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A Cross-Age Study of Iranian Students' Various Conceptions about the Particulate Nature of Matter

Abed BADRIAN[1], Taleb ABDINEJAD[2], Akbar NASERIAZAR[3]

[1] Asist.Prof.Dr., Research Institution for Curriculum Development & Educational Innovations, Tehran-Iran.
[2] Teacher, Faculty of Chemistry Education, Aslandooz Education Office, Ardebil-Iran.
[3] Teacher, Islamic Azad University of Marand Branch, Marand, East Azarbaijan-Iran.

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ABSTRACT

This study aims to investigate Iranian students' understanding of the particulate nature of matter via a cross-age study. The students involved in this study were high-school students who studied chemistry at the basic level (9th grade) and advanced level (10-11th grade), totalling about 160 individuals. In the study, a test comprising six open-ended and multiple choice diagnostic questions, students' drawings, and semi-structured interviews were employed to collect data. According to the findings students have various conceptions about matter and many of which have not been previously documented. Further, it was concluded that there is no clear link between students' conceptions and their grades. In the light of the study, it can be suggested that due to the Ministry of National Education's recent revisions of the science education curricula and instructional materials, further emphasis should be given to the particulate nature of matter and its modelling in relation to the course books.

Keywords: Particulate Nature Of Matter; Conception; Drawing; Particle; Macroscopic.

INTRODUCTION

The science education literature of the past three decades includes numerous studies that describe conceptions held by students at different levels. These studies show that students' conceptions are often inconsistent with the scientific concepts they are expected to learn. These conceptions have been variously described by different researchers as misconceptions, preconceptions, naïve conceptions, children's science, alternative conceptions, alternative frameworks, conceptual frameworks, common sense understanding, and so on (Hewson &

Correspondence Author email: ab.badrian@gmail.com

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Hewson, 1984; Zoller, 1990; Nakhleh, 1992; Gabel & Bunce, 1994; Schmidt, 1997; Taber, 1998; Palmer, 1999; Özmen & Ayas, 2003).

Research on students' misconceptions in science and the recent advances in cognitive psychology have emphasized that learning takes place within the context of already acquired knowledge. This realization has caused science educators increasingly to be concerned about the knowledge held by the student prior to instruction. When these prior conceptions are misconceptions, then they prove to have a detrimental effect in problem-solving and course performance (Çalık & Ayas, 2005; Krishnan & Howe, 1994).

The concept of matter is essential to chemistry; in particular, since "chemistry is a science of matter and its transformations, appropriate understanding of matter determines the students' understanding of principles and theories of physical and chemical change" (Liu & Lesniak, 2006). Many students at all levels struggle to learn chemistry, but are often unsuccessful. One possible reason that is beginning to emerge is that many students are not constructing appropriate understandings of fundamental chemical conceptions from the very beginning of their studies. Therefore, they cannot fully understand the advanced conceptions that build upon the fundamentals (Nakhleh, 1992).

Students in introductory chemistry courses exhibit an extensive array of misconceptions of chemical behavior (Talanquer, 2006). Reviews of common misconceptions of chemistry concepts and chemical behavior (Çalık, Ayas & Ebenezer, 2005; Johnson, 1998a, b; Gabel & Bunce, 1994; Wandersee, Mintzes, & Novak, 1994) and an extensive bibliography (Pfund & Duit, 2004) are available. Research in this domain has attempted to answer questions such as which misunderstandings occur, what are their origins, how extensive are they, and, of course, what can be done about them? (Gil-Perez & Carrascosa, 1990).

Literature Review

Students' ideas about particulate nature of matter have been extensively dealt with by researchers (Ayas, Özmen & Çalık, 2010; MacDonald & Bean, 2010; Stains & Talanquer, 2007; Yilmaz & Alp, 2006; Liu & Lesniak, 2006). Most of the work in this area has been done with high-school pupils, and a number of studies have investigated the development of students' ideas about particulate nature of matter at a range of age levels. Some of these studies have provided useful insights into how students' views, beliefs and preconceptions of the particulate nature of matter differ. For example, Liu and Lesniak (2006) tried to investigate progression in children's understanding of the matter concept from elementary to high school by interviewing 54 students from grade 1 to grade 10. They found that the progression of students' conceptions on matter from elementary to high school is multifaceted. And also, there is much overlap in conceptions among students of different grades. Students consistently and erroneously hold that matter is continuous and attribute macroscopic properties of matter to its sub-microscopic particles (Albanese & Vicenti, 1997; Johnson, 1998a, b; Harrison & Treagust, 2002).

Boz (2006) tried to explore year 6, 8 and 11 pupils' views about the particulate nature of matter within the context of phase change by using 6-item open-ended questions about (i) arrangement and movement of particles in a solid, liquid and gas and (ii) application of particulate ideas to explain phase changes. Working with 8th, 10th and 11th grade students, Yilmaz and Alp (2006) investigated the effect of grade level on students' achievement in matter concept by using the matter concept test The results of the study indicated that there was a significant effect of grade level on students' achievement in favor of 11th students. In the test, 10th grade students did better than 8th graders and 11th grade students did better than the others. Ayas and Özmen (2002) investigated the 9th grade and 10th grade high-school students' understanding of the particulate nature of matter by using a test with five open-ended questions related to daily phenomena about the subject.

Other studies report that students use the macroscopic properties of a substance to infer its particle properties. In other words they think or reason from what is visible (i.e. large), to what is invisible (i.e. small). For example, "*molecules in ice are thought to be heavier than those in liquid, with molecules of water vapor being the lightest*" (Krnel, Watson & Glazar, 1998, p. 265). Beginning students intuitively believe that copper atoms are red-brown because copper is red, or that chlorine atoms are green because it is a greenish yellow gas (Ingham & Gilbert, 1991). A research carried out by Lee and co- workers (1993), showed that the idea that gas particles are static is a strongly held notion that includes heated gas being lighter and so it will rise to the top of its container.

Some of the studies revealed students' ideas about space between particles. Novick and Nussbaum (1981) investigated this notion and showed that the notion that empty space exists between particles causes students considerable difficulties. They found that 25% of the younger group suggested that although the particles were themselves discrete entities, the space between them was either filled, for example, with" *Dust and other particles; other gases such as oxygen and nitrogen; air, dirt, germs; maybe a liquid; unknown vapors..*" or was non-existent, for example:- "*The particles are closely packed - there is no space between them" or "No place is completely empty*".

Research in chemistry education in Iran was a young branch on the tree of science education, much younger than research in educational science. About 5 years ago, chemistry education reform in Iran has stimulated the rise of chemical education research. In the beginning, studies were mainly focused on students' ways of reasoning and learning processes. Many studies involve qualitative methods for collecting data, for example, by recording discussions in classrooms. Chemistry education research has provided a lot of data for helping particular groups of professionals, especially people who are involved in curriculum development or assessment designs.

However, studies in this area are rare in Iran. This study has been carried out in order to elicit students' understanding of the particulate nature of matter via a cross-age study. The findings and educational implications obtained from this research are expected to provide useful references for science teacher preparation as well for planning curriculum design. So the key research question in this study was therefore determined as: "What are high-school pupils' conceptions regarding the particulate nature of matter?"

METHODOLOGY

a- The Context of the Study

The structure of Iranian educational system in schools comprises of three principal levels: primary education (age 7–11; 5 years); middle school education (age 12-14; 3 years); secondary education (or high schools, age 14–17; 3 years) and pre-university education (age 18; 1 year). There is a national examination at the end of the 5-year primary school cycle, which students have to pass to enter middle schooling. This 3-year phase also provides students with general education and encourages them to think about their options for secondary education. Students must pass a regional examination at the end of the middle school level in order to proceed to the secondary level (Naseriazar & Badrian, 2010).

Since the particulate theory is a key central concept in science education (Snir, Smith & Raz, 2003), it underpins student understanding of many phenomena and concepts. Students must know about the properties of materials and their combinations, changes of state, effects of temperature, behavior of large collections of pieces, the construction of items from parts, and even about the desirability of nice, simple explanations.

Although the age level at which students should be introduced to the particulate nature of matter is somewhat variable, examination of Iranian science textbooks shows that atoms, molecules, and the particulate nature of matter are depicted even in the primary grades. In Iranian science textbooks, the particulate nature of matter concept is implicitly mentioned at grades 4 and 5 (aged 10-11). It appears explicitly again in grades 6, 7 and 8 (aged 12–14).

The strategy here is to describe the complexity of atoms gradually, using evidence and explanations from several connected story lines. Students first learn the notion that atoms make up objects, not merely occupy space inside them; then they are introduced to crystal arrays and molecules. Students need to become familiar with the physical and chemical properties of many different kinds of materials through firsthand experience before they can be expected to consider theories that explain them. With this understanding, they can imagine how molecules and crystals lead to visible, tangible matter. Only then should the study of the internal structure of atoms be taken up in secondary education.

To that end, students should become familiar with characteristics of different states of matter -now including gases- and transitions between them. Most important, students should see a great many examples of reactions between substances that produce new substances very different from the reactants. Then they can begin to absorb the rudiments of atomic/molecular theory, being helped to see that the value of the notion of atoms lies in the explanations it provides for a wide variety of behavior of matter. Hence, for chemistry and physics lessons at the secondary level, these concepts are referred to within different units.

In secondary schools (grade 9, 10, 11), students take general chemistry under the headings of "chemistry for life" (grade 9), "structure, reactivity, and relations between them" (grade 10) and "interactions among matters"(grade 11).

“The particulate nature of matter” is taught in detail in the grade 9 chemistry curriculum. For instance, the curriculum includes supplying our water needs, property of water, gases, air and climate, conserving chemical resources, Petroleum to build and energy survey. It attempt to enhance science literacy by emphasizing impact of chemistry on society.

The grade 10 chemistry curriculum does not incorporate the particulate nature of matter concept directly; however, it is referred implicitly through concepts such as structure of atom, periodic property of elements, ionic compounds, covalent compounds, carbon and organic compounds.

The grade 11 chemistry curriculum includes units entitled chemical reactions and stoichiometry, chemical termodynamics and solutions. The particulate nature of matter is taught in detail in this grade’s chemistry curriculum.

Students wishing to enter higher education must take a 1-year pre-university course, at the end of which they may obtain a pre-university certificate. In this grade, students take advanced chemistry called "chemical process". The grade 12 chemistry curriculum includes units entitled chemical kinetics, chemical equilibrium, acids and bases and electrochemistry.

b- Sample

The sample consisted of 160 male students, 80 from grade 9 (aged 14–15), 40 from grade 10 (aged 15–16), and 40 from grade 11 (aged 16–17), who were selected from city centre of Aslandooz in the North West of Iran. All participants came from similar middle-class socioeconomic backgrounds and fairly well-educated families.

c- Data Collection

There are many methods for determining conceptual understanding and misconceptions. Open-ended questions, two-tier diagnostic test, concept mapping, prediction-observation-explanation, interviews about instances and events, interviews about concepts, drawings and word association can be given as the examples of these methods (Kose, 2008). This study used some of these methods but its main focus was on students' drawings. Drawings have been considered as simple research instruments that enable easy comparisons at the international level. Because the drawing method allows us to capture more information than words, this method was utilized to prevent missing data due to problems of articulation that students at different grades might have (Harrison & Treagust, 2002; Coll & Treagust, 2002; Gokdere & Çalık, 2010).

The questionnaire comprising six open-ended and multiple choice diagnostic questions, students' drawings, and semi-structured interviews was constructed by collecting items used for similar purposes from the national and international literature. All questions were piloted, and required modifications were made prior to the administration of the test. The content validity of the test questions was assessed by chemistry lecturers. A group consisting of one professor, one associate professor, two assistant professor, and five chemistry teachers, was asked to judge the items for their validity and suitability for the context. The discussion about the questions and answers lasted for two 60-min sessions. All group members confirmed that, in terms of the content validity, the questions used in this study were in harmony with the aim of the study (α = 0.85). All items of diagnostic questions and what they measured were detailed in Table 1.

The test was administered under usual class conditions without previous warning (in 40- 45 minutes). The students were confirmed that the results of the test would be used for research purposes and would be kept confidential. Some items in the test required students to write and others required them to draw their ideas. The items that required students to draw their ideas, also, required them to describe their drawings.

Table 1. *Items of diagnostic questions and their specific aspects*

Item	Specific aspect	Purpose of data collection
1	students' conceptions about nature of matter	combination of multiple choice test and drawing
2	students' conceptions about condensation and expansion of matter	combination of open-ended test and drawing
3	students' conceptions about strike to the piece of matter	combination of open-ended test and drawing
4	students' understandings about origin of color of matter	multiple choice test
5	students' abilities to use their ideas about matter	combination of open-ended test and drawing
6	students' understandings of random motion of gas particles	combination of open-ended test and drawing

After exploring students' responses to all items, a sub-sample of 21 students was purposively selected (McMillan & Schumacher, 2001) with the aim of seeking maximum diversity with respect to students' misconceptions presented in their written responses. Students who presented misconceptions and did not provide detailed or clear explanation for their responses were asked to be interviewed. Through the interviews not only were students' written responses clarified and confirmed, but also their conceptual understandings and misconceptions were further probed. The duration of interviews varied between 15-20 minutes. The purpose was to check the validity of the interpretation of the drawings. During the interviews, students were asked about the nature of matter, condensation and expansion of matter, strike to the piece of matter, origin of color of matter, their ideas about matter and random motion of gas particles. The interviews were not subject to a detailed analysis, but were instead used to clarify students' drawings and explanations.

d- Data Analysis

The authors examined students' drawings and explanations separately and grouped them according to the following models (Ayas, Özman & Çalik, 2010; Abraham, Grzybowski, Renner, & Marek, 1992):

- *Sound understanding* (SU): Responses that included all components of the acceptable responses.
- *Specific misconception* (SM): Responses that included partial understanding, descriptive, incorrect, or illogical information and no components of the acceptable response. Students' drawings and explanations that were clearly not particulate in nature labeled in this category.

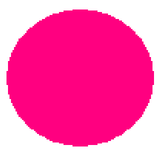
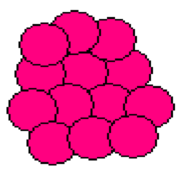
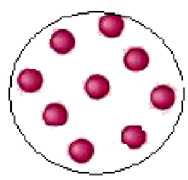
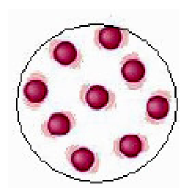
After the drawings and explanations were evaluated according to the criteria above, conceptions were determined and percentages were calculated. The results were given below by comparing with the drawings and explanations.

RESULTS

a-Findings from the students' drawings and explanations related to item 1

Item 1. Four students were asked to draw a small piece of copper and describe their drawings (10^{o}C). The drawings are illustrated in Figure 1. Which of them is more consistent with scientific model? If you think all of them are incorrect, draw your own drawing and describe it.

Figure 1. *Students' choices or drawings related to the small piece of copper*

Student	1	2	3	4
Drawings				
Descriptions	matter is continuous	matter consists of particles and there are not any space between them	matter consists of particles that are static and there are spaces between them.	matter consists of particles that aren't static and there are spaces between them.

The students' choices or drawings (with explanations) related to item 1 was analyzed and the conceptions presented in Table 2 were identified. As seen from Table 2, most of the grade 9 students' drawings fell into the continuous matter model (43.7%), whereas most of the grade 10 and 11 students' drawings referred to the matter consisted of particles that were static and had space between them (45.0 % for Grade 10, and 50.0 % for Grade 11). Twelve of the grade 9 students (15.0 %), eight of the grade 10 students (20.0 %) and nine of the grade 11 students (22.5 %) had conceptions that corresponded to the scientific view. They believed that matter was composed of particles that were not static and did not have space between them.

The sum of the students' responses categorized in the "specific misconceptions" category ranged from 77.5% to 85%, and showed a steady decrease with educational level from grade 9 to grade 11. Typical students' responses in this category were: "matter is continuous and matter is composed of particles that are static and there are spaces between them."

Table 2. *The students' conceptions related to item 1 identified through their choices and drawings (with explanation).*

Students' conception about the nature of matter	Understanding Level	Grade 9		Grade 10		Grade 11		Total	
		n	%	n	%	n	%	n	%
Matter is continuous	SM	35	43.7	6	15.0	5	12.5	46	28.7
Matter is composed of particles and there is no space between them	SM	20	25.0	8	20.0	6	15.0	34	21.2
Matter is composed of particles that are static and there are spaces between them	SM	13	16.2	18	45.0	20	50.0	60	37.5
Matter is composed of particles that aren't static and there are spaces between them	SU	12	15.0	8	20.0	9	22.5	27	16.9
Total		80		40		40			

b- Findings from the students' drawings and explanations related to item 2

Item 2. If the piece of copper in item 1 undergoes thermal changes, what happens to your drawing in question 1? Please draw the new shape of copper in 40 ^{o}C and in -20 ^{o}C respectively. Describe your drawing in any case.

The students' conceptions related to item 2 were analyzed and the conceptions presented in Table 3 were identified. As can be seen from Table 3, the percentages of the students' responses categorized under the "sound understanding" category are 7.5%, 17.5% and 42.5%, respectively, and indicate a steady increase with educational level. These students exploited scientifically accepted responses such as: "the movements of particles increase and lead to increase in the space between them". The sum of the students' responses categorized in the "specific misconceptions" category ranged from 57.5% to 92.5%, and showed a steady decrease with educational level from grade 9 to grade 11. Typical response in this category was; "particles expand or contract and it is added to the number of particles".

Table 3. The s*tudents' conceptions related to item 2 identified through their drawings (with explanation).*

Students' conceptions about condensation and expansion of matter	Understanding Level	Grade 9		Grade 10		Grade 11		Total	
		n	%	n	%	n	%	n	%
Particles expand or contract	SM	12	15.0	10	25.0	3	7.5	25	15.6
Particles expand (or contract) and space among them become larger	SM	38	47.5	12	30.0	15	37.5	65	40.6
It is added to the number of particles	SM	24	30.0	11	27.5	5	12.5	40	25.0
The movements of particles increase and lead to increase space between them	SU	6	7.5	7	17.5	17	42.5	30	18.7
Total		**80**		**40**		**40**			

c-Findings from the students' drawings and explanations related to item 3

Item 3. If you strike with hammer to the piece of copper mentioned in question 1, what happens to your drawing in question 1? Please draw the new shape of copper. Describe your drawing.

The students' conceptions related to item 3 were analyzed and the conceptions presented in Table 4 were identified. As seen from Table 4, the percentages of the students' responses classified as being a "sound understanding" category are between 10% and 23%, and indicate a steady increase with educational level. While grade 9 students showed the lowest understanding (10%), grade 11 students revealed the highest (23%). A typical response in the sound understanding category was: "When (you) strike to the piece of matter**,** particles arrange in new way but distance among them doesn't change".

As can be seen from Table 4, the sum of percentages of the students' responses categorized in the "specific misconception" category ranged from 42.5% to 66.2%, and showed a steady decrease with educational level from grade 9 to grade 11. A typical response was; "The shape of particles change and particles become scatter-come together".

Table 4. The s*tudents' conceptions related to item 3 identified through their drawings (with explanation).*

Students' conceptions about strike to the piece of matter	Understanding Level	Grade 9		Grade 10		Grade 11		Total	
		n	%	n	%	n	%	n	%
The shape of particles change	SM	33	41.2	5	12.5	3	7.5	41	25.6
Particles become scatter-come together	SM	20	25.0	13	32.5	14	35.0	47	29.4
Particles arrange in new way but distance among them doesn't change	SU	10	12.5	20	50.0	23	57.5	53	33.1
Other ideas	-	17	21.2	2	5.0	-	-	19	11.9
Total		**80**		**40**		**40**			

d- Findings from the students' drawings and explanations related to item 4

Item 4. Which statement is more consistent with the scientific view?

A. copper is continues red-brown matter.

B. copper is red-brown matter because its constituent particles are red- brawn.

C. copper is red-brown matter but its constituent particles are colorless. The origin of color in copper relates to aggregation and linkage of particles to each others.

The students' conceptions related to item 4 were analyzed and the conceptions presented in Table 5 were identified. As can be seen from Table 5, the percentages of the students' responses categorized under the "sound understanding" category are 8.7%, 27.5% and 42.5%, respectively, and indicate a steady increase with educational level. These students exploited scientifically accepted responses such as: "The block of copper is red-brown but its particles are colorless. When particles join together the color of copper appears". The sum of the students' responses categorized in the "specific misconceptions" category ranged from 57.5% to 92.5%, and showed a steady decrease with educational level from grade 9 to grade 11. A typical response in this category was; "Copper is a continuum-even very small piece of it has a red-brown color and the block of copper is red-brown and the origin of its color relates to colorful particles".

Table 5. The s*tudents' conceptions related to item 4 identified through their choices.*

Students' conceptions about origin of the color of matter	Understanding Level	Grade 9		Grade 10		Grade 11		Total	
		n	%	n	%	n	%	n	%
Copper is a continuum-even very small piece of it has a red-brown color	SM	18	22.5	9	22.5	10	25.0	37	23.1
The block of copper is red-brown and the origin of its color relates to colorful particles	SM	55	68.7	20	50.0	13	32.5	88	55.0
The block of copper is red-brown but its particles are colorless. When particles join together, the color of copper appears	SU	7	8.7	11	27.5	17	42.5	35	21.9
Other scatter ideas	-	-	-	-	-	-	-		
Total		**80**		**40**		**40**			

e- Findings from the students' drawings and explanations related to item 5

Item 5. There is some Oxygen gas in a closed container. Please draw a picture representing gas molecules in the container. Describe your drawing.

The students' conceptions related to item 5 were analyzed and the conceptions presented in Table 6 were identified. As seen from Table 6, the percentages of the students' responses classified in the "sound understanding" category are between 10% and 22.5%. While grade 10 students showed the lowest understanding (10%), grade 11 students revealed the highest (22.5%). A typical response in the sound understanding category was: "Particles of gas are diffused in continuous context (this context is air or something else) and fill container".

As can be seen from Table 6, the sum of percentages of the students' responses categorized in the "specific misconception" category are 82.4%, 90% and 95%, respectively, and showed a steady decrease with educational level from grade 9 to grade 11. Typical responses in this category were: "Particles of gas fill container, particles of gas don't fill container and particles of gas are diffused in continuous context (this context is air or something else) and don't fill container".

Table 6. The s*tudents' conceptions related to item 5 identified through their drawings (with explanation).*

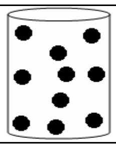
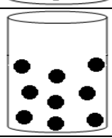
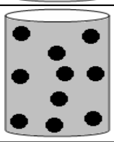
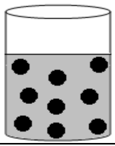
Students' abilities to use their ideas about matter	Understanding Level	Example	Grade 9		Grade 10		Grade 11		Total	
			n	%	n	%	N	%	n	%
Particles of gas fill container	SM		42	52.5	26	65.0	25	62.5	93	58.1
Particles of gas don't fill container	SM		11	13.7	6	15.0	4	10.0	21	13.1
Particles of gas are diffused in continuous context (this context is air or something else) and fill container	SU		13	16.2	4	10.0	9	22.5	26	16.2

Table 6. *Continued*

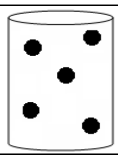
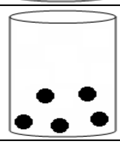
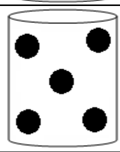
Particles of gas are diffused in continuous context (this context is air or something else) and don't fill container.	SM		8	10.0	3	7.5	2	5.0	13	8.1
Other scatter ideas	-		6	7.5	1	2.5	-	-	7	4.4
Total			**80**		**40**		**40**			

f- Findings from the students' drawings and explanations related to item 6

Item 6. If the half of gas in item 5 sucked out of the container, please draw a picture representing the reminder of gas in the container. Describe your picture.

The students' conceptions related to item 6 were analyzed and the conceptions presented in Table 7 were identified. As can be seen from Table 7, the percentages of the students' responses categorized under the "sound understanding" category are 31.2%, 70% and 85%, respectively, and indicate a steady increase with educational level. These students exploited scientifically accepted responses such as: "The reminder particles fill the container". The sum of the students' responses categorized in the "specific misconceptions" category ranged from 15% to 78.7%, and showed a steady decrease with educational level from grade 9 to grade 11. Typical responses in this category were: "The reminder particles don't fill the container and the reminder particles become bigger to fill the container and/or it is added to the number of particles".

Table 7. *Students' conceptions related to item 6 identified through their drawings (with explanation).*

Students' abilities to use their ideas about matter	**Understanding Level**	**Example**	**Grade 9**		**Grade 10**		**Grade 11**		**Total**	
			n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
The reminder particles fill the container	SU		25	31.2	28	70.0	34	85.0	87	54.4
The reminder particles don't fill the container	SM		38	47.5	8	20.0	4	10.0	50	31.2
The reminder particles become bigger to fill the container and/or it is added to the number of particles	SM		17	21.2	4	10.0	2	5.0	23	14.4
Other scatter ideas	-		-	-	-	-	-	-		
Total			**80**		**40**		**40**			

DISCUSSION

It can be concluded from the data that the number of students' responses categorized under the "sound understanding" category for each item increased with educational level. An increase in students' conceptual understanding with their grade is, of course, an expected result (e.g., Çalık, 2005). Moreover, as can be seen from the data, the students' specific misconceptions decreased steadily from grade 9 to grade 11, except for items 4 and 5. This may result from the fact that students' motivation may have decreased towards thinking about chemistry after a highly competitive exam.

Analysis of the students' drawings and choices related to item 1 revealed that students had misconception about the particulate nature of matter. Most 9th grade students (43%) had the misconception that matter is continuous. This is consistent with the findings of the studies by Johnson (1998c) and Nakhleh (1992). Most 10th and 11th grade students believe that matter consists of particles but these particles are static (45% and 55% respectively). Just small proportion of the students (15% of 9th grade, 20% of 10th and 22.5% of 11th grades) had conceptions that corresponded to the scientific view.

The students' drawings related to item 2 showed that just a few number of students (7.5% of 9th grade, 17.5% of 10th grade and 42.5% of 11th grade) had conception that expansion and contraction of matter relates to the movement of particles. Most students attributed macroscopic properties of a substance to its particles. For example, some of them showed in their drawings that particles got bigger as the temperature increased. The results also showed that students who perceived matter as an aggregation of particles had more scatter ideas about expansion and contraction than students who saw matter as a continuum. This means that this misconception is very strong to justify many physical variations, and, therefore, hard to change.

The analysis of students' drawings related to item 3 showed that most of the grade 9 students (41.2%) believed that particles of metal were malleable. This group attributed macroscopic properties of matter to constituent particles. About 50% of the grade 10 and 57.5% of the grade 11 students held an idea that is close to the scientific view (Particles arrange in new way but distance among them doesn't change).

In response to item 4, most of the students (68.7% of grade 9, 50% of grade 10 and 32.5% of grade 11 students) chose option (B) that shows that they attribute color of copper to constituent particles, as reported by other researchers (Ingham & Gilbert, 1991; Albanese & Vicente, 1997). Harrison and Treagust (2002) suggested that this conception may result from students' extending textbook statements beyond the authors' intention. For example, Wilbraham, Staley and Matta (1997) described the division of a copper penny into ever-smaller pieces. 'Eventually you would come upon a particle of copper that could no longer be divided and still have the properties of copper. *This particle would be an atom, the smallest particle of an element that retains the properties of that element'* (p.85), (emphasis in the original).

The analysis of the students' drawings related to item 5 showed that some of the students thought that the particles of gas were diffused in continuous context. When asked about the nature of this context, they had various ideas, for example, '*the space between particles is filled with air, other gas or unknown matter*'. This view suggests that the notion that an empty space exists between particles causes students considerable difficulties. The students find space difficult to imagine and intuitively "fill" it with something. This misconception is consistent with those reported by previous research (Novick & Nussbaum, 1981).

The analysis of the students' drawings related to item 6 revealed several misconceptions. First, a great proportion of students believed that when some of the gas sucked out of the container, the remainder does not fill the container as demanded by the scientific model. The idea that gas particles are static is a notion held by the students strongly. Second, some of the students who use particles idea believed that when some of the gas sucked out of the container, the reminder particles became bigger to fill the container or were added to the number of particles. This is common misconception that particles can change form and/or size. As mentioned in items 3 and 4, the students ascribed macroscopic properties to particles. For example, particles may explode, burn, contract, expand and/or change shape.

CONCLUSIONS and IMPLICATIONS

The particulate nature of matter is a key concept taught at the early stages of schooling. Although other conceptions are also important, the literature suggests that students often have difficulties in learning chemistry topics if they do not understand the scientific model for the particulate nature of matter.

From this study it is evident that many students found it difficult to imagine macroscopic events microscopically using the particle model as reported elsewhere (Onwu& Randall, 2006). Several studies had shown that grade level and teaching about matter have significant effect on students' achievement (Yilmaz & Alp, 2006; Kind, 2004) but our study showed that grade level has little effect on students' achievement.

The findings of this research revealed that students have inadequate understanding of the concepts related to the particulate nature of matter. They hold many misconceptions. Evidence indicated that teaching does not prompt significant change in children's thinking. Children's naive view of matter is based on the "*seeing is believing*" principle. Particles cannot be "seen", so they do not need to be exist in a functioning model to explain the behavior of matter. The results of the study revealed that the students find space difficult to imagine and intuitively "fill" it with something. Since students depend on visible, sensory information about solids and liquids to develop their naive view of matter, their difficulty accepting a model proposing there is "nothing" in the spaces between particles is unsurprising.

The findings of this research revealed that a great proportion of students believed that macroscopic properties are attributed to particles. The idea that all substances can be separated into tiny indivisible particles called atoms, molecules and ions is widely accepted. Students are familiar with atoms and molecules per favour of the popular media and stylized atoms are the logo for several science TV programs (Johnston, 1990). Children are aware of atoms and molecules well before particle theory is taught in school (Lee, Eichinger, Anderson, Berheimer & blakeslee, 1993). But this is where the similarity between science and student preconceptions ends because students consistently attribute the macroscopic properties of matter to its sub-microscopic particles (Albanese & Vicenti, 1997).

The results of the study showed that a great proportion of students believed that Matter is continuous. This is consistent with Aristotle's maxim that 'nature abhors a vacuum' (Nussbaum, 1997). The accepted scientific view is ontologically very different - discrete, dynamic particles that are separated by empty space (De Vos & Verdonk, 1996). However, our study showed that the contrasting idea that particles are in substances, rather than that substances are composed of particles is common.

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