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PARTICULATE NATURE OF MATTER MISCONCEPTIONS HELD BY MIDDLE AND HIGH SCHOOL STUDENTS IN TURKEY

Hasan Özgür Kapici[1i], Hakan Akcay[2]
[1,2]Department of Mathematics and Science Education, Faculty of Education,
Yildiz Technical University, Istanbul-Turkey

Abstract:
Misconceptions are one the biggest troubles for both teachers and students. In order to have scientifically valid knowledge, students should have meaningful conceptual understanding. Researchers have been designing studies based on different teaching methods so as to reach beneficial outcomes to handle with misconceptions. In this study, the main purpose is to reveal misconceptions about particulate nature of matter held by middle and high school students in Turkey by examining the related studies done since 2010. In addition, another goals are to see which kind of data gathering instruments have been used frequently and to determine these studies have been implemented in which level, whether middle school or high school. With specific keywords and criteria, 21 related articles were reached and examined. The findings shows that open ended questionnaire or interview forms are the most frequent instruments in order to gather data in the studies which were done for diagnosing misconceptions about particulate nature of matter. The participants of studies are usually from middle school students. Lastly, misconceptions are common among students.

Keywords: particulate nature of matter, misconception, middle school students, high school students

Introduction

Learning should be based on scientifically valid concepts. In other cases, it is indispensable fact that students may have misconceptions. Furthermore several studies

[i] Correspondence: email hokapici@yildiz.edu.tr, hakcay@yildiz.edu.tr

(e.g. Duit & Treagust, 2003; Duit, Treagust & Widodo, 2008) show that students come to class with concepts that they have learnt before formal education stage and which are not appropriate with scientific knowledge. On the other hand, it is possible to change these misconceptions with scientifically appropriate concepts through the process which is called as conceptual change process (Treagust & Duit, 2009). It is also known that students build up new concepts with respect to former concepts (Driver, Guesne & Tiberghien, 1985; Palmer, 1999; Tsai, 1998). For this reason, researchers advocate that students' previous knowledge should not contradict with scientifically valid ones; if not, students may constitute new concepts based on incorrect concepts.

Studies about conceptual change process and students' conceptual understanding are based on several theoretical frameworks (Duit & Treagust, 2003). For example, Driver and Easley (1978) state that studies which investigate the effects of misconceptions in science education based on two major viewpoints (ct. Duit, Treagust & Widodo, 2008). These were developed by Piaget and Ausubel. Piaget believes that learning is a kind of individual activity, in which schemas in mind change as a result of assimilation or accommodation. On the other hand, Ausubel (1960) advocates that the most important factor that has a major role in learning is former concept knowledge and student's learning take shape with respect to these former concept understanding.

Conceptual change studies reveal that it has usually investigated with respect to three different viewpoints, which are epistemological, ontological, and affective (Duit & Treagust, 2003). Posner, Strike, Hewson and Gertzog (1982) developed classical conceptual change model with respect to epistemological view. This model claims that student's discontent with previous knowledge initiate conceptual change process and if new concept accepted as logical, understandable and useful by the student, accommodation takes place (Treagust & Duit, 2009). If misconception held by the student is not contrary to student's thoughts, the student accepts new concept by assimilating it (Treagust & Duit, 2009). In other words, if new concepts are seemed as logical, useful and apprehensible by the students, conceptual change occurs. If not, student shapes new concept based his/her previous concept knowledge and assimilates it (Treagust & Duit, 2009).

Ontological conceptual change defined as how students see the change in 'reality' (Chi, Slotta & Leeuw, 1994). Chi (1992) divided the ontological conceptual change in two different levels. In one of them, conceptual change occurs in the same ontological category. In the second one, conceptual change takes place between different ontological categories and whereas the former one called as hierarchical conceptual change, the latter one known as radical conceptual change. Furthermore she advocates that conceptual change and understanding occurs through different ontological categories in science education. That's why, it is perceived difficult by students.

The study done by Pintrich, Marx and Boyle (1993) revealed that social and affective factors should be considered in conceptual change process. They advocate that, in addition to cognitive activities, motivation and social interactions are also crucial for conceptual change. For example, students' self-efficacy, goals, expectations, ambition and needs, classroom environment are important factors as much as cognitive elements. If teachers do not take consider these affective agents, conceptual change does not occur completely.

As a consequence, it is obvious that in conceptual change process student should be active for both mentally and socially. Student should be convinced that new concept is scientifically valid and should accept it. Learning environment, student's motivation and ambitions should support him/her through the conceptual change process in order to accept the scientifically valid concept instead of the incorrect one.

Particulate Nature of Matter in Science Education

The particulate nature of matter (PNM) is one of the basic topics in science education, especially in chemistry. It includes topics such as matter structure and properties, matter phases and phase changes, conservation of mass, chemical reactions and bonding, ions and solutions (Ayas & Ozmen, 2002; Griffiths & Preston, 1992; de Vos & Verdonk, 1996; Haidar, 1997; Lee et al., 1993; Tsai, 1999; Adadan & Savasci, 2012). In order to understand these topics, students must learn PNM successfully.

In Turkey, students come across with the topic more than half of their primary education duration but the studies show that they still have misconceptions about PNM (Boz, 2006; Geban & Bayır, 2000; Kavak, 2007; Tezcan & Salmaz, 2005). One of the main reasons for having too many misconceptions about PNM is that it covers too many abstract concepts (Özmen & Kenan, 2007). Another reason may be wrongly associating background of daily events with PNM (Adadan, Irving & Trundle, 2009). Other study done by Özalp and Kahveci (2011) concluded that students may interpret PNM with respect to the physical state of matter. This may be other misconception source for students.

In related literature, there are many studies about PNM, which were done with students from different grades (Boz, 2006; Gabel, 1993; Geban ve Bayır, 2000; Harrison ve Treagust, 1996; Kavak, 2007; Nakhleh ve Samarapungavan, 1999; Nakhleh, Samarapungavan ve Sağlam, 2005). Whereas some of these studies directly investigated misconceptions about PNM, the other studies tried to release misconceptions about

PNM related topics such as phase change, solubility, physical and chemical change. The primary aim of this paper is to analyse misconceptions about PNM held by Turkish students. In addition, types of used instruments and participants' grade level in the studies, which investigate misconceptions about PNM, are examined. Current study has an important role in related literature since it addresses curriculum developers, science and chemistry teachers and researchers. It reveals possible misconceptions about the topic and their possible sources. On the other hand, although the study examines research from Turkey, its audiences are curriculum developers, teachers and researchers from all over the world since misconceptions about PNM are common for all students. That's why; it indeed has an international importance. Within this respect, the research questions are determined as following:

1. What kinds of instruments have been used to diagnose misconceptions about PNM in the studies which were done between 2010 and 2015?
2. What are the common misconceptions about PNM held by middle and high school students in Turkey with respect to the studies which were done between 2010 and 2015?
3. In which level (middle school or high school), do the studies, which were done between 2010 and 2015, generally have been implemented?

Methodology

Qualitative research method was used in the study. In qualitative research studies, the aim is not confirming predetermined ideas (Sherman & Webb, 1988); instead of it, finding out of events, processes or concepts. Document analysis, which is a kind of data collection techniques in qualitative research, was used in current study.

Three main criteria were determined for choosing the studies.

- The study must be done with Turkish middle and/or high school students.
- The study must be about diagnosing misconceptions about PNM.
- The study must be done in 2010 or later.

Within these considerations and the keywords "*particulate nature of matter*", "*misconceptions*" and in Turkish "*maddenin tanecikli yapısı*" and "*kavram yanılgıları*", 21 articles were reached.

Data Analysis

The studies were analysed with respect to the instrument or rubric they used, grade level of participants and findings. In order to provide reliability, the analyses were also done by another researcher, who is an expert on chemistry education, and some critical points were discussed and achieved a consensus.

Findings

The studies done about PNM were analyzed with respect to the instrument(s) used in the studies, grade levels of students and findings misconceptions about PNM. Table 1 shows that types of instruments used for diagnosing misconceptions about the topic.

Table 1: Instruments used in selected studies

Type(s) of Instrument	f	%
Open ended questionnaire or Interview	7	33.3
Achievement / Conceptual understanding test	6	28.5
Drawing test	3	14.2
Conceptual understanding test + Interview	2	9.5
Drawing test + Open ended questionnaire	1	4.7
True/False questionnaire	1	4.7
True/False questionnaire + Open ended questionnaire	1	4.7

It can be seen from Table 1, the most common kinds of instruments used in research about diagnosing misconceptions about PNM are open ended questionnaire, semi-structured interview forms, achievement and conceptual understanding tests. In addition, some of achievement and conceptual understanding scales are two-tier tests. In the first step, the student chooses the answer and for the next, explains his/her reasoning. Drawing tests are another type of instruments used in studies for determining PNM misconceptions held by middle and high school students. Lastly, there are other types of instruments which are not very common about PNM studies such as true/false questionnaire and combination of open ended questionnaire with drawing test or conceptual understanding test.

Table 2 shows that distribution of studies with respect to grade level. It can be seen that most of the studies have been done with middle school students. The number of studies which were done with high school students is five. Lastly, one of the studies' participants is from both middle and high school students.

Table 2: Studies Distribution with respect to Grade level

Grade Level	f	%
Middle School	15	71.4
High School	5	23.8
Middle and High School	1	4.7

Lastly, Table 3 shows common misconceptions about PNM which are held by middle and/or high school students. It can be see that students mainly assume that physical properties of a process or an object are also valid for its particulate nature. In addition, misconceptions about sub-microscopic level are common among middle and high school students. Due to the fact that PNM is related with many other topics in chemistry, misconceptions were found from different topics.

Table 3: Misconceptions held by middle and high school students

Misconception(s)	Cited by
Solids or matters have continuous structure.	Aslan (2014), Ayas, Özmen and Çalık (2010), Demircioğlu, Vural and Demircioğlu (2013), Leblebicioğlu (2012)
Whereas particles in a solid object do not move, particles in a liquid or gases object move. In liquids and gases, the particles just have rotational movement, they do not shake. Solids do not have particles while liquids consist of particles. There are no gaps between the particles of a liquid or gas. There are gaps among atoms, which can be seen.	Gökulu (2013), Ormancı and Balım (2014), Özmen (2011a), Özmen (2011b), Öztuna Kaplan and Boyacıoğlu (2013)
Atoms can be seen by microscope. Atoms cannot be seen because protons, neutrons and electrons are colourless. Particles are alive. Atoms are made up of cells.	Çökelez and Yalçın (2012), Demircioğlu, Altuntaş Aydın and Demircioğlu (2012), Gökulu (2012), Meşeci, Tekin and Karamustafaoğlu (2013), Ormancı and Balım (2014)
Ink particles have a constant shape, but water particles do not have, so the shape of ink particles affects water particles.	Ayas, Özmen and Çalık (2010),
Proton's mass and neutron's mass are equal to each other.	Demircioğlu, Altuntaş Aydın and Demircioğlu (2012)
There are concrete objects between atoms like stick in order to bond two atoms to each other.	Öztuna Kaplan and Boyacıoğlu (2013)
Thawing is a chemical process.	Aslan (2014), Demircioğlu, Dinç and Çalık (2013)
If a matter's or objects' physical appearance changes, than its molecular structure also changes. If copper plate is compressed, then its atoms also compressed and their shapes change.	Çayan ve Karslı (2015), Ergün and Sarıkaya (2014), Gökulu (2013), Kıngır and Geban (2014), Leblebicioğlu (2012), Meşeci, Tekin and Karamustafaoğlu (2013), Sarıkaya and Ergün (2014)

When coal or a pin is peened, its atoms' shape changes. When a plane hits nitrogen molecule, its shape change. When an iron nail is rusted, its mass decreases. Gas molecules in a closed container sink to the bottom. Properties of dissected copper wire are not same with the normal copper wire. Macroscopic properties of matters are also valid for sub-microscopic entities.	
Number of particle decreases when phase change occurs. When naphthalene melts, its molecules' shape change. Same amount of a subject or object in different phases have different number of particles. When a matter is heated, the number of particles changes. The numbers of particles decrease when the balloon is cooled. The particles get smaller when they are cooled and the particles combine with each other and their numbers decrease.	Demircioğlu, Vural and Demircioğlu (2013), Gökulu (2013), Ormancı and Balım (2014), Özmen (2011a), Özmen (2011b), Sarıkaya and Ergün (2014)
Inner structures of matters do not change through chemical change process. Sublimation of naphthalene is a chemical event. Becoming overcast of silver spoons' is a physical change. Burning of a candle is a physical change since after melting of a candle; it is possible to change back into a candle.	Çayan ve Karslı (2015), Demircioğlu, Demircioğlu, Ayas and Kongur (2012), Kıngır and Geban (2014)
Shapes of a mercury atom in solid form and in liquid phase are different from each other. Shapes of objects are formed with respect to combination of different shaped atoms or molecules. Atoms' shapes change with respect to the object's physical appearance.	Ergün and Sarıkaya (2014), Kaya and Ergun (2012), Sarıkaya and Ergün (2014)
Na ions compound bonding just with Cl	Doğan and Demirci (2011)

ions. Na ions compound bonding just with one electron because there is just one electron in its electron shell. Cl ions compound bonding just with one electron because there is just one electron in its electron shell.	
The number of molecules in reactants is equal to the number of molecules in products.	Aslan (2014)
More than half of participants believe Thomson or Rutherford atom theory.	Karagöz and Sağlam Arslan (2012)

Table 3 shows that middle and high school students have misconceptions about PNM and other related topics such as chemical bonding and reactions, phases changes and physical and chemical changes. Detailed data can be reached via Appendix 1.

Discussion and Conclusion

The study reveals types of instruments used in studies that investigate to diagnose misconceptions about PNM, grade levels of participants and misconceptions. In Turkey, students start to learn about PNM and related topics from third grade (age 9) to the almost end of high school (age 16). Although they face with topic for a long time, they still have misconceptions about the subject.

In related literature, researchers offer some possible sources as reasons for these misconceptions. For example, Balım and Ormancı (2012) claim that primary and middle school students are at concrete operational stage but PNM involves many concepts that are intangible. That's why, middle school students may have difficulties to deal with this topic. Similarly, Özmen and Kenan (2007) advocate that because of including too many abstract concepts in PNM, students may have trouble while learning the topic. In another study, Adadan, Irving and Trundle (2009) state that student usually have difficulty to handle with inner structure of subjects or concepts due to its 'unseen' construction. Furthermore students usually believe that physical properties of an object are same for its particles (or atoms) (Özalp and Kahveci, 2011). In addition, textbooks are one the main sources in classrooms (Sanchez and Valcarcel, 1999) and some researchers (e.g. Cheng and Gilbert, 2014) say that inappropriate usage of representations in textbooks may be another source for misconceptions about PNM. Lastly, students have confusion when they have to translate among representation levels such as from macroscopic level to sub-microscopic level or symbolic level or vice versa (Margel, Eylon & Scherz, 2008; Nyachwaya et al., 2011; Valanides, 2000; Vermaat, Terlouw & Dijkstra, 2003).

It is also reached that open ended questionnaire or interview forms are most frequently used in the studies which aim to diagnose misconceptions about PNM. These instruments enable researcher to understand participant's deep thoughts about process or subject. Researcher can get more detailed data why and how participant can think like that. It is also appropriate to be used for both middle and high school students. This can be another reason about using much more these instruments than others. Secondly, achievement and conceptual understanding tests are used in such kind of studies. These instruments are usually two-tiered. In the first step, participants choose from their choice from multiple choices or give their answers; in the second step, they explain their reason(s) why they choose that choice. This type of instruments also provides meaningful data for researchers about participant's views. Drawing tests are another instrument type used in these studies. Drawing tools just used in studies in which participants are from middle school. Drawing can be another easy way to reveal young participants' thoughts and beliefs. In addition, due to the fact that children have usually much more powerful creativity than adolescents, drawing is mainly used with children. Lastly, it is obvious that researchers usually try to gather data through open ended questionnaire or interview, even they use another instrument as a main tool, because these instruments provide data how participants think or why they believe like that, which is crucial data for researcher.

It is also reached that studies about diagnosing PNM misconceptions have done with middle school students much more than high school students. PNM is taught with specific units in middle school curriculum. This can be one of the reasons why these studies usually done with middle school students. Furthermore diagnosing misconceptions early as much as possible is important since students may develop wrong conceptual understanding on their misconceptions.

This study suggests that curriculum developers should emphasize possible misconceptions about PNM and should offer how to deal with such kind of misunderstandings. Teachers should be aware of these misconceptions and should be careful while teaching the topic in their classrooms. Researchers may design new studies to find new ways in order to handle with misconceptions.

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