

## The Effect of a Developed REACT Strategy on the Conceptual Understanding of Students: "Particulate Nature of Matter"

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### ABSTRACT

The purpose of this study is to investigate the effect of REACT strategy developed in relation to "Particulate nature of the matter" subject on academic achievement and conceptual change. This study was accompanied by pre-test – post-test control group design. The academic achievement and concept test, which were developed, was distributed to 55 experimental group students and 47 control group students, which makes 102 learners in total. These learners are studying at 6<sup>th</sup> grade. REACT strategy was implemented on experimental group. Control group was exposed to current Science and Technology Curriculum. As a result of conducted implementations, it was detected that both academic achievement and conceptual change of experimental group students are better than control group students. Therefore, it is possible to say that REACT strategy is more efficient than the Ministry of National Education's curriculum. Interview with students in the direction of determined objective in addition to academic achievement and concept test may be recommended for future studies.

**Keywords:** Conceptual Change, Context, Matter, Particle, REACT.

### INTRODUCTION

According to constructivist approach, learning takes place when pre-knowledge of individuals interacts with new information and when they are compared which leads to emergence of new conceptual structures. Pre-knowledge of learners or alternative concepts are playing important roles both in designing instruction and in learning of learners. One of the most important factors influencing learner achievement negatively is alternative concepts. The change in these concepts is of importance for constructivist approach (Cobern, 1994; Duit & Treagust, 2003; Sinatra & Broughton, 2011). Science is the effort to understand the events of nature (Bybee, 1991; Çepni, 2014; Hurd, 1975). Students misinterpret the events of nature because of alternative concepts (Duit & Treagust, 2003). Thus, these alternative concepts, which reduce the efficiency of educational practices and situated in students' minds, should be analyzed through conceptual change process (Duit & Treagust, 2003; Johnson, 1998).

"Particulate nature of the matter" is one of the subjects on which learners have maximum number of alternative concepts (Adadan, Trundle & Irving 2010; Adbo & Taber,



2009; Ayas, Özmen & Çalık, 2009; Aydeniz & Kotowski, 2012; Boz, 2006; Bunce & Gabel, 2002; Gomez, Benarroch & Marin, 2006; Kokkotas, Vlachos & Koulaidis, 1998; Maskill, Cachapuz & Koulaidis, 1997; Nakhleh & Samarapungavan, 1999; Özmen, Ayas & Coştu, 2002; Taber & Garcia-Franco, 2010; Tsitsipis, Stamovlasis & Papageorgiou, 2010). This subject is included in science and technology curriculum for 6<sup>th</sup> grade that was revised in 2005 in Turkey. Based on this subject, students learnt that matters are constituted of particles and these particles are called “atoms”. It was followed by subjects covering “elements, compounds and molecules”. Therefore, atom concept and properties of this concept should be constructed accurately in the minds of the students so as to facilitate the learning of other concepts. However, conducted studies still indicate that students have alternative concepts regarding “atom” concept. For instance, students believe that atom is living beings (Griffiths & Preston, 1992; Harrison & Treagust, 1996; Kenan, 2005). They even assume that atoms in living beings are animate while the atoms in non-living beings are not animate (Özalp & Kahveci, 2011). They think that atoms of the objects are different even if they are made of the same matter (Pideci, 2002; Kenan, 2005). The other beliefs are as follows: a matter can be divided until there is nothing left (De Vos & Verdonk, 1996; Novick & Nausbaum, 1981; Stavy, 1990; Nakhleh, 1992), scientists have seen atoms and it is possible to see them through a microscope (Bektaş, 2003; Griffiths & Preston, 1992; Ireson, 2000; Nakhleh & Samarapungavan, 1999), air does not have a mass or volume since it cannot be seen (Valanides, 2000) atom looks like a solid globe with its compounds and it has simple circulations within a circle (Bektaş, 2003; Griffiths & Preston, 1992; Harrison & Treagust, 1996).

One of the reasons as to why students have difficulty in comprehending this subject (Boz, 2006; Brook, Briggs & Driver, 1984; Özmen, 2011a; Özmen, 2011b; Tsai, 1999) is that they are incapable of associating the science concepts with the ones they encounter (Burbules & Linn, 1991; Gilbert, 2006; Stolk, Bulte, De Jong & Pilot, 2009, 2012). Another reason is that they have low levels of interests and motivations towards the course (Wolters & Rosenthal, 2000). McLeod (2003) states that in learning environments where constructivist approach was adopted, the instruction should be based on a context to draw the attention of the student that distinguishes these environments from the other ones. In order to draw the attention of the student, it is important to make them perceive how they will benefit from what is being taught. This can only be achieved within a context (Morrison, Ross, Kemp & Kalman, 2010).

### *Context Based Learning*

If the aim is to teach a concept, scientific aspect of that concept and its role in our lives should be combined. The concept should be considered as an implementation of the real world (King, Bellocchi & Ritchie, 2008; Whitelegg & Parry, 1999). According to context based learning theory, individuals make associations based on the examples of daily life. By gaining experience, they start to learn. (Choi & Johnson, 2005). What distinguishes context based learning from other theories that adopted constructivist approach is this philosophy. Main purpose of this theory, which was started to be employed in 1980, is to raise the attention of students towards science and to make them realize the association between real life issues and science (Bennett, Hogarth & Lubben, 2003). A teacher who prepares himself/herself according to context based learning theory cannot ignore prior knowledge of students on which the new ones will be constructed. In order to overcome the differences among students, s/he creates a common ground by building contexts during education (Whitelegg & Parry, 1999). Therefore, employing context is of importance for science education (Gilbert, 2008).

That students cannot find answer to the question, “Why do I have to learn this subject?” influence their interests and motivations as well as conceptual change processes (Gilbert, Bulte & Pilot, 2011; Gilbert, 2008). Finding an answer to this question will increase both their motivations and their academic achievements (Bennett & Lubben, 2006). According to context based learning, the answer to this question should be given within the instruction process.

Thus, students should learn particulate nature of the matter in such a way that a context will be provided to make them associate it with their own experiences and lives. If students know they will use what they learn to interpret the events of their daily life, this will have a positive effect on their conceptual change processes (Gilbert, 2008). Therefore, REACT strategy is one of the ways to practice a theory based on context. This strategy is claimed to create an environment to make association between scientific concepts and context. It is also believed that this strategy is effective on both conceptual change and academic achievement (Ayvaci, Er Nas & Dilber, 2016; Er Nas, Şenel Çoruhlu & Kirman Bilgin, 2016; Ingram, 2003; Kirman Bilgin & Yiğit, 2017a,b).

### *REACT strategy*

An organization named The Center of Occupational Research and Development (CORD) created REACT strategy as a result of studies conducted due to problems encountered in Math and Science. It consists of “Relating– Experiencing– Applying – Cooperating– Transferring” stages. It assists teachers and students to make associations between concepts regarding the subject and the context derived from real life experiences. It raises the interest and motivation towards course. Teachers may start the instruction by asking a question regarding a situation that may be encountered in daily life. The context or properties are brought into classroom. Students experience laboratory activities such as finding, discovering and researching. After students experience the association between context and concept, professional aspect of the context is emphasized. Students communicate with their friends, share what they learn and discuss in a process. Transferring refers to a student’s implementation of what s/he learnt in a new context or a situation (Crawford & Witte, 1999; Hull, 1999; Crawford, 2001; Navarra, 2006).

Conducted studies on strategy shows that REACT strategy provides permanent learning (Demircioğlu, Vural & Demircioğlu, 2012; Ingram, 2003, Kirman Bilgin, Er Nas & Şenel Çoruhlu, 2017; Ültay, Durukan & Ültay, 2015).

Based on such proposals, this study aims at investigating the effect of REACT strategy developed in relation to “Particulate nature of the matter” subject this end, the questions below were tried to be answered:

- Is there a significant difference between pre-test and post-test scores of learners indicating an effect of instruction on academic achievement?
- Is there a significant difference between pre-test and post-test of learners indicating an effect of instruction on conceptual change?

## **METHODS**

Quasi - experiment model and pre-test/post-test control group design is suitable for this research.

### **a) Sample**

Sample of this study consists of 6<sup>th</sup> grade students from a primary school randomly selected in Trabzon province. There are four 6<sup>th</sup> grade classes in the school and two of them

were randomly assigned as experimental group while the others became control group. The study was conducted with 102 students in total 55 of which is in experimental group while the 47 were in control group.

### b) Developing Data Collection Tools

Science and technology curriculum was investigated and researchers decided on the objectives of the first subject of “Particulate nature of the matter” unit, named as “Particles Making up the Matter”, in relation to Academic Achievement Test (AAT- App. 1). The subject covers eight gains. An instruction of six hours was prepared. AAT, prepared in accordance with gains and containing 16 multiple-choice questions. KR20 reliability coefficient value of measurements from the test was calculated as 0.89.

In order to measure conceptual comprehension of learners, concept test (CT - App. 2) containing 5 two-stage questions. First stages of first 5 questions are multiple choice questions while the other stage asks learners to write the reason of their selection. KR20 reliability coefficient value was calculated as 0.72.

### c) Data Analysis

Pre-test results of AAT and CT were compared with non-parametric Mann-Whitney U test. As a result of the comparison, there was no significant difference between the scores of experimental and control groups both in terms of AAT and CT pre-test scores (Table 1). Since AAT post-test scores of experimental and control groups provide parametric testing propositions, they were compared with independent t-test while CT was compared with Mann-Whitney U test.

Table 1: Mann-Whitney U test results of AAT and CT pre-test scores

Test	Group	N	Rank Ave.	Rank Tot.	U	P
AAT	Experimental	55	53,19	2925,50	1,200	.52
	Control	47	49,52	2327,50		
CT	Experimental	55	47,88	2633,50	1093,500	.17
	Control	47	55,73	2619,50		

AAT consists of 11 questions in total. Each question scores 1 point. Learner responses of CT analysis were classified and scored separately. This scoring was performed with the classification in relation to two-stage test developed by Abraham, Grzybowski, Renner & Marek (1992). Table 2 shows how learner responses were classified, sample responses from question 4 and scored.

Table 2: CT response classification and scoring

Classification	Score	Sample Responses
Complete comprehension	4	There is no color of the particle regardless of the color and the state of matter. Also, air is a matter
Partial comprehension	3	The atoms of matter are colorless
Partial comprehension with alternative perception	2	The atoms are colorless, however there is no atom in air.
Alternative perception	1	We can not touch the air like a table. So there is no atom in air.
No comprehension	0	I do not know

According to this classification, if a response contains all the components of the valid response, this means *complete comprehension*; if a response contains some of the components, this means *partial comprehension*; when the concept is understood yet if a

misunderstanding is detected, this means *partial comprehension with alternative perception*; and if a response contains illogical or incorrect information, this means *alternative perception*. *No comprehension* refers to responses irrelevant to the subject or ambiguous, rewriting of the selected response or no writing at all.

#### d) Instruction design

Contexts, considered as the starting point of discovering the importance of scientific knowledge, are especially important tools for science and technology courses (Bennett, Hogarth & Lubben, 2003; King, Winner & Ginns 2011). Context may appear in the form of theme, subject, problem, story, case, or as practice within the course (Wieringa, Janssen & Van Driel, 2011). Games, toys, market trips, meals or the events they experience in the streets may be used as context for children. However, these contexts should be enriched with texts, videos, discussions and in-class activities (CORD, 1998). Contexts to be used in teaching may include television news, newspaper's reports or other current events (URL 1). Context may sometimes be concrete in the form of television, radio or any other device as well as a natural phenomenon. In other words, any objects, events or concepts you encounter in your daily life may be a context (Bülbül & Aktaş, 2013). Besides, discussions or research activities may be carried out as teaching activities (URL 1). There are differences between REACT strategy and 5E teaching model. It is necessary to use context to attract the attention of the learner and to conduct group work according to REACT strategy. But, it is not necessary these specifications according to 5E teaching model (Ültay & Çalık, 2011)

Based on these properties, context selected for experimental group was bottled gas. Bottled gases, which we use in household or offices, are perfect examples to make students comprehend that gases have masses. This is because bottled gases used in Turkey are sold in 12 kg portions. Besides, when you shake these bottles, you hear the sound of a liquid since compressed petrol gas is used in them. This can be explained via compressibility of gases. Explosion of these bottles is a great example to explain expansion of gases. Thus, it is an appropriate context for gains of the subject.

The instruction designed for experimental group was prepared taking into account REACT strategy. The Table 3 below shows gains that were dealt with, the materials developed for these gains, alternative concept codes they contain and practice processes.

Table 3: Instruction design implemented on experimental group

Phase of REACT	Gains	Alternative Concepts and Application time	Teaching Process
Relating	<i>“Compares compression and expansion properties of solid, liquid and gaseous matters” and “Infers that there are spaces in gaseous matters from the comparison of compression-expansion properties of them”</i>	Alternative concepts: 6,10,11,12 (Table 8)  (40 minutes)	Ask what they think about the sound of liquid when they shake bottled gases and tubes. Discuss the association between the subject and the context. Conceptual change text is distributed for alternative concepts.
Experiencing	<i>“Realizes that matters can be divided into unseen particles via an experiment” and “Questions to what extent matters can be divided successively”</i>	Alternative concepts: 5,7 (Table 8)  (40 minutes)	Let the student watch the first animation. In this animation, there are objects regarding the solid, liquid and gaseous states of the matter. By selecting any of these objects, the student tries to divide it constantly. S/he has particles every time at the end. Later, teacher emphasizes that each matter is made up of particles which are so small that they cannot be seen through the eyes.



Applying	<i>“States that all kinds of matters are made up of building stones which are difficult to be divided and they are too small to be seen” and “Building stones of the matter which are similar to globes are called atoms”</i>	Alternative concepts: 4,8,9,14 (Table 8)  (40 minutes)	Let the student watch the second animation. In this animation, a student wonders what a leaf is made of. S/he examines the leaf under microscope and observes that it is made up of cells. Afterwards, students are asked what cells are made up of. Students discuss among themselves. Animation tries to explain that even a single cell consists of billions of atoms. Later, conceptual change text is distributed regarding relevant alternative concepts.
Cooperating	<i>“Realizes that opinions regarding the concept of atom change in time” and “Expresses that atoms are comprised of even smaller particles”</i>	Alternative concepts: 7, 15 (Table 8)  (40 + 40 minutes)	Group work in relation to scientists such as “Democritus, John Dalton, Marie Curie and Becquerel” as well as their claims regarding the atom is performed.
Transferring	All of the gains	Alternative concepts: 1, 2, 3 (Table 8)  (40 minutes)	A discussion environment is created asking “Are atoms in living beings animate while atoms in non-living things inanimate? Are atoms of objects with different shapes different even if they are made of same material?” questions and conceptual change text is distributed. Also, students are asked why bottled gases explode. The answers are discussed.

Control group could be instructed using current instruction designed in conformity with 5E Teaching Model by Ministry of National Education (MNE, 2006, s.86-94). However, it was seen from the interview with the practice teacher that the teacher s/he carried out his/her own instruction instead of the curriculum. At the end of the observations, the instruction covering the same gains (Table 3) was implemented on control group and it is summarized with the following paragraph.

Table 4: Instruction design implemented on control group

#### Teaching Process and Application Time According to 5E Teaching Model

Firstly, the teacher asks questions about properties and states of the matter and gives examples. Then, s/he puts small stones into a syringe and compresses it. They discuss the results (40 minutes - Engagement). S/he adds sugar into the water and mixes it. They discuss the results (40 minutes - Exploration and Explanation). A reading text about the contributions of Democritus, John Dalton, Marie Curie and Becquerel is read (40 minutes - Elaboration). Evaluation questions in the book are answered (40 minutes - Evaluation). A test consisting multiple-choice questions is implemented on students (40+40 minutes - Evaluation).

## FINDINGS

Table 5 shows results of independent t-test conducted in order to reveal if designed instruction created a significant difference on academic achievements of learners in terms of post-test scores.

Table 5: Independent t-test results of AAT post-test scores

Group	N	Ave.	S	sd	T	p
Experimental	55	55,27	21,15	100	2,29	,024
Control	47	45,53	21,65			

When Table 5 comparing the AAT (Appendix 1) post-test scores of groups is examined, it is seen that there is a significant difference on behalf of experimental group, [t(100)=2.29, p<.05].

Table 6: Mann-Whitney U test results of CT post-test scores

Group	N	Rank Ave.	Rank Tot.	U	p
Experimental	55	65,28	3590,50	534,50	.000
Control	47	35,37	1662,50		

CT Scores of experimental group, participated in the instruction designed to develop conceptual change, and control group were compared. As shown in Table 6, there is a significant difference between group scores on behalf of experimental group, [U:534,50, p<.001].

Responses of experimental group students for two-stage questions in CT are classified according to Table 2 and presented in App. 3. When the App. 3 is examined, it is remarkable that most of the learners with alternative concepts in experimental group resolved these concepts while some of them remained in the same conceptual level they had before. The change in alternative concepts of experimental and control group students is shown in Table 7.

Table 7: The Change in Alternative Concepts of Experimental and Control Group Students

No	Alternative Concepts	Experimental Group		Control Group	
		Pre-Test %	Post-Test %	Pre-Test %	Post-Test %
1	Atoms are animate due to their movements.	27,2	1,8	14,8	8,5
2	Atoms in living beings are animate while atoms in non-living things are inanimate.	18,1	5,4	17	21,2
3	Objects with different shapes have different atoms even if they are made of the same material.	27,2	16,3	17	10,6
4	There are atoms among the particles making up the matter.	67,2	36,3	51	59,5
5	A matter can be divided until there is nothing left.	5,4	3,6	21,2	8,5
6	If the matter is unseen, it means there is no matter.	3,6	5,4	10,6	4,2
7	Scientists saw the atoms.	25,4	1,8	12,7	17
8	Atoms are flat and there is another substance between them.	3,6	3,6	10,6	2,1
9	Atoms have a simple cycle within a circle.	12,7	18,1	25,5	14,8
10	Air is not a matter since it does not have a volume and mass.	10,9	10,9	19,1	6,3
11	Gases do not have mass.	40	21,8	36,1	31,9
12	Air is not a matter since it is unseen.	18,1	-	23,4	10,6
13	Atom looks like a solid globe with its components.	27,2	18,1	21,2	23,4
14	There is air between particles making up the matter.	21,8	36,3	29,7	19,1
15	Atoms are big enough to be seen by means of a microscope.	16,3	-	14,8	6,3

Generally, it is seen that some of the alternative concepts decreased while some rose and others remained the same when Table 7 is examined. However, the difference in experimental group is more remarkable considering the decrease in the rates of alternative concepts. For example; the percentage of 7<sup>th</sup> alternative concept decreased from 25,4% to 1,8% in experimental group while it rose from 10,9% to 17% in control group. 15<sup>th</sup> alternative concept was totally eradicated in experimental group while it decreased from 14,8% to 6,3% in control group.

## DISCUSSION and CONCLUSION

According to Table 7, alternative concepts “Atoms are animate due to their movements” (Tezcan & Salmaz, 2005) and “The atoms in living beings are animate while the atoms in non-living things are inanimate” is commonly adopted by learners (Griffiths & Preston, 1992; Pideci, 2002; Salmaz, 2002) Though there is a tremendous decrease in post-test, it is seen that some of the learners still keep them. This may stem from the fact that learners confuse the properties of cells and atoms. Learners may think that living beings are animate since atoms are animate and non-living things are not since atoms are inanimate which may be the root cause of this misconception. Özalp and Kahveci (2011) asked questions about the atoms of a leaf which is not torn apart from the plant. 46,7% of the class expressed that the atoms are animate. 50% of the response owners commented that “atoms are animate since the leaf is alive”. As seen from this example, learner opinions claiming that living beings can move attribute the characteristic of animation to atoms. 40% of control group students from Tezcan and Salmaz’s (2005) study think that atoms are animate thanks to the movements of the matters. However, these alternative concepts were rare limited to a few learners as seen from the post-test. This may stem from the fact that the discussion created and conceptual change text implemented in the class have been effective in changing these alternative concepts with scientific facts. The learners still had alternative concept of “Atoms of matters with different shapes are different even if they are made of the same material” (Griffiths & Preston, 1992) at a rate of 16,3%. This is because learners regard physical appearance as a distinguishing characteristic. Based on the fact that “the smallest building stone of the matter is atom”, learners may think that the reason why matters are different stem from atoms’ being different which may be another reason for the abovementioned misconception as well.

The alternative concepts of “There is space between the particles making up the matter” and “There are atoms between the particles making up the matter” (Griffiths & Preston, 1992; Pideci, 2002; Salmaz, 2002) are remarkable with a rate of 36,3% in post test accompanied by “Atoms are flat and there is another substance between them” (Griffiths & Preston, 1992) with a rate of 3,6%. This may be caused by the fact that learners could not concretize the concepts of atom-particle-matter and the quantities of their sizes, which did not allow learners to relate these concepts with each other and envisage the concept of *space* in their minds. While teaching the subjects in relation to Earth and Universe, the concept of space is used to define airspace. This might have made learners experience difficulty in imagining space between atoms. Thus, learners think that there are atoms or air between atoms.

In relation to movement and properties of atoms, the alternative concepts of “Atoms have a simple cycle within a circle” and “Atoms look like a solid globe with its components” (Bektaş, 2003; Griffiths & Preston, 1992; Ireson, 2000; Nakhleh & Samarapungavan, 1999; Tezcan & Salmaz, 2005) could not be replaced by scientific facts thoroughly. It is due to the fact that the symbols and scientific definitions as well as microscopic and macroscopic shapes in addition to daily life usages are not provided together and at the same time which led learners to have difficulty in envisaging them in mind. Çalık (2006) said that structuring of some of the alternative concepts requires a long process. This may apply to these alternative concepts, too.

The alternative concept of “Air is not a matter since it is unseen” (Bektaş, 2003; Nakhleh, 1992; Yeğnidemir, 2000) was not observed in the post-test. This indicates that *relating* step which conceptual change text was enough for this alternative concept to a great extent. The alternative concepts of “Air is not a matter since it does not have volume and mass”, “If the matter is unseen, it means there is no matter” (Bektaş, 2003; Nakhleh, 1992; Yeğnidemir, 2000) and “A matter can be divided until there is nothing left” (Bektaş, 2003;



Nakhleh, 1992; Stavy, 1990; Yeğnidemir, 2000) were observable in the post-test though at a quite low percentage. Learners have difficulty in concretizing and envisaging the matters they cannot see which may be the reason of this result (Çepni, Taş & Köse, 2006; Margel, Eylon & Scherz, 2004). As for the alternative concept of “Gases do not have mass” (Griffiths & Preston, 1992; Stavy, 1990), it decreased to a considerable extent in experimental group students yet still 18,1% had this idea in post-test. Learners consider air as an example to gaseous matter. Since they cannot see air, they cannot imagine it having a volume and mass. Thus, they believe that matter must be seen to prove its existence. It is clear that learners must accurately comprehend what kinds of properties change in matters while they are transiting between states.

When Table 7 is examined, it is seen that the alternative concept of “Scientists saw the atom” (Tezcan & Salmaz, 2005; Uzun 2010) has a rate of 1,8% while “Atoms are big enough to be seen by means of a microscope” (Bektaş, 2003; Griffiths & Preston, 1992; Harrison and Ireson, 2000; Lee & et al., 1993; Nakhleh & Samarapungavan, 1999; Treagust, 1996; ) was not observed in the post-test. Control group has higher rate on this alternative concepts (see, Table 7) which indicates that REACT strategy implemented on experimental group is more effective than teaching implemented on control group. Tezcan and Salmaz (2005) conducted interviews regarding the same alternative concepts and accomplished a result at a rate of 40-20% from experimental group. Thus they stated that the developed material was not efficient enough for these alternative concepts. Current study led to a considerable decrease which indicates that the developed animation and conceptual change text were efficient for these alternative concepts.

When AAT and CT pre-test and post-test scores of experimental and control groups were analyzed, it is remarkably seen that experimental group progressed more positively than control group both in terms of academic achievement and conceptual change. The reason may be REACT strategy that is application of Context Based Learning.

It was decided that the activities and the practice developed and conducted for experimental group had been more effective than control group in terms of academic achievements of 6<sup>th</sup> grade students within the frame of curriculum objectives/gains. Most of the alternative concepts possessed by learners were replaced by scientific facts and constructed accurately (1,2,7,12,15) while some of them were somewhat affected (3,4,5,11,13). Some of the alternative concepts remained the same (8,10) while some of them rose at the end (6,9,14). Taking into account the results of the implementation carried out with control group, it is seen that they did not experience a decrease as much as experimental group. Therefore, it is possible to say that REACT strategy is more effective than 5E teaching model implemented by Ministry of National Education in terms of both academic achievement and conceptual change. This is because in the instructions employing context based learning, students should be made to feel that the subject is also a part of their lives. In the developed REACT strategy, bottled gas was used as context and the attention of students were tried to be raised.

## Suggestions

In this study, REACT strategy was more effective than control group in terms of changing alternative concepts in relation to subject of particles making up the matter. But, it was revealed that learners have difficulty in envisaging the fact that there is space between particles forming the matter. Different conceptual change pedagogies can be designed and integrated into REACT strategy and tested for efficiency. Learners think that gases cannot be matters since they do not have volume and mass. Hence, different connections and visual materials can be developed to enable learners to construct states of matters with particular

importance to properties of gas state. Simulations and animations can be used to assist learners when they fail to imagine. Visual materials can be designed to teach abstract concepts which they do not make sense and encounter in daily life. Within the frame of current implementation, it was not questioned to what extent this learning was permanent. Besides, the learners were not interviewed clinically in relation to alternative concepts. Thus, data variety and reliability can be increased by performing interviews in addition to current implementation with a new sample that may yield different results.

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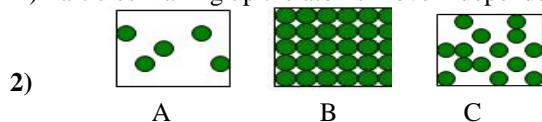


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## Appendices

### App. 1: AAT questions

- 1) A student read in a newspaper that tiny particles making up the atom are used to treat some disorders. The student reading this **can** infer that
- Cells are made up of atoms.
  - Atoms can be divided.
  - Atoms are everywhere in matters.
  - Particles making up the atoms move independently where there is no matter.



The figure above show granular structures of matters differing from each other. There are some statements in relation to these matters below. Which of them is **incorrect**?

- Matter A may be water vapor, matter B may be water and matter C may be ice.
- Matter A does not have a certain volume but it takes the volume of the cup it is in.
- Matter C has a certain volume and it takes the shape of the cup it is in.
- Matter B has a certain volume but it does not take the shape of the cup it is in.

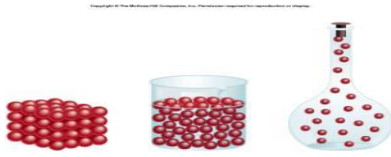
- 3) An idea occurs to Kağan's mind while eating nuts and he wants to implement it. He takes a press and puts nuts in it. He tries to pure them but realizes that they do not divide into tiny pieces. He wants food processor from his mother and this processor makes nuts powdery.

To you, **what is the purpose** of Kağan with this experiment?

- He proved that solid matters are more easily fragmented than gases.

- B) He wanted to divide into tiny pieces to compress the nuts.  
 C) He questioned to what extent matters can be successively divided.  
 D) He wanted to increase the space between particles making up the matter.

4)



I                      II                      III

The figures above shows the order of particles making up matters in three different physical states. Considering the spaces between particles, choose the **correct** matching below.

- |    | I     | II    | III         |
|----|-------|-------|-------------|
| A) | Apple | Peach | Air         |
| B) | Peach | Apple | Soup        |
| C) | Milk  | Table | Cloud       |
| D) | Table | Milk  | Water vapor |

5) X and Y matter of the same quantity are put into identical cups having pistons. When equal force is applied on both pistons, it is seen that matter Y is compressed while matter X is not.

Based on this observation, which of the statements below is **true** for the particles making up matter X and Y?

- A) Matter X has integral structure while matter Y is granular.  
 B) The space between particles making up the matter Y is bigger.  
 C) There is no space between the particles making up the matter X.  
 D) The space between particles making up the matter X and Y is the same.

6) If a researcher thinks that particles of different types of matters are different from each other, **which** of the ideas below should be implemented by him?

**I-** He should compare the particle models of three different matters.

**II-** He should divide a matter he takes in his hand as many as he can.

**III-** He should compare models of solid, liquid and gase particles making up a matter.

**IV-** He should examine an animal cell with a microscope.

- A) Only I    B) Only IV    C) I and III    D) II and IV

7) Ayşe knows that the word atom means indivisible and she made a research about atoms. Which of the following statements **cannot** be one of her explorations?

- A) Building stones making matters which are different from each other are called atoms.  
 B) Atom is named by Democritus.  
 C) Atom means indivisible.  
 D) Atoms are impossible to divide and break.

8) Which of the following statements is **correct**?

- A) If we cannot see tiny particules of a matter which are hard to divide, this means there is no matter at all.  
 B) All kinds of matters are comprised of building stones which are too tiny to be seen.  
 C) Undivided tiny particles of only solid and liquid matters can be seen.  
 D) Even if gases are not seen, they are comprised of tiny particules which can be seen via microscope.

9)



Which of Ayşe's statements about atoms is **correct**?

- A) Atoms are building stones of the matter similar to globes.  
 B) Atoms can be seen via microscopes.  
 C) Atoms transform as well while matters make transition from one state to another.  
 D) All matters are comprised of the same atoms.

10) Nazlı first dripped a drop of milk into a glass of water. She realized that the color of the water did not change after she mixed it. Later, she dripped a drop of tea and again observed that the color did not change.

Which of the following statements is **irrelevant** to what Nazlı has tried to do?

- A) Atoms making up the milk and tea diffuse in water.





- B) No change occurs in atom sequence of milk and tea particles.  
 C) Nazlı might have tried to prove that matters are made up of unseen particles.  
 D) If Nazlı had mixed tea with water before milk, the color of water might have been changed.

11) Zeynep left solid balls of naphthalene in the closet to keep the pests away. After a few weeks passed, she realized that the balls were gone. However, there was a heavy odor of naphthalene in the closet. To you, **why** Zeynep did not see balls of naphthalene even though there was the smell of it?

- A) That is because solid balls of naphthalenes disappear after a few days.  
 B) If Zeynep cannot see naphthalene, that means there is no naphthalene.  
 C) That is because matters are formed of tiny particules which are unseen.  
 D) If Zeynep had looked more carefully, she could have seen gas particles of naphthalene.

### App. 2: CT questions

- 1) Four friends are discussing about atoms. To you, which statement is correct?

- A)  → Atoms are animate due to their movements.  
 B)  → Atoms of living beings are animate while atoms of non-living things are inanimate.  
 C)  → Atoms of objects with different shapes are different even if they are made of the same material.  
 D)  → Matters are comprised of atoms and these atoms are inanimate.  
 That is because

.....

- 2) Which of the following statements in relation to matters is correct?

- A) There are atoms between the particles making up the matter.  
 B) A matter can be divided until there is nothing left.  
 C) Atoms making up the matter are colorless.  
 D) If the matter is unseen, then there is no matter.

That is because

.....

- 3) Which of the following statements in relation to atoms is correct?

- A) Scientists saw the atom.  
 B) Atoms are flat and there is another substance between them.  
 C) Atoms have a simple cycle within a circle.  
 D) Our cells are comprised of many atoms.

That is because

.....

- 4) Which of the following statements is correct?

- A) Air is not a matter since it does not have volume and mass.  
 B) Gases do not have masses.  
 C) Air is not a matter since it is unseen.  
 D) Particles making up the solid, liquid and gaseous matters are colorless.

That is because

.....

- 5) Which of the following statements is correct?

- A) Atom is similar to a globe with its components.  
 B) There is air between particles making up the matter.  
 C) Atoms are big enough to be seen by means of a microscope.  
 D) There are tinier particles making up the atoms.

That is because

.....

App. 3: Classification of learner responses given to two-stage questions in CT (experimental group)

