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Cross-Age Study Of The Understanding Of Some Concepts In Chemistry Subjects In Science Curriculum

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ABSTRACT

The alternative ideas and misconceptions of the students play an important role in the studies of chemistry education in science. Among these, the cross-age studies could easily point out the comprehension levels of students from different age groups. The basis of the chemistry education is constructed at schools through having the students understand and use the concepts of atom and molecule. The cross-age study was conducted with a total of 239 students (138 male, 101 female) aged 11, 12, 13 and 14 from 6th, 7th and 8th grades of Kuyubaşı Elementary School in Ankara within the 2001-2002 School Year. The questions related to pressure, the transformation of matter, density physical-chemical transformation and mixture topics 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 to the same topics. In this cross-age study, the changes in the mental development and knowledge of the students were investigated. The 12 and 13-year-old students provided the best results among the age groups of 11, 12, 13 and 14

Key Words: *Chemistry Education, Cross Age Study, Concept Misunderstanding*

INTRODUCTION

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 (Bel, 1981; Brumby, 1982). The cross-age studies display and reflect a light on the middle steps of the conceptual development of the students in a better way. With the help of the cross-age studies, it becomes possible to determine in what age the misconceptions of the students occur. It is going to be easier to correct the misconceptions that the cross-age studies determined. The misconceptions that occur when the students first meet the chemistry education are permanent and resistant to change (Ausubel, 1968). 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 misconceptions 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 learnt correct concepts by the students at school and their misconceptions and real life experiences by relating them to each other (Trowbridge and Mintzes, 1988). Moreover, it provides the observation of how the experiences of the students in their daily lives and their personal development are transmitted to their science classes (Westbrook and Marek, 1991). Determining the level of students' understanding of atom and molecule concepts could be possible by using the cross-age studies (Westbrook and Marek, 1992). The answer to the question that "which subject should be taught in what age" could be found and the students' levels of readiness to learn the concepts could be determined as a result of the cross-age studies. The cross age-studies put forward that the students' definitions of the concepts, the lessons taught and the teaching techniques are not enough for the students to make correct conceptualizations. The students in this study were chosen from different ages and classes in order to observe their learning process. Different methods were used to assess the students' knowledge. As a result of these methods, the differences in the learning stages could be determined.

PURPOSE

The purpose of the study is to investigate the levels of students' understanding aged between 11 and 14 from the 6^{th}, 7^{th} and 8^{th} grades about some concepts of chemistry. This study was conducted to make a research on the misconceptions, alternative conceptualizations of the elementary school students aged between 11 and 14 who have learnt the topics of pressure, transformation of matter, density, mixtures and physical-chemical transformations. Ages which more learning occurred was also studied. The effects of the misconceptions on the personal development process of the individuals and their occurrences in every age level were investigated.

This study forms the basis of a study that could be helpful in developing the effective science curriculum.

The goals of this research are to;

1. Investigate the influence of grade level (amount of instruction) and the reasoning ability on the understanding of selected chemistry concepts.
2. Trace the number and type of alternative conceptions held by students after various amounts of instruction in chemistry.
3. Trace the use of atomic and molecular explanations by students who had various amounts of instruction in chemistry.

METHODOLOGY

a-Samples

The participants of the study were the students from the Kuyubaşı Elementary School in Keçiören, Ankara, at the 2001-2002 school years. The total of 239 students with 138 boys and 101 girls from 6^{th}, 7^{th} and 8^{th} grades formed the study group. The subjects of the written exam in the study were limited with "pressure, density, mixture, and transformation of matter, physical-chemical transformation". 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.

b-Instruments

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 approved by the NME (National Ministry of Education, 1992, 2001), and the publications by TUBITAK (The Scientific and Technical Research Council of Turkey) were used as resources in the preparation process of the questions. The tests covered the topics of “pressure, mixture, transformation of matter, density, and physical-chemical transformation”. The chemistry topics were chosen from the science curriculum in order to establish the two test forms. 9 questions were prepared for each test form and they were applied to the students one week after the other. The first test that was applied to the students was 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 that had the same answers with 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 “pressure, mixture, transformation of matter, density, and physical-chemical transformation”. The results 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.

The tests were given to the students in science classes under the monitors’ control. No negative situation regarding the student motivation was observed during the applications. There was not any time limitation during the tests. A survey was administered in order to assess the socio-economical conditions of the students.

c-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 (1991) concept evaluation scheme was used for assigning points to the answers. The conceptual understanding of the students was evaluated through five different formats. The point scales are shown on Table-1. 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 student’s 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 (Abraham et al., 1992; Haidar & Abraham, 1991; Simpson and Marek, 1988; Westbrook and Marek, 1991; 1992; Pell & Jarvis, 2001). Other researchers have used different schemes comprised three, four, five or six categories but the scheme used in this study comprised five categories listed and defined below.

Table 1. *The classification criteria of the students' 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
Partial Understanding(PU)	Responses demonstrating partial understanding of the concept were characterized by the student mentioning at least one not all of the element of the validated response representing sound understanding of that concept.
Partial Understanding with Specific Misconceptions (PU SM)	Responses that show understanding of the concept also contain a misconception.
Specific Misconception(SM)	Responses that include illogical or incorrect information.
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.

RESULTS

The general knowledge of the students on the topics of pressure, mixture, transformation of matter, density, and physical-chemical transformation 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 the Application Test. This test was administered before the theoretical test, which formed the basis of the cross-age study. The aim of the application test was to determine the general knowledge levels of the students about the topics and to reach reliable conclusions at the end of the theoretical test. Table 4.1 shows the results of the application 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 responses to the questions and use the scientific concepts appropriately by making connections with the daily life in the theoretical test. Results of The Application Test-Success Rates of the Students are shown in Table 2.

Table 2. *Results of the Application Test-Success Rates of the Students*

	Application Test	*Gender*	
Subject	*Questions*	*Girls (%)*	*Boys (%)*
Mixture	Question 1	54,55	50,72
Mixture	Question 2	60,59	53,26
Transformation of Matter	Question 3	50,00	52,89
Physical-Chemical Change	Question 4	54,45	52,54
Pressure	Question 5	64,72	50,00
Pressure	Question 6	54,95	51,99
Density	Question 7	67,32	60,86
Transformation of Matter	Question 8	52,49	61,23
Pressure	Question 9	50,77	50,25

Two tests were applied to the elementary school students aged between 11-14 years old. They were the 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. Then the theoretical test was applied. The aim of the application test that was primarily applied to the students aged 11, 12, 13 and 14, was to assess their knowledge on pressure, mixture, transformation of matter, density, and physical-chemical transformation. The results of the application test showed that the participants had knowledge related to the above-mentioned topics. Studies continued over the knowledge database that the students already had and secondly the theoretical test assessing the same topics was applied. The data source of the study was the theoretical test. The results of the theoretical test are given in the following paragraphs.

7, 89% of the 13 year-old students answered, which was about the olive oil and water mixture. These students explained that the olive oil and water mixture is a heterogeneous liquid-liquid mixture that was called the emulsion mixture and both liquids had different molecular structures. They also expressed that olive oil and water had different densities and the one with the less density floated over the one with the greater density.

Some students could not use the concepts appropriately for this question. They used the concept “atom” instead of olive oil and water molecules. They indicated that the densities of water and olive oil were different. Among the 17, 11% of the 13 year-olds, partial understanding was observed.

It was determined that the students with “partial understanding/specific misconception” have a large rate in all age groups. These students stated in their answers that the densities of the two liquids were different. They explained why the two liquids did not mix. They also explained the structural characteristics of the liquids by giving examples from their daily lives.

The students who had specific misconception used the concept of “volume” instead of “density”. These students stated that the liquids with different densities did not mix. 38,98% of the 11 year-old students had specific misconception about this question.

Table 3. *Distribution of level of student understanding of first question*

Age	NU	SM	PU/SM	PU	SU
11	25.42	38.98	27.12	3.39	5.09
12	10.34	37.93	48.28	0	3.45
13	7.89	21.05	47.36	17.11	7.89
14	22.86	31.43	37.14	5.71	2.86

The second question that was about the chalk and water mixture was “sound understanding” and answered by the 10.5% of the 13 year-old students. The students indicated in their answers that the mixture of chalk and water is a solid-liquid mixture called the suspension mixture. They stated that chalk did not dissolve in water, its dissolver was not water and the mixture had a heterogeneous appearance. They explained that water molecules did not surround the chalk molecules and therefore the solid matters did not dissolve in water.

Some students could not reach the “sound understanding” level because they had some misconceptions. They were confused about the concepts of suspension and emulsion. They explained the chalk is not dissolving in water as solid-liquid mixture and they defined the chalk as the granular structure in water. They used the word “blurred” instead of the word heterogeneous. They tried to answer the question by giving some examples from their daily lives. “Partial understanding” was determined in 42, 85% of the 14 year-old students. The 13 year-old students with “partial understanding/specific misconception” had the highest answering rate with 42, 11% within the entire study group. These students explained that the chalk could not dissolve in water because of its structure and it sinks to the bottom of the glass after some time by giving different examples. They tried to exemplify using the water and soil mixture 42, 85% of the 14 year-olds had specific misconception about this question. These students stated that chalk dissolved very little in water.

Table 4. *Distribution of level of student understanding of second question*

Age	NU	SM	PU/SM	PU	SU
11	25.42	42.37	25.42	3.38	3.38
12	18.96	29.31	31.03	12.07	8.62
13	15.79	17.1	42.11	14.47	10.53
14	34.28	42.85	20.0	0	2.85

The third question was about the transformation of the matter. The transformation of ice because of the heat was observed. The "sound understanding" level in all age groups was found to be quite low. The students explained the transformation of ice through heating as a physical transformation. They stated that the ice transformed into first liquid and then gas state after heating and at the end of the transformation its molecular structure did not change. They mentioned that in its solid state, the molecules were well organized whereas in liquid state they were spread out and in the gas state they were in free motion.

"Partial understanding" was determined for the 17, 24% of the 12 year-old students. They stated that the 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 transformation. They did not give any information about the molecular structure of ice in solid, liquid or gas states.

60, 53 % of the 13 year-old students had "partial understanding/specific misconception" about this question. These students had explained the transformation of matter. They indicated that the solid transformed into liquid and then gas states. They did not give any information about reforming the matters or about their molecular structures in their answers.54.24% of the 11 year-old students had "specific misconception" about this question. They did not give any information about the molecular structure.

Table 5. *Distribution of level of student understanding of third question*

Age	NU	SM	PU/SM	PU	SU
11	10.16	54.24	25.42	8.47	1.7
12	12.07	32.76	34.48	17.24	3.45
13	3.95	17.11	60.53	14.47	3.95
14	11.43	34.29	48.57	5.71	0.00

When the fourth question about physical and chemical change was examined, it was determined that 13, 79% of the 12 year-old students replied to this question exactly. They explained that melting of ice was a physical and burning of candle was a chemical change. They expressed that melting of ice was only a transformation of state and it could be retransformed into ice without any changes in its molecular structure whereas when a candle burned, new products could be occurred and in its molecular structure occurred changes, which could not be retransformed.

Partial understanding rate was found to be 24, 14% at the 12 year-olds group, which was higher than the other age groups. 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 candle was a chemical change; however they did not explain about changes in the structure. The concepts of atom and molecule were not seen in their answers.

It was determined that 25, 71% 14 year-old students have "specific misconception". Students expressed that the ice turned into water through transformation but they did not mention that it could be retransformed. They used the concepts of physical and chemical change in different places in their answers; however, the concepts of atom and molecule were not seen in their answers. They did not mention any new products as a result of the burning of candle.

Table 6. *Distribution of students' understanding level of fourth question*

Age	NU	SM	PU/SM	PU	SU
11	42.37	23.73	23.73	3.39	8.47
12	25.86	6.89	29.31	24.14	13.79
13	28.95	9.21	25.0	23.68	13.15
14	40.00	25.71	22.86	8.57	2.86

Looking at the fifth question about the existence of the open-air pressure, sound understanding could not be observed at the age groups of 11 and 14. 3, 43% of the 12 year-olds and 3, 95% of the 13 year-olds had sounded understanding and replied to this question. The students explained that gas molecules were dynamic in every direction, liquid molecules could pressurize to the sides of the container and the open-air pressure was greater than the water as a result of that movement.

Similar rates of "partial understanding" were observed in all age groups. These students talked about the existence of the open-air. While explaining the movement of the molecules in the air, they stated that the open-air pressure was greater than the liquid pressure without explaining how the liquid pressure occurred.

The rates of "partial understanding/specific misconception" in all age groups were similar. These students talked about the existence of the open-air pressure but they did not write anything about how the pressure occurred or the molecules moved. They did not compare or contrast the open-air pressure with the liquid pressure.

31, 48% of the 12 year-old students had "specific misconception" about this question. They talked about the existence of the open-air pressure, however, they did not talk about the movement of the gas molecules or how the water pressure occurred.

Table 7. *Distribution of students' understanding level of fifth question*

Age	NU	SM	PU/SM	PU	SU
11	37.29	18.64	28.81	15.25	0.00
12	17.24	34.48	31.03	13.79	3.45
13	26.32	26.32	30.26	13.16	3.95
14	17.14	17.14	28.57	14.29	0.00

The sound understanding percentage of the 6th question was 12,07% in the 12 year-olds group whereas it was 0,13% in 11, 11,84% in 13 and 2,8% in 14 year-old groups. The students explained the relationship between the pressure and decreasing of oxygen molecules as a result of burning in a closed container by establishing the volume-pressure connection. They expressed that the air pressure outside the container was greater.

17, 14% of the 14 year-olds was found to be at the "partial understanding" level. These students talked about the open-air pressure. They stated the importance of the oxygen while burning. They explained that the open-air pressure was greater than the closed container pressure without giving any information about the changes in the gas pressure. They did not talk about the volume-pressure connection in gasses or the molecular structure in the closed container.

14, 29% of the 14 year-olds had "partial understanding/specific misconception" about this question. They expresses that the amount of oxygen decreased in the closed container while burning and oxygen was needed for burning. They stated that the pressure changed in the closed container but they used the concepts of high and low pressure in different places.

27, 59% of the 12 year-olds had "specific misconception" ideas about pressure. These students, without making any scientific explanations, stated that burning air in the closed container absorbed the egg. They did not use the concepts of low and high pressure, molecule, and molecular movement or volume-pressure relationship.

Table 8. *Distribution of students' understanding level of sixth question*

Age	NU	SM	PU/SM	PU	SU
11	47.46	23.73	13.56	15.25	0.00
12	41.38	27.59	8.62	10.34	12.07
13	51.32	11.84	9.21	15.79	11,84
14	42.86	22.86	14.29	17.14	2,86

The rate of students who answered the seventh question about the density exactly was 11, 84% in 13 years olds group. The students who answered this question knew that density is the distinctive feature of the matter and differs from matter to matter. They used the Principle of Archimedes while explaining their answer. They determined the water molecules, the distribution of the salt ions in water and their effects on density.

The rate of students who replied to this question at the level of "partial understanding" was 27, 82% and most of these students were in the 11 year olds group. These students mentioned that the concept of density is the distinctive feature of the matter. They talked about the differences in density, distribution of salt ions in water and their effects on density without explaining the Principle of Archimedes.

The rate of students who had "partial understanding/specific misconception" was 17, 14% in the14 year olds group. These students with the partial understanding/specific misconception defined density as one of the distinctive features of the matter but they did not relate the differences in density to floating, swimming or sinking. They replied to question without using the concepts of ion or molecule.

The rate of students with "specific misconception" who replied to this question in 13 year-olds group was 27, 63%. These students confused the concept of density with the concept of volume. They tried to answer the questions without establishing connection between the salty water, water and the egg. They did not inform about the concepts of molecule or ion.

Table 9. *Distribution of students' understanding level of seventh question*

Age	NU	SM	PU/SM	PU	SU
11	47.45	8,46	15,25	27,82	1,69
12	50.00	10,34	10,34	18,97	10,34
13	28,95	27,63	11,84	19,74	11,84
14	51,43	11,43	17,14	11,43	8,57

For the eighth question about a transformation of matter and pressure, all of the age groups had high rates in "sound understanding". These students explained that when the water is heated, it transforms into gas without any changes in the molecular structure. They stated that the water molecules moved faster in the gas state, thus the gas pressure increased parallel to the heat and therefore moved the cork.

15, 22% of the 12 year-old students belonged to the "partial understanding" group. These students expressed a transformation of matter and they stated that the liquid moved the cork because of its transformation into the gas state without giving any information about the molecular structure or movement. They explained it by using examples from their daily lives.

The percentage of 12 year-old students who had "partial understanding/specific misconception" was 18, 97%. These students gave some information about the transformation; however they did not talked about its effects on the movement of the cork. They just explained that the heated water moved the cork without inform about the molecular structure.

13, 56% of the 11 year-old students had "specific misconception" about this question. They said that water needed heat for transformation. They did not talk about the forces which cause the movement of the cork. They did not give any information about the molecular structure or pressure.

Table 10. *Distribution of students' understanding level of eighth question*

Age	NU	SM	PU/SM	PU	SU
11	30,51	13,56	16,95	6,78	32,20
12	22,41	8,62	18,97	15,52	34,48
13	34,21	9,21	10,53	13,16	32,89
14	34,29	11,43	8,57	11,43	34,29

"Sound understanding" could not be determined in the 11, 12 and 14 age groups for the ninth question that was about the pressure of gasses. 13 year-olds had a "sound understanding" rate of 1, 32%. These students established connection between volume and pressure in gasses, the movement of the gas molecules and their compressibility.

The students in the "partial understanding" group mentioned that the gasses were compressive and they explained the movement of the molecules. However, they did not give any information about the relationship between the volume and the pressure. 8, 57% of the 14 year-olds belonged to the "partial understanding" group.

13 year-old students who had "partial understanding/specific misconception" had a percentage of 19, 74. They expressed that the gasses were compressive with the example of a balloon. However, they did not give any information about the gas molecules, molecular movements or decreasing/increasing pressure.

44, 06% of the 11 year-old students had "specific misconception" about this subject (34, 48%, 12 year-olds; 22, 37%, 13 year-olds; and 17, 14%, 14 year-olds). These students said that air could be compressed without explaining any concepts. They used "air" word instead of gas", thus they did not make any scientific explanations.

Table 11. *Distribution of students' understanding level of ninth question*

Age	NU	SM	PU/SM	PU	SU
11	45,76	44,06	8,49	1,69	0,00
12	51,72	34,48	8,63	5,17	0,00
13	52,63	22,37	19,74	3,95	1,32
14	60,00	17,14	14,29	8,57	0,00

The general errors in the answers of the students from the age groups of 11, 12, 13 and 14 are shown below.

Density; All age groups used the concept of volume instead of the concept of density. When comparing the densities of two liquid matters, they assumed that the one with the greater density would float. They confused the matters which have the higher densities with the matters which have the lower densities.

Mixture; There are a lot of students who were confused concepts of suspension with concepts of emulsion in the solid-liquid and liquid-liquid mixtures. Some of the students misused concepts of homogeneous and heterogeneous. They avoided using the concepts of dissolving, dissolver or dissolvent. They expressed a dissolving of a solid matter by using "melting" word.

Transformation Of Matter*;* The students, who explained that matter could be transformed into liquid state from its solid state and to gas state from its liquid state, were not able to explain the retransformation. They could not express that matter could transform into liquid state from gas state and to solid state from liquid state.

Physical-Chemical Transformation; The students misused concepts of physical transformation and chemical transformation for the question related to the physical and chemical transformation. A burning of a candle was expressed as a melting of a candle. New products were defined as physical changes. The transforming of ice from solid state to liquid state was explained as a physical change whereas its transformation from liquid state into gas state was mentioned as a chemical change.

Pressure; They could not establish a connection between movement of molecules in the air and pressure. They confused concepts of high and low pressure and misused these concepts. Volume and pressure were confused at every age group and a concept of pressure was expressed with "movement" word.

DISCUSSION AND IMPLICATIONS

The studies showed that misconceptions that occur during a transmission of scientific concepts to students obstruct the learning of the science subjects. Every subject that is learnt following the misconceptions further causes permanent misconceptions. A way of preventing misconceptions is to determine these misconceptions and an age level at which they occur. The teachers should determine a readiness of the students by discussions which are controlled by teachers before teaching the concepts. By determining ideas that students already had or created in their minds, occurred or possibly occurring misconceptions could be determined and alternative ways of transmitting these subjects to students should be investigated. The misconceptions that occur in the minds of the students who are just introduced to science stay permanent and resistant to change (Ausubel, 1968).

Most of the alternative concepts were indicated to come out in the primary school years and stayed permanent until adult ages. The answers of the students were determined not to come out according to their ages (Trowbridge and Mintzes, 1988).

In this study that conducted among 11-14 age groups on the basic concepts of chemistry, 14 year-old students, who were expected to have more knowledge than others, had less achievement rates than 12 and 13 year-old students. As the tests were evaluated, students were found not to understand subjects 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 seen that they misused these concepts.

The students' learning of subjects by understanding depends on that scientific concepts were being taught to students not in an abstract but in a concrete way. This would provide permanency of learnt concepts with the classroom activities, visualizations in connection with real life experiences. The objective skills for the students should be constructed upon their fields of interest by determining their ideas related to subjects in their own world and their experiences. How a topic should be taught in a students-centered way should be determined. In this way, discovering pre-knowledge of the students could form basis of the knowledge that they would learn.

The students of the study group were members of the families that belonged to middle or low-income groups. Under these circumstances, their achievement was limited their own efforts and the guiding of the teacher. The students could not get any help from their parents. The socio-economical status of 239 students in the study group was examined and families of these students were found to belong to the low or middle (earning) income groups. The opportunities that could be provided to these students by their parents were similar and there were not many differences among an income or educational levels of these parents. The educational levels of parents of 239 students in our study group were examined and found low. Among 239 students of our study group, fathers of 112 were primary school, 64 were middle school, 31 were high school and 32 were university graduates.

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 developments of children negatively.

The sound understanding rates of the girls were higher than that of the boys for each question and concept at the 11-year-olds age group. 11 year-old girls could be classified as "successful". The most well understood subject was the transformation of matter whereas the concept of pressure was not understood at all.

When girls and boys were compared at the age group of 12, the sound understanding level of girls for each question and concept was found to be higher than that of the boys. Girls could be classified as "successful" at this age group. The gas pressure and the concept of pressure were a common subject that was not comprehended for both gender groups. The question about a transformation of matter and a concept of density was the one that was answered the most.

The 13 year-old boys had a higher level of sound understanding than the girls of their age group for each question and concept. The boys of this age group could be classified as "successful". A transformation of matter had the best level of sound understanding among the subjects. 13 years old boys were found to have better understood the subjects of density, mixture, physical-chemical transformation and pressure than students of the other age groups.

The sound understanding levels of 14 year-old boys was higher than that of girls of the same age group for each question and concept. 14 year-old boys could be classified as "successful". The concept of pressure was one of the subjects that was not understood by girls and boys of the age group.

Prospects for Further Work

It is one of the facts of nowadays that the contents of the National Education System and the Science Curriculum are full of theoretical knowledge and are transmitted to students in teacher-centered way. That is why the students try to learn the subjects without connecting them to their daily experiences. The most important issue of our educational system, is making it clear that chemistry and science are inseparable parts of our lives and every knowledge acquired at school are related to the ordinary events of our daily lives. Since school subjects have theoretical contents and they are transmitted in a teacher-centered way, the knowledge and concepts that are taught in science classes cannot be transmitted to the future. Therefore an intellectual level cannot be established for the students. The knowledge that is acquired through these ways causes misunderstandings in the students. The students further develop their own concepts and they try to construct new knowledge over the old one by keeping misunderstood knowledge permanent. The intellectual levels of students were expected to increase parallel to their growing ages, however, the results of the cross-age study showed that the intellectual level was not parallel to the age. In the cross-age study was found that "pressure" was a subject that could not be understood and answered by the students of all age groups among the subjects of "mixture, transformation of matter, density, physical-chemical transformation and pressure". The subject that had a high level of sound understanding and was answered by all of the students from all of the age groups was determined as a "transformation of matter".

The cross-age study method is seen as a method that enables us to find answers to the questions of "when" and "at which level" the subjects should be taught to the students while constructing the curriculum. The results of our study showed that adequate knowledge could not be taught to the students of all age groups in the science classes.

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