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A Cross-Age Study on the Understanding of Chemical and Physical Change and Their Components

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The purpose of this study involves alternative ideas and misconceptions of the students play an important role in the studies of chemistry education in science. The basis of the chemistry education is constructed at schools through having the students understanding and the concepts of melting, dissolution, evaporation and chemical-physical change. The cross-age study was conducted with a total of 160 student (98 male, 62 female) aged 11, 12, 13 and 14 from 6th, 7th and 8th grades of Atakent elementary school in Adiyaman during 2008-2009 school year. Each group consists of 40 students. The questions related to melting, dissolution, the transformation of matter, chemical-physical changes and mixture topic were chosen from the science curriculum. The first test was the application test which assessed how to prepare the students for these subjects. The second test, named as the theoretical test, consisted of questions which seek the same answers related the same topics. In this cross-age study, the changes in the mental development and knowledge of the students were investigated. The 13 and 14 years-old students provided the best results among the age groups of 11, 12, 13, 14.

Key Words: Chemistry education, Misconceptions, Chemical-physical change, Dissolutions.

INTRODUCTION

Chemical and physical changes, because of its importance, has attracted attention of many researchers who have focused on different perspectives in chemical and physical change and attempted to elicit students' understanding of the concepts involved. These perspectives are presented as follows: (a) the dissolution concept[1-6] (b) the nature of solutions[7]; (c) solubility[5]; (d) the effects of temperature and stirring on the dissolution of solids[8]; the conservation of mass during the dissolution process[9,10]; (e) types of solutions[11,12]. Another study have investigated students' understanding of chemistry concepts; physical and chemical change[13] and strategies to overcome misconceptions[14-17]. Understanding of the change of states (evaporation, boiling, condensation, freezing, *etc*.) is necessary to grasp and comprehend many aspects of chemistry, physics, earth science and biology[18,19].

The cross-age study provides the opportunity to observe the changes in the mental development and knowledge of the students. The previous cross-age studies in chemistry education showed that the students had misunderstood many science topics during their educational processes[20,21]. The students start schools with some concepts in their minds, which stem from their environment: later affect the concepts that are taught in the lessons and lead to misconception in science classes. The cross-age studies help us to understand the fact that some alternative concepts remain the same from kindergarten till the University education. The cross-age study method enables the evaluation of the learned correct concepts by the students at school and their misconceptions and real life experience by relating them to each other[22]. Moreover, it provides the observation of the experiences of the students in their daily lives and their personal development trends emitted to their science classes[21].

The cited studies have tried to answer several questions; (a) what kinds of misconceptions do students have; (b) how common are the misconception; (c) how these misconceptions may be replaced with correct ideas and (d) suggestions as to what teachers can do to improve teaching learning environment that would reduce students' misconceptions.

As can be seen in the related literature, even though the cited studies on chemical-physical change have concentrated on different perspectives, there is an absence of what students' understand about the terms "dissolution", "melting", "evaporation" and "transformation matter" whether they are able to apply theoretical knowledge to novel situations, whether the students are able to make connections between school and life experience and how the instruction that students receive influences their ideas.

The students in this study were chosen from different ages and classes in order to observe their learning process. Different tests were used to asses the students' knowledge. As a result of these methods, the differences in the learning stages are determined.

EXPERIMENTAL

Samples: The participants of the study were students from the Atekent Elemantary school in Adiyaman during 2008-2009 school years. The total of 160 students with 98 boys and 62 girls from 6th, 7th and 8th grades formed the study group. The subjects of the written examination in the study were limited with "dissolution, melting, mixture, evaporation and transformation of matter, physical-chemical change". Students from different age groups (11, 12, 13 and 14) participated in this study. The effects of the students' developmental levels, gender effects and socio-economical situations on their understanding of the chosen topics were investigated.

In this study, questions were prepared from the chemistry topics of the 6th, 7th and 8th grades science curriculum of the school year. The books were approved by the National Ministry of Education 2008-2009 (NME) and publications by NME were used as resources in the preparation process of the questions. The test covered

the topics of "dissolution, mixture, transformation of matter, evaporation and physical-chemical change". The chemistry topics were chosen from the science curriculum in order to establish the two test form and they were applied to the students 1 week after the other. The first test that was applied to the students were the "application test". In this test, the students were asked to express themselves using their daily language while answering the questions. This test assessed their levels of readiness. The second test was named as the theoretical test and it covered the questions of the first test. This time, the students were asked to answer the questions using the scientific concepts and the scientific language. As a result of the application test, the students that were aged 11, 12, 13 and 14 were observed to have knowledge about the topics of "dissolution, mixture, evaporation, transformation of matter and physical-chemical change". The result of the application test that were evaluated regarding the age differences and their knowledge levels were found to be adequate. The theoretical test, assessing the same topics was administered to the students that were aged 11, 12, 13 and 14.

Analysis and scoring: At the end of the applications, concept evaluation scheme (CES) was used in order to classify and assess the answers of the students, which were in written forms. The revised form of the westbrook and Marek's[23] concept evolution scheme was used for assigning points to the answers conceptual understanding of the students and was evaluated through five different formats. The points scales are shown on Table-1.

TABLE-1
CLASSFICATION CRITERIA OF THE STUDIES' ANSWERS

Degree of understanding	Criteria for scoring
Sound understanding (SU)	Valid responses for each concept statement were developed which represented sound understanding of that concept, from information theoretical test.
Practical understanding (PU)	Responses demonstrating portal understanding of the concept were characterized by the student mentioning at least one not all of the element of the validated response representing sound under standing of that concept.
Practical understanding with specific misconceptions (PU, SM)	Responses that show understanding of the concept also contain a misconception.
No understanding (NU)	These responses were characterized by one of the following; the student simply restated the question; the student gave an irrelevant answer to the statement the student replied, "I don't know" or no response was given to the statement.

The answers were classified as no replies, superficial understanding, alternative ideas insufficient understanding and sound understanding. The students' answers for each question were evaluated step by step. The students' each answer was classified and the students' understanding levels of the concepts were investigated. The five chemistry concepts were evaluated with the scheme listed below. Similar scales

were used in other studies[1,23-25]. Other researchers have used different schemes comprise 3, 4, 5 or 6 categories but the scheme used in this study compride 5 categories listed and defined below.

RESULTS AND DISCUSSION

The general knowledge of the student on topics of dissolution, mixture, melting, evaporation, transformation of the matter and physical-chemical change was determined. In order to assess the knowledge levels of the students aged 11, 12, 13 and 14, a test was administered before the cross-age study. This test was called application test. The aim of the application test was to determine the general knowledge levels of the students about topics and to reach reliable conclusions at the end of theoretical test. It was determined that students have general knowledge about the topics according to their answers. The theoretical test was given one week later. While the students were asked to use their daily life experiences in answering the questions of the application test, they were asked to give scientific concepts appropriately by making connections with daily life in the theoretical test. Result of the application test success rates of the students are shown in Table-2.

TABLE-2
RESULT OF THE APPPLICATION TEST SUCCESS RATES OF THE STUDENTS

Subject (%)	Application test questions	Gender	
		Girls (%)	Boys (%)
Physical-chemical change	Question 1	36	54
Mixture	Question 2	38	55
Transformation of matter	Question 3	44	60
Mixture	Question 4	35	57
Transformation of matter	Question 5	43	62

Two test were applied to the elementary school students aged between 11-14 ages old. They were tests named as the “application test” and the “theoretical test” and contained questions which sought the same answers. The students’ readiness’ was determined as a result of the application test. It was determined that students have knowledge about the chosen science topics. The theoretical test was applied. Two test were applied to the elementary school students aged between 11-14 years old.

The result of the theoretical test are presented below by taking each item into consideration. Percentage of the obtained responses for each question are shown in Table-3.

The first question about physical and chemical change was examined. It was determined that 12.5 % of 12 year old studies replied to this question exactly. They expressed that melting of ice was a physical change and burning of paper was a chemical change. They expressed that melting of ice was only a transformation of state while when a paper is burned, a new productions could occur and its molecular structure can change, which could not be retransformed.

TABLE-3
PERCENTAGE OF RESPONSES GIVEN TO QUESTIONS

Questions	1				2				3				4				5			
Age	11	12	13	14	11	12	13	14	11	12	13	14	11	12	13	14	11	12	13	14
SU	3	5	5	1	3	2	4	1	1	2	3	1	3	2	5	1	12	13	14	14
PU	2	7	9	6	2	1	8	2	3	7	6	4	2	1	7	3	3	6	5	4
PUMS	10	13	10	8	12	18	19	14	11	13	22	19	11	18	17	15	7	8	4	5
SM	9	4	4	11	15	15	8	13	19	13	7	15	15	15	8	13	6	5	5	4
NU	16	11	12	14	8	4	1	10	6	5	2	1	9	4	13	8	12	8	12	13

Practial understanding rate was found 17.5 % at the 12 year-old student. These students easily expressed that a transformation of ice was a physical change and the ice could turn into liquid and gas state. They explained that the molecular structure of the ice did not change. They stated that burning of the paper was a chemical change, however they did not explain about changes in the structure.

It was determined that 27.5 % 14 year-old students have "specific misconception" students expressed the ice turned into water and gas state then vanished. They used the concepts of physical and chemical change indifferent places in their answers. They did not mention any new products as a result of the burning of paper.

The second question was about the sugar chalk, water mixture was "sound understanding" and answered by the 10 % of the 13 year-old. The students indicated in their answers that the mixture of chalk and water is a solid-liquid mixture called the suspension, mixture sugar and water is a homogenous mixture.

Some students could not reach the "sound understanding" level because they had some misconceptions. They were confused about the concepts of suspension and solutions. They tried to answer the question by giving some examples from their daily lives. The 13 year-old students with "partial understanding/specific misconception" had the highest answering rate with 47.5 % within the entire study group. They were expressed when sugar dissolved in water its vanished.

The third question was about the transformation of the matter. The "sound understanding" level in all age groups was found to be quite low. They stated that the ice transformed into first liquid and the gas state after heating and at the end of the transformation its molecular srtucture did not change.

"Partial understanding" 17.5 % of the 12 year-old students. They stated that transformation of ice into first liquid state and then gas state was a physical change and the structural characteristics of the ice did not change after transformaion. But they did not give any explaination about molecular structure of ice in solid, liquid or gas states. 55 % of the 13 year-old students had "partial understanding/specific misconception" about this questions. They indicated that the solid transformed into liquid and then gas. They did not give any information about the molecular structure. 47.5 % of the 11 year-old students had "specific misconception" about this question.

The fourth question about olive oil and water mixture was "sound understading" answered by the 12.5 % of the 13 year-old students. These students explained that

the olive oil and water mixture is a heterogenous liquid-liquid mixture that was called emulsion mixture and both liquids had different molecular structure.

Some student indicated that the densities of water and olive oil were different. Among the 17.5 % of the 13 year-old students, partial understanding was observed.

It was determined that the students with partial "understanding/specific misconceptions" have large rate in all age groups. They explained why the two liquids did not mix because of densities of the two liquids were different. They tried to answer the question by giving some examples from their daily lives.

The students who had specific misconception used the concept of "mass" instead of "density".

The fifth question about transformation of matter. All of the age groups had high rates in "sound understanding". These students explanined that when the water is heated, it transforms into gas without any changes in the molecular structure.

The percentage of 12 year-old students "partial understanding/specific misconception" was 20 %. These students gave some information about the transformation. But they did not distinguished between intra and inter molecular bonding. 15 % of the 11 year-old student had "specific misconception" about this question. These were as water boils its molecules change chemically "as intra molecular bonds are broken by giving off hydrogen and oxygen gases" as a candle melts its covalent bonds melts.

One of the aims of the Turkish secondary science curriculum is to increase student's scientific literacy[26]. Scientific, literacy includes the following fundemantal dimension: (a) Understanding key concepts and principles of science; (b) having the capacity for scientific ways of thinking and (c) using scientific knowledge and thinking for individual and social development.

The studies showed that misconceptions that occur during a transmission of scientific concepts to students obstruct the learning of the science subject. The misconceptions that occur in the minds of the students who are just introduced to science stay permanent and resistant to change[27].

In this study that conducted among 11-14 age groups on the basic concepts of chemistry, 14-yeard old students, who were expected to have more knowledge than 12 and 13 year-old students. As the tests were evaluated, the students were found not to understand and rapidly forgot subjects that they had memorized. As a grade levels of the students increased, the usage of scientific terms also increased, but it was observed that the by misused these concepts.

The students of the study group were members of families that belonged to middle or low-income groups. Under these circumstances, their achievement was limited for their own efforts and guiding of the teacher. The students could not get any help from parents. The socio-economical status of 160 students in the study group was examined and families of these students, were found to belong to the low or middle income groups.

The opportunities that could be provided to these students by their parents were similar and there were not many differences among income or educational levels of these parents.

The studies had shown that poor families paid less attention to their children, treated them more strictly and violently and valued their own intentions primarily instead of their children's. These behaviors of parents affected mental and emotional developmenty of children negatively.

However, active learning approach was prefered in Turkish Education System, it has been thought that active learning approch was not applied efficiently.

It is one of the facts that the contents of national education system and the science curriculum are full of theoretical knowledge and are transmitted to students by teacher. That is why the students try to learn the subject without connecting them to their daily experiences. The most important issue of our educational system, is making it clear that chemistry and science or are important parts of our lives and every knowledge acquired at school are related to the ordinary events of our daily lives.

The cross-age study mthod is seen as a method that enable us to find answers to the questions of "when and at which level" the subjects should be taught to the students while finalizing the curriculum. The result of present study group showed that adequate knowledge could not be thought to the students of all age groups in the science classes.

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