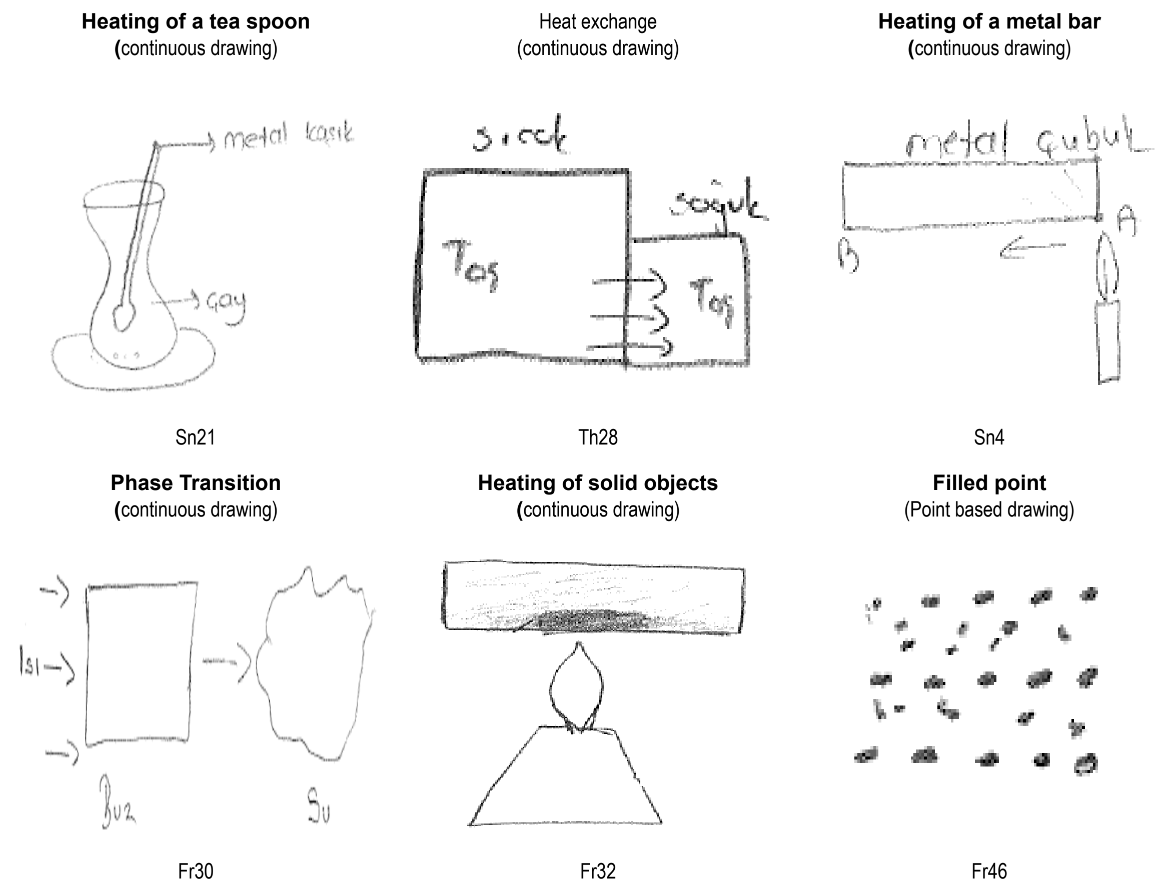

Figure 4: The examples of continuous drawings and point-based drawings by PSTs.

Figure 4 reveals that Sn21 drew the heating of a tea spoon, Sn4 drew the heating of a metal bar, Fr32 drew the heating of solid objects, Th28 drew heat exchange, and Fr30 drew phase transition. Fr46, on the other hand, depicted the particle structure of atoms, by drawing filled points.

Discussion

The vast majority of the PSTs at every year of the teacher training program were found to provide partially correct responses, as Table 2 attests. The overwhelming majority of PSTs stated that the tea spoon is a solid object, and that heat transfer in solid occurs through conduction. The PSTs associated the solidness of the tea spoon with heat transfer, and responded to the question from a macroscopic perspective. Only a very limited number of PSTs explained heat transfers at the particle level. The interviews also support this finding (Table 1). The review of the science curriculum reveals that the students are introduced to the concept of particle-based structures in 6th grade. The example of tea spoon heating our hand is about a case we often come across in our daily life. PSTs failed to provide particle-level explanations for this quite ordinary example from daily life. Indeed, it is well known that the students are unable to refer to the particle-based structure of matter, as well as the space in between the particles comprising it, when providing explanations for cases in daily life (Haidar & Abraham, 1991; Tsai, 1999). This point is once again apparent in the drawings made by the students. Figure 1 shows that the number of students who made continuous drawings fall as they progress through years of program. The studies carried out with respect to the particle-based structure of matter found that PSTs provide continuous depictions, and that they have rather macroscopic perspectives (Ayas & Özmen, 2002; Ben-Zvi, Eylon & Silberstein, 1986; Nakhleh & Samarapungavan 1999; Novick & Nusbaum, 1981). In the same vein, the PSTs are known to have difficulties in terms of getting a grasp of the particle-based structure of solid, liquid, and gaseous forms of matter

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(Pozo & Gomez Crespo, 2005). Lack of a microscopic-level insight into the particle-based structure of matter, on part of PSTs led them to continuous depictions. Only a few PSTs (Tables 1 and 2) explained heat transfer in solid matter, with reference to the arrangement and movement of particles. Fr3, Sn1, Sn2, Ft3 explained conduction in solids with reference to the space between the particles. Sn2, Sn4, Th4, Ft1, on the other hand, associated the transfer with the movement of particles of solid matter. While importance is attached to providing a macroscopic level of insight into processes discussed in chemistry classes, not enough emphasis is placed on microscopic level teaching. Failure to learn concepts at a microscopic level, in turn, prevents a meaningful learning at the conceptual level (Demircioğlu, 2003; Mammino & Cardellini, 2005). It is evident that a larger portion of second year and fourth year student provide particle-level explanations for conduction in solids (Table 2). Second year students have referred to vibration of and close proximity of particles with one another, when trying to explain conduction in solids. This is perhaps due to the General Chemistry I, General Chemistry II, and laboratory practice courses they had taken during the first year of their undergraduate education. As PSTs learned about the solid, liquid, and gaseous forms of matter in a context discussing the particle level as well, they provided mostly accurate explanations. Yet, the percentage of particle-level explanations fall from 26.31% to 16.07% as we move from 2nd year to 3rd year PSTs. Forgetting about the information learned earlier as the PSTs proceed from the 2nd to 3rd year of education may have something to do with this trend. As PSTs fail to register the information they received earlier, on a more permanent basis, they seem to forget such information in time. However, the percentage of PSTs providing particle-level explanations for conduction of heat in solids rises once again in the 4th year, from the earlier 16.07% to 28.57%. A possible explanation may lie in the fact that PSTs need to take the Teaching Content Knowledge Test as part of the Public Personnel Selection Examination (KPSS) for a teaching position at public schools. PSTs take this exam applied country-wide, in order to become eligible for public employment. From 2013 on, PSTs in a number of fields are subjected to the Teaching Content Knowledge Test within the framework of KPSS. One such field is science teaching. Teaching Content Knowledge Test is composed of questions on content knowledge and education in one's field. The content knowledge part directs physics, chemistry, biology, earth sciences, astronomy, and environment science questions to the candidates. 22% of the questions are in the field of chemistry. That is why it is crucial for 4th year PSTs to respond correctly to the chemistry questions in the Teaching Content Knowledge Test. The fact that a larger portion of PSTs in the 4th year of education have noted particle-level vibrations as the means of heat transfer in solids may owe to their enhanced grasp of these topics, as a way to prepare for the exam. On the other hand, the fact that PSTs tend to forget about the knowledge they received in earlier years of education suggests that they tend to memorize, rather than engage in meaningful conceptual learning. Re-learning in 4th year, with a view to achieving success in the exam, the knowledge they had learned but forgotten earlier, may be an effective solution for the short term, but may not be helpful in terms of rendering information permanent in the long run.

A glance at the drawings by PSTs reveals that the vast majority provided continuous drawings (Figure 1, 3 and 4). The overwhelming majority of PSTs drew how a metal bar got hot. It is well-known that spaces between the particles of metals are tighter compared to other forms of matter. Yet, the PSTs evident emphasis on metals may be due to a confusion of the terms "electrical conductivity" and "heat conduction". In the drawings, the PSTs explicitly referred to metal bars. The drawings by Sn21 and Sn4, as shown in Figure 4, support this argument. Both PSTs explicitly mentioned the word "metal" in their drawings. Brook et al. (1984) found that students confused conductivity of heat and electricity. The findings here, particularly the explicit emphasis on the concept of "metal" in continuous drawings lead one to a similar conclusion. Moreover Lubben et al. (1999) observed that university teachers did not have a sufficient level of information regarding the transfer of heat through conduction, and that they had misconceptions about wood, considering it a material which would not be conducive to heat transfers.

Figure 2 shows that when using drawings to depict solid particles, PSTs drew the particles in a state lacking reference to vibrations. This has perhaps something to do with the students' conception of solid particles in a motionless state. Lee, Eichinger, Anderson, Berkheimer & Blakeslee (1993) had also observed such a misconception of motionless particles in solids. The literature is not poor in studies which revealed students' misconceptions of lack of movement on part of the particles of solids (Lee et all 1993; Valanides 2000; Adadan, Irving & Trundle 2009; Adadan, Trundle & Irving 2010). The misconception has perhaps something to do with confusing the characteristics of particles and the characteristics of solids. It is widely known that students tend to ascribe the observable macroscopic characteristics of matter to its particles in the microscopic level as well (Gomez Crespo & Pozo 2004; Griffiths & Preston 1992; Kokkotas et al., 1998; Novick & Nussbaum 1981; Valanides

2000; Papageorgiou, Johnson & Fotiades 2008; Talanquer 2009). Against this background the misconceptions on part of PSTs would easily translate into a failure to direct their students into an accurate scientific domain. It is therefore necessary to identify the PSTs' misconceptions and to intervene removing such misconceptions through an effective conceptual transformation in the learning process.

The research by Kokkotas et al.'s (1998) led to the conclusion that students' confusion between the characteristics of particles and the characteristics of matter played a substantial role in developing the misconception. The depictions provided by PSTs, of still particles, may also have their roots in the belief that particles of solids have no energy. Indeed Çökelez (2009) noted the misconceptions of students in the phrase "particles of solids do not vibrate at all, as they do not have energy." The students do not think heat as a form of energy (Yeo & Zadnik, 2001). In this vein, for the students to get a solid grasp of the states of matter and the movement of particles, they need to have strong logical thought skills (Tsitsipis, Stamovlasis & Papageorgiou, 2010). This suggests that PSTs have problems in terms of demonstrating the movement of particles with reference to the heat energy in the matter.

Conclusions

PSTs apparently have difficulties in establishing the connection between heat, energy, and the particle-based structure. In order to eliminate misconceptions about these, and to replace them with scientific knowledge instead, emphasis in content-courses should be placed on fundamental concepts, and more time should be dedicated to the teaching of such concepts within the framework of curricula.

One may forcefully argue that students have problems concerning microscopic-level drawings of the particle-based structure of solids. In the research PSTs majority of the students at each grade drew the particles in a state lacking reference to vibrations. Different education strategies which can help students grasp the particle-based structure of matter are necessary. Teaching staff offering General Chemistry courses may contribute to learning on part of the students, by using a number of techniques such as drawings and animations at the classroom level. Animations focus on microscopic-level of the movement of the particles of solids under the impact of heat.

It was found out that PSTs tend to forget about the knowledge they received in earlier years of education suggests that they tend to memorize, rather than engage in meaningful conceptual learning. The percentage of PSTs providing particle-level explanations for conduction of heat in solids rises in the 4th year because of KPSS exam. The knowledge they had learned but forgotten earlier, may be an effective solution for the short term, but may not be helpful in terms of rendering information permanent in the long run. So, meaningful concept learning gains importance. Students don't learn with memorizing concepts only. They should be done experiments and actively involved in the process. However, such meaningful learning takes place.

It was focused on PSTs conceptions of the "Conduction of heat in solids" with a cross age study supported by drawings, interviews, and open-ended questions in this research. Future research should be conducted to examine PSTs conceptions of the convection or radiation. This research should be revealed with students' conceptions in detail with different data collection tools.

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Appendix

Items used in the conceptual understanding test

1. In the figure to the left, when Burak Emre stirs tea with a tea spoon, Burak Emre realizes that his hand gets heated. What do you think about heat transfer from tea to Burak Emre' hand? Please provide your response below.

Answer: For, ….

2. How the particles of solid are seen under the heat? (Think of the particle-based structure of solid and describe it with a drawing)

Draw:

References

Abraham, M. R., Williamson, V. M., & Westbrook, S. L. (1994). A cross-age study of the understanding of five concepts. *Journal of Research in Science Teaching, 31* (2), 147– 165.

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

Adadan, E., Trundle, K. C., & Irving, K. E. (2010). Exploring grade 11 students' conceptual pathways of the particulate nature of matter in the context of multi-representational instruction. *Journal of Research in Science Teaching*, *47* (8), 1004-1035.

Adbo, K., & Taber, K. S., (2009). Learners' mental models of the particle nature of matter: A study of 16-year-olds Swedish science students. *International Journal of Science Education, 31* (6), 757-786.

Alwan, A. A. (2011). Misconception of heat and temperature among physics students. *Procedia Social and Behavioral Sciences, 12,* 600–614.

Amettler, J., & Pinto, R. (2002). Students' reading of innovative images of energy at secondary school level. *International Journal of Science Education, 24* (3), 285-312.

Ayas, A., & Özmen, H. (2002). Lise öğrencilerinin maddenin tanecikli yapısını anlamaları üzerine bir araştırma [A study of students' level of understanding of the particulate nature of matter at secondary school level]. *Boğaziçi University Journal of Education, 19* (2), 45-60.

Ayas, A., Özmen, H. & Çalık, M. (2010). Students' conceptions of the particulate nature of matter at secondary and tertiary level, *International Journal of Science and Mathematics Education, 8,* 165-184.

Babbie, E. (2009). *The practice of social research*. Belmont, USA: Cengage Learning Publishing.

Ben-Zvi, R., Eylon, B. S., & Silberstein, J. (1986). Is an atom of copper malleable? *Journal of Chemical Education, 63* (1), 64-66.

Brook, A., Briggs, H., Bell, B., & Driver, R. (1984). *Aspects of secondary students' understanding of heat: Full report*. Leeds, UK: The University of Leeds, Centre for Studies in Science Education and Mathematics Education.

Carlton, K. (2000). Teaching about heat and temperature. *Physics Education, 35* (2), 101-105.

Cengel, Y. A. (2007). *Heat transfer*. Encyclopedia of Energy Engineering and Technology-3 Volume Set (Print Version) (pp. 822-829). CRC Press. doi: 10.1201/9780849338960.ch97

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education.* Oxon, USA: Routledge Publishing.

Çalık, M. (2005). A cross-age study of different perspectives in solution chemistry from junior to senior high school, *International Journal of Science and Mathematics Education, 3,* 671–696

Çalık, M., Turan, B., & Coll, R. K. (2014). A cross-age study of elementary student teachers' scientific habits of mind concerning socio-scientific issues, *International Journal of Science and Mathematics Education, 12,* 1315-1340.

Çepni, S. (2010). *Araştırma ve proje çalışmalarına giriş* [Research and introduction to project work]. Trabzon: Celepler Printing.

Çepni, S., & Keleş, E. (2006). Turkish students' conceptions about the simple electric circuits. *International Journal of Science and Mathematics Education, 4,* 269-291.

Çökelez, A. (2009). İlköğretim ikinci kademe öğrencilerinin tanecik kavramı hakkındaki görüşleri: bilgi dönüşümü [Students' (Grade 7-9) ideas on particle concept: Didactical transposition]. *Hacettepe University Journal of Education*, *36,* 64–75.

Demircioğlu, G. (2003). *Lise II asitler ve bazlar ünitesi ile ilgili rehber materyal hazırlanmasi ve uygulanması* [Development and implementation of guidance material on high school II acids and bases unit]. Doctoral Dissertation, Karadeniz Technical University, Trabzon.

Gomez Crespo, M. A., & Pozo, J. I. (2004). Relation between everyday knowledge and scientific knowledge: Understanding how changes matter. *International Journal of Science Education, 26* (11), 1325-1343.

Griffiths, A. K., & Preston, K. R. (1992). Grade 12 students' misconceptions relating to fundamental characteristics of atom and molecules. *Journal of Research in Science Teaching, 29* (6), 611- 628.

Haidar, A., & Abraham, M. (1991) A comparison of applied and theoretical knowledge of concepts based on the particulate nature of matter. *Journal of Research in Science Teaching, 28,* 919-938.

Harrison, A., Grayson, D., & Treagust, D. (1999). Investigating a grade 11 student's evolving concepts of heat and temperature. *Journal of Research in Science Teaching, 36,* 55–87.

Jackson, S. L. (2009). *Research methods and statistics: A critical thinking approach.* USA: MacMillan Publishing.

Jacobi, A., Martin, J., Mitchell, J., & Newell, T. (2004, October). Work on progress: A concept inventory for heat transfer. *Proceding of the 34th Asee/Ieee Frontiers in Education Conference,* Savannah, GA.

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

Jasien, P. G., & Oberem, G. E. (2002). Understanding of elementary concepts in heat and temperature among college students and K-12 teachers. *Journal of Chemical Education, 79* (7), 889-895.

Kaper, W. H., & Goedhart, M. J. (2002). Forms of energy, an intermediary language on the road to thermodynamics? Part I. *International Journal of Science Education, 24* (1), 81-95.

Kesidou, S., & Duit, R. (1993). Students' conceptions of the second law of thermodynamics-an interpretive study. *Journal of Research in Science Teaching, 30* (1), 85-106.

Kokkotas, P., Vlachos, I., & Koulaidis, V. (1998). Teaching the topic of the particulate nature of matter in prospective teachers training courses. *International Journal of Science Education, 20* (3), 291-303.

Lee, O., Eichinger, D. C., Anderson, C. W., Berkheimer, G. D., & Blakeslee, T. D. (1993). Changing middle school students' conceptions of matter and molecules. *Journal of Research in Science Teaching, 30* (3), 249-270.

Leong Wong, C., Chu, H. E. & Chin Yap, K. (2016). Are alternative conceptions dependent on researchers' methodology and definition. A review of empirical studies related to concepts of heat, *International Journal of Science and Mathematics Education, 14,* 499-526

Lubben F., Netshisaulu T., & Campbell B. (1999). Culture and comparative studies students' use of cultural metaphors and their scientific understandings related to heating. *Science Education, 83* (6), 761–774.

Mammino, L., & Cardellini, L. (2005). Studying students' understanding of the interplay between the microscopic and the macroscopic descriptions in chemistry. *Journal of Baltic Science Education, 4* (1), 1648-3898.

Marek, E. A. (1986). They misunderstand, but they'll pass. *Science Teacher, 53* (9), 32-35.

Ministry of National Education [MoNE], (2004a). *Fen ve Teknoloji dersi öğretim programı (4-5. Sınıflar)* [Science and technology curriculum (for grades 4-5)]. Ankara: Head Council of Education and Morality.

Ministry of National Education [MoNE], (2004b). *Fen ve Teknoloji dersi öğretim programı (6-8. Sınıflar)* [Science and technology curriculum (for grades 6-8)]. Ankara: Head Council of Education and Morality.

Ministry of National Education [MoNE], (2011). *Kimya dersi öğretim programı (9-12. Sınıflar)* [Chemistry Curriculum (for grades 9-12)]. Ankara: Head Council of Education and Morality.

Nakhleh, M. B., & Samarapungavan, A. (1999). Elementary school children's beliefs about matter. *Journal of Research in Science Teaching, 36* (7), 777-805.

Nakhleh, M. B., Samarapungavan, A., & Saglam, Y. (2005). Middle school students' beliefs about matter. *Journal of Research in Science Teaching*, *42* (5), 581-612.

Novick, S., & Nusbaum, J. (1981). Pupils' understanding of particulate nature of matter: A cross-age study. *Science Education, 65* (2), 187-196.

Özmen, H. (2011). Turkish primary students' conceptions about the particulate nature of matter. *International Journal of Environmental & Science Education, 6* (1), 99-12.

Özmen, H. (2013). A cross-national review of the studies on the particulate nature of matter and related concepts. *Eurasian Journal of Physics and Chemistry Education, 5* (2), 81-110.

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Özmen, H., Ayas, A., & Coştu, B. (2002). Determination of the science student teachers' understanding level and misunderstandings about the particulate nature of the matter. *Educational Sciences: Theory and Practice, 2* (2), 507-529.
Papageorgiou, G., Johnson, P., & Fotiades, F. (2008). Explaining melting and evaporation below boiling point. Can software help with particle ideas? *Research in Science and Technology Education, 26* (2), 165-183.
Pathare S. R, & Pradhan, H. C. (2010). Students' misconceptions about heat transfer mechanisms and elementary kinetic theory. *Physics Education, 45* (6), 629-634.
Pozo, J. I., & Gomez Crespo, M. A. (2005). The embodied nature of implicit theories: the consistency of ideas about the nature of matter. *Cognition & Instruction, 23* (3), 351 – 387.
Prokop, P., Usak, M., Özel, M., Fančovičová, J. (2009). Chıldren's conceptions of animal breathing: A cross age and cross cultural comparıson. *Journal of Baltic Science Education, 8* (3), 191-207.
Ruane, J. M. (2005). *Essentials of research methods: A guide to social sciences research.* UK: Blackwell Publishing.
Soloman, J. (1985). Teaching the conservation of energy. *Physics Education, 20,* 165-170.
Stylianidou, F., Ormerod, F., & Ogborn, J. (2002). Analysis of science textbook pictures about energy and pupils' readings of them. *International Journal of Science Education, 24* (3), 257-283.
Tanahoung, C., Chitaree, R., & Soankwan C. (2010). Probing Thai freshmen science students' conceptions of heat and temperature using open-ended questions: A case study, *Eurasian Journal of Physics and Chemistry Education, 2* (2), 82-94.
Thomaz, M. F., Malaquas, I. M., Valente, M. C., & Antunes, M. J. (1995). An attempt to overcome alternative conceptions related to heat and temperature. *Physics Education, 30* (1), 19-26.
Tsai, C. C. (1999). Overcoming junior high school students' misconceptions about microscopic views of phase change: A study of an analogy activity. *Journal of Science Education and Technology, 8* (1), 83–91.
Tsitsipis, G., Stamovlasis, D., & Papageorgiou, G. (2010). The effect of three cognitive variables on students' understanding of the particulate nature of matter and its changes of state. *International Journal of Science Education, 32* (8), 987-1016.
Valanides, N. (2000). Primary student teachers' understanding of the particulate nature of matter and ıts transformations during dissolving. *Chemistry Education Research and Practice in Europe, 1* (2), 249-262.
Yeo, S., & Zadnik, M. (2001). Introductory thermal concept evaluation: Assessing students' understanding. *The Physics Teacher, 39,* 495-504.
Yen, C. F., Yao, T. F., & Chiu, Y. C. (2004). Alternative conceptions in animal classification focusing on amphibians and reptiles: A cross-age study. *International Journal of Science and Mathematics Education, 2,* 159–174.
Yıldırım, A., & Şimşek, H. (2013). *Sosyal bilimlerde nitel araştırma yöntemleri* [Qualitative research methods in social sciences]. Ankara: Seçkin Press.

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