Evaluation of eleventh grade Turkish pupils' comprehension of general chemistry concepts

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Contents

Abstract

The main purpose of this study is to evaluate eleventh grade Turkish pupils' comprehension of various general chemistry concepts which in turn enables to investigate chemistry concepts which are easier and harder for students to comprehend. Examining the effect of gender and last semester chemistry course grades on pupils' comprehension of general chemistry concepts is also within the scope of this study. The sample consists of 88 students from two Anatolian high schools in the center of Isparta, Turkey. The Chemistry Concepts Inventory (CCI), that includes non-mathematical conceptual items, was administered to students in order to collect data. Results indicated that the percentage of correct responses of students for all questions ranged from 4.5 % to 75 %. Students have troubles especially with the following chemistry concepts; "Chemical formulas and equations, macroscopic versus atomic and molecular properties, solutions, chemical reactions, properties of atoms". Two-Way ANOVA results indicated that there is no statistically significant effect of gender and chemistry course grades on students' comprehension of chemistry concepts.

Keywords: Constructivism; Conceptual Learning; General Chemistry Concepts; Gender; Chemistry Grades

Introduction

How do students construct knowledge in their mind, in other words, how can learning be accomplished? Questions related to knowledge construction have been discussed deeply that results in accumulation of information related to constructivism, the dominant learning approach in recent decades. Actually, constructivism is a comprehensive approach that roots nature of knowledge (Driscoll, 2005) whereas this paper handles exclusively student learning perspectives of constructivism.

Conceptual learning comes into prominence especially after 1980s and takes place in constructivist learning content. According to conceptual learning, learning is a dynamic process that requires connection of new knowledge with the existing one (Posner, Strike, Hewson & Gertzog, 1982). If new knowledge is constructed without reference to base knowledge, meaningful learning is not possible, and this situation generally results in rote learning. Ausubel (1968) stated that "the most important single factor influencing learning is what the learner already knows" (p. iv). However, existing ideas may be scientifically incorrect or partially correct in some cases. The concepts which are not consistent with science communities' points of view are mentioned with diverse terms like misconceptions, preconceptions, alternative frameworks, children's science, and so on (Helm, 1980; Nakhleh, 1992; Novak, 1977; Driver, 1981; Gilbert, Osborne & Fensham, 1982). Although these terms have similar meanings in nature, their area of usage changes according to researchers' approach to education such as alternative conception reflects an internalization of constructivist point of view (Taber, 2000).

As scientifically accepted concepts, alternative conceptions are also parts of cognitive resources and they interact continuously with each other. Since learners construct knowledge in terms of their own understanding, concepts- whether non-scientific- are plausible for them which results in settling down (Gilbert et al., 1982) and resistance to change (Driver & Easley, 1978). Construction of non-scientific conceptions on each other causes accumulation of non-scientific frameworks which affects comprehension of forthcoming concepts negatively (Jones & Beeth, 1995). Moreover, in that condition (accumulation of non-scientific concepts), the new knowledge may be "ignored, rejected, disbelieved, deemed irrelevant to the current issue, held for consideration at a later time, reinterpreted in light of the students' current theories, or accepted with only minor changes in the students' concepts" (Mulford & Robinson, 2002, p. 739). Because of reputed prohibitive properties, taking alternative conceptions into consideration in learning contexts should be the first step for meaningful concept learning.

As De Jong and Taber (2007) state, chemistry is a discipline that deals profoundly with the inner structure of matter, sub-microscopic level, that covers the particles (atoms, molecules, electrons, and etc.) and interactions among them. Besides sub-microscopic level, symbolic and macroscopic representations are also used to explain chemical phenomena. The symbolic domain includes chemical equations, formulas, and signs. The macroscopic domain is related with the substances and their properties that may be experienced in daily life. All of the representations of chemical concepts- especially, sub-microscopic and symbolic- requires higher level thinking abilities due to abstract nature of the chemistry discipline. As a result, learners may have alternative conceptions on various general chemistry concepts (Tan & Treagust, 1999) whereof main reason is lack of meaningful connections among representations of chemical concepts (Ayas & Demirbas, 1997).

Research studies in science education literature that have focused on alternative conceptions of students at almost all grade levels on various general chemistry concepts like: "the particulate nature of matter" (Ayas et al., 2010; Boz, 2006; Yilmaz & Alp, 2006; Stains & Talanquer, 2007), "chemical bonding" (Coll & Treagust, 2001 a, b; Taber, 1997 a; Tan & Treagust, 1999; Ünal et al., 2010), "dissolution" (Çalik, 2005; Çalik & Ayas, 2005; Çalik et al., 2005; Çalik et al., 2007, 2009; Ebenezer & Erickson, 1996; Valanides, 2000 a, b; Abraham et al., 1994; Prieto et al., 1989), and "gases" (Novick & Nussbaum, 1981; Stavy, 1988) showed that students of all grade levels had difficulties in understanding chemistry concepts.

In addition to the studies that are concerned with alternative conceptions, there are several studies conducted to investigate the effect of various variables such as, gender, grade level, reasoning abilities, and etc. on students' understanding of science concepts (Abraham et al., 1994; Çalik, 2005; Robinson & Niaz, 1991; Sungur & Tekkaya, 2003; Valanides, 1997; Demircioglu & Norman, 1999; Sarier, 2010). Actually, there are inconsistent results in the literature related to the effect of gender on students' science achievement. Sarier (2010), for instance, stated that Turkish girls are more successful than boys (students at the age of 15) in the context of science education according to the results of PISA carried out in 2003 and 2006. Some other studies reported, on the other hand, males are superior than females in terms of science achievement during the middle school years (Simpson & Oliver, 1990; Campbell, Voekl & Donohue, 1998). Furthermore, Demircioglu & Norman (1999) declared that there is no significant effect of gender on Turkish high school students' chemistry achievement. Similar to Demircioglu & Norman (1999), Shaw & Doan (1990) reported no significant effect of gender on science achievement scores of elementary students who were at different grades that varied from grade 2 to 5.

Besides aforementioned concerns, there is one more point to discuss which is that researchers generally prefer dealing with one of the general chemistry concepts in their studies that results in understanding the situation in terms of that concept, exclusively. But, what about the whole picture, that is, to what extent do students comprehend general chemistry concepts? Combining results for various general chemistry concepts may be a way of deducing the whole picture whereas studies include different controlling variables and evaluating on these studies may not reflect the real situation. Instead of the way described, conducting a study that evaluates the extent of Turkish pupils' comprehension of various general chemistry concepts- the whole picture- leads to more reliable results.

In this way, the main purpose of this study is to evaluate the extent of comprehension of eleventh grade Turkish pupils on various general chemistry concepts as well as to investigate chemistry concepts that are easier and harder for students to comprehend. Additionally, to examine the effect of gender and last semester chemistry course grades on pupils' comprehension of general chemistry concepts is another aim of this study. Based on stated purposes, the following research questions were examined:

1. What is the extent of eleventh grade Turkish students' comprehension of general chemistry concepts?
2. What are the chemistry concepts that are easier and harder for students to comprehend?
3. What is the effect of gender and previous semester chemistry course grades on eleventh grade Turkish students' comprehension of general chemistry concepts?

Methodology

Context

Science program in secondary schools has been altered in a manner that internalizes constructivist perspectives of learning and teaching, in 2007. The main purpose of the relatively newborn science program is to educate scientifically literate individuals who can "use scientific terms for explanations of natural events and interpret results based on evidences by questioning and thinking profoundly" (OECD, 2003, p. 133) and to raise individuals who can develop positive attitudes and even behaviors to environment (Ministry of National Education, 2007). In order to achieve declared purposes, all dimensions of the educational program has undergone dramatic changes. In other words, objectives, contents, teaching-learning situations (e.g. teaching methods, techniques, and strategies), and measurement-evaluation processes were designed on the basis of constructivist approach.

Chemistry, one of the science majors at secondary education, is common for all students enrolling ninth grade and concepts that need to be mastered are as follows; compounds, chemical changes, mixtures and solutions. Students select their major field at the end of ninth grade and then specialize towards their fields for three more years (that is, the duration of high school is 4 years in Turkey). Students who chose science field as their major field are responsible from various additional chemistry concepts which are introduced here, respectively; the particulate nature of matter; periodic system; phase changes; mixtures and solutions at tenth grade; chemical reactions; chemical equilibrium; electrochemistry; nucleus chemistry at eleventh grade; and organic chemistry at twelfth grade. After high school, students have to enter "Student Selection Examination (ÖSS)" based on their major fields if they desire to specialize on a vocation. The duration of education in universities alters according to the selected vocation and university.

To sum up, according to the revised science education program, students at eleventh grade are familiar with the following chemistry concepts; the particulate nature of matter; properties of atoms; chemical bonding; gases; liquids and solutions; conservation of mass and atoms; symbols, equations, and stoichiometry; chemical reactions; heat and temperature; phase changes; and macroscopic versus atomic and molecular properties.

Sample

The sample of the study consisted of 88 eleventh grade (16 to 17 years old) students from two different public high schools in the city of Isparta, Turkey. The selected schools have good opportunities in terms of infrastructure that is, both of the schools have science laboratories, audio-visual equipments, small class size, and etc. Among the sampled individuals, 54 of them were females and the remaining 34 of them were males. The last semester chemistry course grades of students were ranging from 2 to 5, and the mean of grades was 4,2 out of 5,0.

Instrument and Data Collection Process

As mentioned above, this study aims to evaluate eleventh grade students' conceptual understanding of general chemistry concepts, that is, whether students accomplish to learn meaningfully and conceptually. The stated purpose is analogous to the objectives of the Chemistry Concepts Inventory (CCI), developed originally by Mulford and Robinson (2002), that is why CCI was administered for collecting data in this study. Furthermore, the CCI assures information about various general chemistry concepts, that is; enables to figure out the whole picture as stated previously in the introduction section.

CCI was developed "to measure the extent of entering students' alternate conceptions on topics found in the first semester of many traditional general chemistry courses" (p. 739). The original version of the CCI includes 22 non-mathematical questions and not only questions but also distracters were based on common alternate conceptions on general chemistry concepts. The concepts which covered by CCI are as follows; the particulate nature of matter; properties of atoms; chemical bonding; gases; liquids and solutions; conservation of mass and atoms; symbols, equations, and stoichiometry; chemical reactions; heat and temperature; phase changes; and macroscopic versus atomic and molecular properties (See sample items in the Results section). Six of the twenty two questions are paired questions which ask a question and continue with the reason of that question (Table I).

Table I: Nature of items included in the original version of the CCI

Non-paired Items	Paired Items
1, 2, 3, 4, 5, 6, 9, 14, 15, 22	7-8, 10-11, 12-13, 16-17, 18-19, 20-21

The original version of the CCI was administered to eighteen chemistry graduate students in order to take feedback for clarity and length and to four experienced chemistry education researchers to control level and content. In addition to validity evidences, the authors checked for reliability after conducting the inventory as a pretest and posttest to final 928 freshmen students enrolling science and engineering majors. Average scores of these students were "10.3 on the pretest with a Cronbach α of .704 and 11.2 on the posttest with a Cronbach α of .716" (Mulford & Robinson, 2002, p. 740). These values were accepted as satisfactory (Fraenkel & Wallen, 2006) for deducing that students did not respond questions randomly. The CCI was adapted to Turkish context by Boz and Uzuntiryaki (2005). One of the questions in the original inventory was omitted in the translated version because students found that item difficult to understand. The revised version of CCI was administered to one hundred sixty five pre-service elementary science and chemistry teachers. Cronbach α internal consistency coefficient was found as .70 (Boz & Uzuntiryaki, 2005).

As in the translated version, in the present study, twenty one item-CCI was administered to the sampled individuals in the spring term of 2010-2011. The students were requested to complete the test in 30 min. as offered in the original study (Mulford & Robinson, 2002). The sample was encouraged to perform their best by announcing that they are valuable for a scientific research and assuring confidentiality for their answers.

Data Analysis

Descriptive statistics was conducted through operating SPSS package program in order to evaluate the extent of comprehension of eleventh grade Turkish students on various general chemistry concepts, and to establish the chemistry concepts that are easier and harder for students to comprehend. Moreover, Two-Way Analysis of Variance (Two-Way ANOVA) was conducted to investigate the effect of gender and previous semester chemistry course grades on Turkish pupils' comprehension of chemistry concepts.

Results

Results of Descriptive Statistics

Results of descriptive statistics were interpreted under categories, that is; the percentage of correct responses on the CCI ranged from 4.5 % to 75.0 % and this range was divided into three intervals as the common procedure in item analyses. There were seven items in the 50-75 % interval, eight items in the 30-50 % interval and the remaining six items correspond to the interval of 4-30 % (Table II).

Table II: Items with respect to the intervals they located

Intervals (%)	50-75	30-50	4-30
Items	2, 4, 8, 10, 12, 13, 15	3, 6, 7, 9, 11, 14, 16, 18	1, 5, 17, 19, 20, 21

Both the 50-75 % and 4-30 % intervals were analyzed deeply in terms of students' percentages of correct responses and their possible alternative conceptions in accordance with the purpose of this study. Table III indicates the percentages of responses on choices of items that fall into 50-75 interval.

Table III: The percentages of student responses on each alternative choices and standard deviations within the 50-75 interval

Test Items	A (%)	B (%)	C (%)	D (%)	E (%)	Standard deviation
2	2.3	23,9	3.4	69.3*	1.1	0.94
4	2.3	4.5	23.9	68.2*	1.1	0.70
8	20.5	13.6	10.2	50.0*	5.7	1.30
10	15.9	29.5	54.5*	-	-	0.74
12	5.7	12.5	75.0*	4.5	2.3	0.68

13	10.2	75.0*	8.0	2.3	4.5	0.81
15	59.1*	17.0	19.3	4.5	-	0.93

** indicates the correct choice of that item; - indicates items that do not have such a response*

Figure I: Sample items from the CCI

Item 12. 1 gram of solid iodine is put into a sealed tube and the tube is closed after vacuumed. The total weight of solid iodine and the tube is 27 gram. What will be the total weight after the tube is heated and all of the iodine vaporized?

a. Less than 26 gram
b. 26 gram
c. 27 gram
d. 28 gram
e. More than 28 gram

Item 13. What is the reason for your answer?

a. A gas weighs less than a solid.
b. Mass is conserved.
c. A gas is less dense than a solid.
d. Gases rise.

Item 12 investigates whether or not students could comprehend the conservation of mass of solid iodine as it changes to iodine vapor by heating. Seventy-five percent of students marked "The mass would be the same", but the remaining thought as "The mass would be less or more". The reason of answer given to the 12th item was asked in 13th item and same percentage (75 %) of students marked "Mass is conserved" as the result. Except correct response, the percentage of the most common response was approximately 10 %, which states that "A gas weighs less than a solid". This alternative conception is analogous to results of related studies reported in related literature (Stavy 1988, 1990; Mas et al. 1987; Lee et al. 1993).

Item 2 explores the contents of bubbles in boiling water and about 70 % of the students stated the content as “Water vapor”. Besides correct answer, the most common answer was “The oxygen and hydrogen gases” (24 %), which is consistent with the related literature (Costu et al., 2007). About 68 % of students gave correct answer (Mass of a solution equals to sum of the masses of solute and solvent) to the 4th item that asks about conservation of mass during dissolution. Among the remaining respondents, nearly 24 % of them indicated “A value between mass of solvent and total mass of solute and solvent” as the correct answer, which indicates that they have alternative conceptions about the law of “conservation of mass”. Item 15 asks about heat of water and alcohol having equal temperature and mass after being heated a while, and nearly 59 % of respondents replied correctly whereas approximately 20 % of them confused heat and temperature by selecting the common alternative conception “both of them receive same amount of heat”. Many research studies also indicated the confusion of heat and temperature concepts by students (Erickson, 1979; Kesidou & Duit, 1993; Harrison, Grayson & Treagust, 1999; Niaz, 2000; Yeo & Zadnik, 2001). Item 10 seeks the change in water level as ice melts in a mixture of water and ice and about 55 % of pupils stated the correct answer “It stays the same” and the remaining answered as “Decreases”, “Increases” (almost 30 % and 16 %, respectively).

Interestingly, the item 8 had higher percentage of correct response (50 %) than item 7 (nearly 47 %), which were paired questions and the former explores the reason of question 7 (true or false type question) in case of whether or not matter is destroyed as a match burns. The percentages of other choices for item 8 suggests that some of the respondents are not able to comprehend chemical change but they recall changes during chemical reactions such as “The atoms are not destroyed, they are only rearranged” (Figure II).

Figure II: Sample items from the CCI

Item 7. Specify the following sentence as True or False; "There is matter lost as match burns"

a. True
b. False

Item 8. What is the reason for your answer to the above question?

a. This chemical reaction terminates matter
b. Matter is consumed by fire
c. Mass of ash is less then mass of match
d. Atoms do not dissappear but re-arranged
e. Weight of burned match is less then its initial mass

Up to here, the items within the 50-75 interval were introduced and now, it is the place to submit results related to the items that fall into 4-30 interval. Table IV presents the related items.

Table IV: The percentages of student responses on each alternative choices and standard deviations within the 4-30 interval

Test Items	A (%)	B (%)	C (%)	D (%)	E (%)	Standard deviation
1	33.0	10.2	10.2	14.8*	30.7	1.69
5	15.9	15.9	20.5	4.5*	43.2	1.55
17	50.0	17.0	20.5*	12.5	-	1.10
19	67.0	12.5	19.3*	-	-	0.80

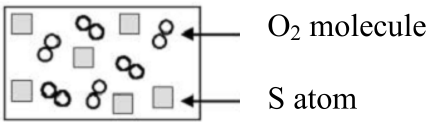
20	44.3	13.6*	33.0	8.0	-	1.05
21	11.4	4.5	22.7*	48.9	11.4	1.12

** indicates the correct choice of that item; - indicates items that do not have such a response*

As can be seen from Table IV, the poorest percentage belongs to item 5 that investigates chemical formulas and equations.

Figure III: Sample item from the CCI

Item 5. The larger diagram at the top represents a mixture of S atoms and O_2 molecules in a closed container. Which diagram (a-e) shows the result after the mixture reacts as completely as possible according to the equation $2S + 3O_2 \rightarrow 2SO_3$?



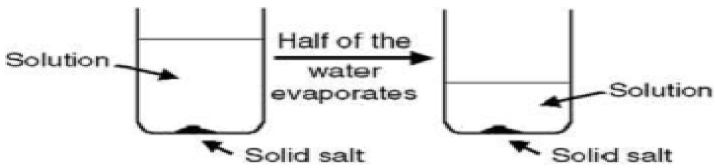
The correct answer was selected by 4.5 % of respondents, solely. Percentage of students who selected other choices (a, b, c, and e) is about 95 % which can be interpreted as students are unable to comprehend conservation of atoms in chemical reactions. Students who selected "a, b, and e" (75 %) do not know about conservation of kinds of atoms during chemical reactions, and students who marked "c" as the answer (almost 21 %) are not aware of conservation of number of atoms during chemical reactions. Being unable to conserve kinds of atoms during chemical reactions may be the result of not knowing the difference between the meaning of coefficient (that is "2" in the item, 2SO3) and subscript (that is "3" in the item, 2SO3). This result is in accordance with the study of Mulford and Robinson (2002).

Actually, the result for the item 5 is consistent with the item 1, which explores also the concepts of conservation of mass, molecules, and atoms during chemical reactions. Only 15 % of respondents comprehend the conservation of both the number of atoms and the total mass in chemical reactions. Students have common alternative conceptions such as "Only total mass is conserved in chemical reactions", and "The total number of molecules is also conserved in chemical reactions", which indicates confusion between molecules and atoms. Combining results of items 5 and 1 indicates that students have trouble especially with sub-microscopic and symbolic representations of chemistry concepts.

Items 19 and 20 are also paired questions, which asks about concentration characteristics of a saturated solution as water evaporates.

Figure IV: Sample items from the CCI

Item 19. Salt is added to water and the mixture is stirred until no more salt dissolves. The salt that does not dissolve is allowed to settle out. What happens to the concentration of salt in solution if water evaporates until the volume of the solution is half the original volume? (Assume temperature remains constant).



The concentration

a. Increases

b. Decreases

c. Stays the same

Item 20. What is the reason for your answer?

a. There is the same amount of salt in less water.

b. More solid salt forms.

c. Salt does not evaporate and is left in solution.

d. There is less water.

Data analysis, results and discussion

Hypothesis 1

Among students, only 19 % of them responded as "The concentration stays constant", and only 13 % of them thought the reason of staying constant as "More solid salt forms". Most of the students (67 %) marked "The concentration increases" as a result of "There is the same amount of salt in less water" (44 %), "Salt does not evaporate and is left in solution" (33 %), and "There is less water" (8 %). Respondents' concepts related to the concentration of saturated solution after evaporation of water are poor whereas their states of reason are poorer which conveys the message that students can use chemical concepts without comprehending the logic behind those concepts. In other words, they do not learn meaningfully but rather recall some facts.

Item 17 investigates mass of a rusting iron nail and only, 21 % of students answered as "The rust would weigh more". Half of the students responded as "The rust would weigh less", 17 % believed that "The weight of rust would be the same", and nearly 12 % thought as "It is impossible to predict". An interesting result, when students were asked in order to explain reasons of changes related to mass of rust (Item 18), they gave higher correct percentages (almost 32 %).

Item 21 is the last question to be analyzed at the 4-30 interval which asks about the properties of a single sulfur atom by giving necessary properties of macroscopic sample of sulfur. Solely, 23 % of students responded as "It forms sulfur dioxide by combining with oxygen". Most of the students (49 %) believed that "It has same properties with macroscopic sample of sulfur". Attribution of macroscopic properties to microscopic entities (atoms in this case) are also reported as alternative conceptions of students in the related literature (Abraham et al., 1994; Griffiths & Preston, 1992; Novick & Nussbaum, 1981).

Results of Inferential Statistics

Two-Way ANOVA results indicated that there is no statistically significant effect of gender on pupils' comprehension of chemistry concepts as $F(1, 77)=0.028$, $p>0.05$, as well as, there is no statistically significant effect of previous semester chemistry course grades on pupils' comprehension of chemistry concepts as $F(3, 77)=2.609$, $p>0.05$. ANOVA results also showed that there is no interaction between gender and previous semester chemistry course grades as $F(3, 77)=0.188$, $p>0.05$.

Conclusion

The objective of this study is twofold: to evaluate the extent of comprehension of eleventh grade Turkish students on various general chemistry concepts that in turn provides information related to the chemistry concepts which are easier and harder for students to comprehend, and to investigate the effect of gender and last semester chemistry course grade on pupils' comprehension of chemistry concepts. The analyses of data suggest that the extent of comprehension of eleventh grade students on various general chemistry concepts is not in conformity with the extent as intended. The percentages of correct responses of students on the CCI ranged from 4.5 % to 75.0 %. Among items, only seven of them had correct response rate within the 50-75 % interval, eight within the 30-50 % interval, and the remaining six items located in the interval of 4-30 %. Investigating items within aforementioned percentage intervals enables to establish the concepts that are easier and harder for students to comprehend which is the concern within the scope of this study.

The highest percentage of correct responses was shared by items 12 and 13 which are paired in nature. Results indicated that most of the students (75 %) do not have problems related to mass conservation during phase changes of matters. However, the remaining 25 % of respondents demonstrated common alternative conceptions such as, "Mass would be less or more as matters change phase", and "A gas weighs less than a solid". Actually, the number of students who marked "Mass would be less" (about 18 %) is much greater than the students who signed "Mass would be more" (about 7 %) which is a situation that resulted from students' alternative conception of "A gas weighs less than a solid" (almost 10 %). This instance verifies that alternative conceptions hinder students' further learning (Jones & Beeth, 1995). These alternative conceptions are analogous to the results of studies reported in related literature (Stavy 1988, 1990; Mas et al. 1987; Lee et al. 1993). Seventy percent of respondents expressed the contents of bubbles in boiling water (Item 2) as "Water vapor", though 24 % believed that "The oxygen and hydrogen gases" are the nature of bubbles in boiling water, which is an alternative conception also reported by the related literature (Osborne & Cosgrove, 1983; Goodwin, 2000; Costu et al., 2007; Bar & Travis, 1991). About 68 % of pupils clarified conservation of mass during dissolution but 24 % of them gave clues about the alternative conception "Mass of solution takes a value between mass of solvent and total masses of solute and solvent" (Item 4). This result marks that students may have various alternate conceptions about dissolution process such as, "Solvent is the major component of a solution", "Dissolved solute has no weight since it disappears", and "Solvent loses weight during dissolution" (Çalik & Ayas, 2007; Ebenezer & Erickson, 1996; Abraham et al., 1994; Prieto et al., 1989; Uzuntiryaki & Geban, 2005). Item 15 was related to heat and temperature concepts and correct reponse rate was 59 %. Assembling concepts of all seven items within the interval of 50-75 may give chance to declare that; students comprehend "Phase changes, conservation of mass, heat and temperature" concepts easier than other general chemistry concepts included within the CCI.

On the other hand, the poorest percentage belonged to item 5 which investigated chemical formulas and equations. Almost 95 % of respondents selected scientifically incorrect responses that can be commented as students are unable to comprehend conservation of atoms in chemical reactions. This result is similar with the results of Mulford & Robinson (2002) in which the lowest percentage of correct response was also the 5th question. This circumstance points out that some alternative conceptions are not culture bound as reported in the literature (e.g. Çalik & Ayas, 2005). Students believed that "Not only total mass and atoms were conserved but also the number of molecules were conserved during a chemical reaction" (nearly 31 %), which indicates confusion between molecules and atoms (Item 1). These results indicate the difficulty of students in understanding sub-microscopic and symbolic representations of chemistry concepts. Moreover, students were also found to have difficulties concerning concentration behaviors of saturated solutions as water evaporates (Items 19 and 20) and macroscopic versus atomic and molecular properties (Item 21). Gathering concepts of all six items that fall into the interval of 4-30 may be helpful for deducing that; students' comprehension of "Chemical formulas and equations, macroscopic versus atomic and molecular properties, solutions, chemical reactions, properties of atoms" concepts is harder than other general chemistry concepts included within the CCI.

Results of this study are consistent with the results of Mulford and Robinson (2002) and Boz and Uzuntiryaki (2005) in which freshmen entering students and pre-service science teachers were examined, respectively. Mulford and Robinson (2002) reported difficult chemistry concepts for respondents as "atoms and molecules, microscopic behaviour, heat and temperature, chemical formulas, gases, and other qualitative concepts" (p. 742). Boz and Uzuntiryaki (2005), similarly, reported the hardest chemistry concepts for pre-service teachers as; solutions, chemical formulas, and macroscopic versus microscopic properties. To conclude, freshmen entering students, pre-service science teachers and eleventh grade students have common alternative conceptions as stated in the related literature (Haidar & Abraham, 1991; Garnett & Treagust, 1992).

Other conclusion of the study is that there is no significant effect of gender and chemistry course grades on eleventh grade Turkish pupils' comprehension of general chemistry concepts.

Implications

The main purpose of this study was not to evaluate the revised secondary chemistry program directly but to evaluate students who are educated in high school with the revised chemistry program. In spite of that this study gives opportunity to deduce some implications for the evaluation of the revised chemistry curriculum. Firstly, in spite of the fact that the chemistry curriculum was revised based on constructivist approach, this was not effective on the elimination of students' alternative conceptions. For instance, results indicated that there is no statistically significant effect of chemistry course grades of students on their comprehension of concepts which is an evidence to conclude as; even students with higher chemistry grades do not score better on the CCI. In other words, chemistry instruction does not promote students' conceptual understanding. This may result from different factors such as inadequate implementation of the curriculum in chemistry classes, students' alternative conceptions not being considered in the curriculum, and etc.

For the effective implementation of the curriculum, chemistry teachers should be trained about constructivist teaching strategies and the applications of them. Moreover, to place science program on sound bases in Turkey, chemistry teachers and program developers should take students' alternative conceptions into account while designing or suggesting chemistry instruction.

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