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Suat Celik
Ataturk University, Kazım Karabekir Education Faculty, Department of Secondary Science and Mathmatics Education,
suatcelik25@yahoo.com

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Chemical Literacy Levels of Science and Mathematics Teacher Candidates

Suat Celik
Ataturk University

Abstract: The goal of this study was to investigate Turkish science and mathematics teacher candidates' levels of attainment in chemical literacy. These candidates had all studied the new Turkish chemistry curriculum in high school. The sample of the study consisted of 112 students, who were first-year students in the Department of Secondary Science and Mathematics Education. The participants' levels of nominal, functional, conceptual, and multi-dimensional literacy were tested. The data were collected by a questionnaire previously developed and used in the literature. The participants' levels of nominal and conceptual chemical literacy were found to be satisfactory in terms of the expectations for the new curriculum, but their levels of functional and multi-dimensional were insufficient. These results are discussed in relation to the literature on the new Turkish chemistry curriculum and on chemical literacy more generally.

Introduction

Rapidly changing scientific and technological products continually emerge to influence modern society. Thus, understanding scientific facts and the inter-relationships between science, technology, and society is extremely useful. The possession of such knowledge and the ability to apply it to real world problems is called scientific literacy (Bond, 1989).

DeBoer (2000) said that educating people to be scientifically literate is one of the main goals in the reforms of science education. He also noted that although everyone agrees on this goal, there is no current consensus on the meaning of the term scientific literacy. According to DeBoer, without a clear definition, science education reforms will not produce this desired outcome.

Bybee (1997) proposed a broad framework to define and identify degrees of scientific literacy. According to this framework, an individual can possess several levels of scientific literacy at once, which are based on contexts and subjects. Nominal, functional, conceptual, and multi-dimensional scientific literacy are components of this framework.

Recognizing words and issues related science but can't explain them meaningfully is nominal literacy. At this level, students can only memorize the name of concepts and terms but can't define them meaningfully. They have misconceptions about them (Uno & Bybee, 1994). Functional literacy is the capacity to use scientific concepts to read and write about science and technology, but there are misconceptions existed into these concepts. They can define the concepts, which they memorize, but they haven't enough understanding to define them with their own words about. This is similar to the "knowledge" level of Bloom Taxonomy of learning objectives (Koballa, Kemp, & Evans, 1997). Conceptual literacy highlights conceptual understandings about scientific concepts and their relation with other concepts. This level requires a scientific habit of mind as well as. According to Shwartz, Dori, and Treagust (2013) conceptual literacy requires integrating and organizing information instead of just memorizing inert knowledge. The highest level of literacy, which is multi-dimensional literacy, requires understanding science and technology concepts from a philosophic and historical perspective, and relating that understanding to society and daily life. Koballa et al. (1997), called this level “true” scientific literacy based on the model of (Shamos, 1995).

Given the multiple aspects of scientific literacy, the definition can be very broad. In practical usage, when the term is used, its definition often depends on the context and society in which it is being discussed (Laugksch, 2000). Despite this, there have been many attempts in science education studies to define scientific literacy.

According to DeBoer (2000), scientific literacy allows the public to live effectively in a very rapidly changing natural world. Hazen and Trefil (1991) similarly defined scientific literacy as knowledge that the public needs to understand the scientific content of public issues. According to Hazen and Trefil, if someone treats news about the ozone layer, genetic engineering, or chemical waste in the same way as news about sports, business, or government, it can be inferred that this person is scientifically literate.

As scientific literacy is a broad concept, teaching any special subject in science education should contribute to the goal of training scientifically literate people. Teaching chemistry contributes to chemistry literacy in particular, and to scientific literacy in general (Shwartz et al., 2006b). To achieve the goal of educating chemically literate people, chemistry curricula have been recently and increasingly changed, in keeping with reforms of the other science subject curricula in many countries (Herscovitz, Kaberman, Saar, & Dori, 2012). The main goal of the new chemistry curriculum of Turkey is to educate people to be chemically literate. It is thought that studying the effects of these reforms in chemistry education on educating people, as chemical literate is very important.

Understanding chemistry is very critical, because our physical environment is heavily affected by chemistry and filled with chemical products (Gilbert & Treagust, 2009). Understanding chemical explanations is also very important for most people, because such explanations have practical applications in daily life. Understanding chemistry helps people to take part in public debates, and to make sense of their everyday lives and environment. Understanding chemistry and the ability to apply that understanding to daily life is what is referred to as chemical literacy (Tsaparlis, 2000).

Most studies on what kinds of knowledge and skills are covered by the term chemical literacy and on how chemical literacy is taught and measured are very new. To date, studies about chemical literacy are mostly based on broader studies about general scientific literacy (Bond, 1989). But Bond (1989) asked many years ago whether this subservient focus would provide sufficient emphasis to support public interest in atomic theory, the mole concept, radioactivity, or other fundamental concepts of chemistry.

To form an answer to that question, several attempts have been made to identify chemical literacy among groups of research subjects. Barnea, Dori, and Hofstein (2010) framed chemical literacy as including an understanding of the particulate nature of matter, chemical reactions, laws and theories of chemistry, and common chemistry applications in daily life. Chemical literacy entails an understanding of the chemical components of any publicly discussed issue. Possessing an understanding of the concepts of chemistry, in order to make informed decisions that will affect society, is more important than mastering a body of chemical knowledge (Harlen, 2001).

There have been numerous attempts to define chemical literacy. To facilitate curriculum development for science and chemistry education, Shwartz, Ben-Zvi, and Hofstein (2005) asked chemistry teachers and scientists to define chemical literacy. A framework, which included chemical concepts, contexts, learning skills, and applications, was generated from the result of the study. According to this framework, a chemically literate person should understand basic scientific concepts, such as that chemistry is a branch of science and involves theories which help to explain the natural world, and that knowledge obtained from the study of chemistry can be transferred and applied to other topics in science and technology. A chemically literate person also should know the basic goals of the field of chemistry. These include the principles that chemistry teaches us to understand macroscopic phenomena by means of the microscopic and symbolic level of chemistry, and that chemistry scholars investigate the dynamics of processes and reactions, and the energy changes in reactions. A chemical literate person should appreciate and be able to use this knowledge in his/her daily life. To be chemical literate, a person must possess higher "learning skills," such as the ability to generate useful questions and to seek information to answer questions. For affirmative dimension of chemical literacy people should have a realistic view about chemistry (Shwartz, Ben-Zvi, & Hofstein, 2006a; Shwartz et al., 2005).

As most studies about identifying chemistry literacy are based on studies concerning scientific literacy, similarly, attempted scholarly measurements of chemistry literacy have also been largely based on the same studies about scientific literacy. For example, Shwartz et al. (2006b) adopted the scientific literacy framework developed by Bybee (1997) to measure levels of scientific literacy among Israeli high school students who were studying a reformed chemistry curriculum. Based on scientific literacy frameworks, which existed in the literature, they developed an assessment tools to measure the Israeli students' levels of nominal literacy, functional literacy, conceptual literacy, and multi-dimensional literacy. According to their framework, the criteria of the nominal, functional, conceptual, and multi-dimensional categories were to recognize chemical concepts, define key concepts of chemistry, use an understanding of chemical concepts to explain phenomena, and comprehend any article about chemistry. Shwartz, et al. (2006b) found that the students' nominal literacy was adequate, but only a small percentage of the students in the sample could define any chemical concepts with what could be called functional literacy, after taking basic chemistry courses. They also found that advanced chemistry courses had contributed very little to the students' functional, conceptual, and multi-dimensional chemistry literacy levels.

Many nations, such as Israel, Australia, and the USA, have tried to reform their science education programs in the light of recent developments in science education. Since 2004, curricula also have been reformed in Turkey. In 2007, the Turkish Ministry of National Education (MONE) formed a commission of academics from the fields of Chemistry and Educational Science, to prepare a new chemistry curriculum (MONE, 2007).

The new curriculum was organized by themes, such as the structure of matter, interactions among substances, relations between matter and energy, chemical properties and the structures of materials used in daily life, positive and negative effects of the technological products of chemistry on the environment and on human life, and the value of a scientific way of thinking. The curriculum has four main goals, which were grouped under the themes of chemistry content knowledge; scientific processing skills; chemistry, society, and the environment; and technology, applications, and communicative skills in science.

There are also two parts of the curriculum. The first part is for all students, regardless of their selected major. This includes training in more general chemistry concepts and basic processes of chemistry. The second part is designed to provide more conceptual insights into the field of chemistry.

The research question of the study is:

What are secondary science and mathematics teacher candidates' levels of chemical literacy?

Methodology

The purpose of this study was to measure the chemistry literacy levels of secondary science and mathematics teacher candidates, who had participated in the high school chemistry curriculum in Turkey.

The Sample of the Study

The participants consisted of 112 secondary science and mathematics teacher candidates. The sample was chosen based on the convenient sampling method. Because all of these students had been taught both parts of the chemistry curriculum, at high school they were chosen as the sample of the study. The percentile of females and males in the sample were 64% and 36%, respectively. The distribution of the population according to subject majors is shown in Table 1.

Subjects	Number of Students	Percentile
Chemistry	22	20
Biology	43	38
Physics	18	16
Mathematics	29	26
Total	112	100

Table 1: The distribution of the sample

The Data Collection

To collect the data, questionnaires developed by Shwartz et al. (2006b) were used. These original questionnaires were translated into Turkish for this purpose. The questionnaires set was administered to each group at different times and each administration took approximately 80 minutes. The data was collected with three different questionnaires.

The first questionnaire measured levels of the nominal and functional chemical literacy of the students. This questionnaire consisted of questions, which asked the students to identify and define a list of chemical concepts, such as temperature, protein, atom, and ozone. Because this questionnaire just tests students' acquaintances with words and concepts of chemistry it doesn't test students' conceptual understandings. Teachers usually use this kind of tools to test students' chemistry knowledge at high school (Uno & Bybee, 1994). In this questionnaire, there were Likert-type scale (1-3) questions, which measured the students' acquaintance with each concept. The Cronbach's alpha reliability coefficient for this part of the questionnaire was 0.97. There were also open-ended items, which asked students to define some concepts of chemistry.

The second questionnaire measured the students' ability to use their understanding of chemistry to explain daily issues. This ability refers to conceptual chemical literacy. Students should use their conceptual understandings about concepts and process in chemistry at this level of literacy (Uno & Bybee, 1994). In this questionnaire, a number of phenomena related to daily life were presented, with a statement following each example. The students were asked to classify these statements as correct or incorrect. There were 11 different phenomena, collected into three groups in the original questionnaire. Only five of these phenomena were used for the current study. These were related to "diffusion and smelling," "temperature," "limestone reacting with acid," "reduction-oxidation," and "water and oil." Two professors of chemistry were asked to choose these phenomena, to match the Turkish high school chemistry curriculum.

The last questionnaire was used to measure the students' levels of multi-dimensional literacy. This questionnaire investigated the students' ability to read and comprehend a paragraph that included chemical information. There were three similar paragraphs presented to each group of students in the study of Shwartz et al. (2006b). For the current study, only one paragraph was used, entitled "green chemistry." The paragraph was about reducing the side effects of technology on the natural world through chemistry. Following the paragraph, there were questions, which measured the students' reading comprehension, ability to relate their chemical knowledge to the question, and reasoning.

The Data Analysis

Descriptive data analysis was used in this study. To show the secondary science and mathematics teacher candidates' various levels of chemical literacy, percentiles and frequencies of their responses were calculated. The responses given to the open-ended questions were organized into three categories: correct, partially correct, and incorrect. For the reliability analysis of responses to the open ended item, the author reanalyzed 15% of the data set. Inter rater reliability of the two analyses were calculated as 87%.

If the answer doesn't contain any misunderstandings labeled as correct, contains some misunderstandings labeled as partially correct and doesn't reveal any understanding labeled as incorrect. Three examples of responses for the each label were presented in the following. The letter after the excerpt shows first letter of students' study subjects and the following number shows their place in the group.

<u>Correct:</u> *A molecule is a structure consisted of two different or same types of atom such as H_2, O_2 and H_2O.* (M.31 Student)

<u>Partially Correct:</u> *A molecule is formed by different type of atoms such as H_2O.* (B.54 Student)

<u>Incorrect:</u> *Molecule is the basic particle of the elements. (C.3 Student)*

For the likert scale items descriptive analysis also was performed. There are 38 concepts in the list to test students' accountancies based on 1-3 likert scale and 6 concepts to be defined by students. Concepts included in the list were categorized based on Shwartz et al. (2006b). Two professors at the chemistry education department also asked check the validity of the categorization.

The Results

In this section, descriptive results of students' responses are presented, to display their varying levels of chemistry literacy.

The Students' Levels of Nominal Literacy

Category	Concepts	Mean
Scientific inquiry	Conservation law, temperature, electrical conductivity, microwave, model, conclusion, fact, scientific theory, scientific hypothesis.	2.16
Structure: sub-micro concepts	Atom, isotope, electron, ion, molecule, chemical bond.	2.36
Materials: general types of substances	Acid, base, protein, element, mineral, metal, polymers, compound, solution.	2.36
Materials: specific substances	Ozone, air, crude oil, carbon, steel.	2.09
Chemical reactions	Chemical reaction, reaction rate, electrolysis, combustion, activation energy, catalyzer, distillation, oxidation, radioactivity	2.28

Table 2: The mean scores of each category, showing the students' acquaintance with chemical concepts based on a scale (1-3)

As indicated in Table 2, the students displayed a fairly high acquaintance with many chemical concepts. The means of all the categories were higher than the median of the likert scale. But the students were least familiar with "specific substances," such as petroleum, ozone, and steel. Another category with which the students were least familiar is "scientific inquiry." This category includes concepts such as hypotheses, facts, and scientific theory. Although there is an emphasis on the nature of science in the new chemistry curriculum, the students indicated that they were not sufficiently acquainted with concepts about the nature of science. According to the students' choices, the most familiar and unfamiliar concepts are presented in Table 1. Based on the students' choices, the concepts were ranked. Top familiar and unfamiliar concepts were obtained from this ranking.

Concepts	%	Concepts	%
Atom	73	Polymer	40
Element	73	Scientific Theory	39
Isotope	71	Chemical connection	37
Compound	68	Radioactivity	35
Base	67	Ozone	35
Acid	67	Electric conductivity	32
Electron	63	Steel	28
Solution	63	Oil/petroleum	26
Combustion reaction	63	Model	24
Catalyst	60	Micro Wave	23
		Fact	20

Table 3: Distribution of the most familiar and unfamiliar concepts, according to the students' choices

The Students' Levels of Functional Literacy

The students' functional literacy levels were determined via their explanations of selected chemical concepts. The students' explanations were classified as correct, partially correct, or incorrect.

		Percentages		
Concept	**Type of Explanation**	**Correct**	**Partially Correct**	**Incorrect**
Molecule	Molecular	11	24	11
	Macroscopic	6	30	18
	Total	**17**	**54**	**29**
Chemical Reaction	Molecular	19	13	2
	Macroscopic	25	33	8
	Total	**44**	**46**	**10**
Acid	Molecular	-	10	-
	Macroscopic	1	64	23
	Total	**3**	**74**	**23**
Ozone	Molecular	-	3	-
	Macroscopic	4	75	18
	Total	**4**	**78**	**18**
Chemical Connection	Molecular	1	5	1
	Macroscopic	19	46	28
	Total	**20**	**51**	**29**
Temperature	Molecular	-	-	-
	Macroscopic	12	22	66
	Total	**12**	**22**	**66**

Table 4. Results of the students' explanations of chemical concepts

Results in Table 4 show that most of the students possessed very limited knowledge about the concepts. Most of their explanations were partially correct and demonstrated a macroscopic point-of-view. Except for explanations about chemical reactions, the percentages of correct explanations were less than both those of the partially correct and the incorrect ones. It also appeared that 66% of the students' explanations about temperature were incorrect. For example, one of the students explained: *"Molecule is the case of more than one element gathering with chemical connections. Some elements and all compounds are composed of molecules in nature. For example N_2, H_2O, and H_2SO_4."* This explanation is categorized as partially correct, because it doesn't refer to ionic compounds, which are not composed of molecules. Because the response included chemical symbols, it was classified as a molecular explanation. Another student incorrectly thought: *"Temperature is the thermal energy that any substance gets or gives from its surroundings."* Here, there is a misunderstanding between temperature and heat. The highest percentages of correct explanations were for chemical reactions. One of the example explanations was: "*Chemical reaction is the interaction of more than one substance. New substances are produced, and the chemical structure of the interacting substances is changed after the interaction."*

In order to examine the levels of the students' functional literacy, they were also asked to choose and explain two concepts, which were the most familiar to them from the concept list. They mostly chose concepts such as isotope, atom, law of material preservation, and acid. Even though they thought they were familiar with these concepts, only 56% of their explanations were correct.

The Students' Levels of Conceptual Literacy

When a bottle of perfume is left open in a room, after several minutes the perfume can be smelled throughout the room. Below are several statements pertaining to this phenomenon.		Percentage of		
		Correct	Incorrect	I can't determine
a.	Some of the perfume passes from a fluid aggregate state to a gaseous aggregate state.	96	3	2
b.	*Transition to the aggregate state will take place only if the boiling point of the perfume is lower than the temperature of the room.*	28	46	26
c.	The perfume molecules spread throughout the room by clashing with other molecules in the air.	90	3	7
d.	The higher the temperature in the room becomes, the faster will be the evaporation.	81	4	15
e.	A weak chemical **bond/connection** forms between the perfume molecules and special **receptors/sensors** found in our noses.	36	29	35
f.	*The connection between the perfume molecules and the smell sensors in the nose is not a chemical connection but rather a biological connection.*	45	19	36
	Average	63	17	20

Table 5: The students' understanding of diffusion

To test the students' levels of conceptual literacy, they were asked to relate their understanding of chemistry to daily life phenomena. There were five phenomena in the questionnaire. The students were asked to label statements following each phenomenon as correct or incorrect. If they thought that they did not have enough information about the statement, they could also indicate that they cannot determine. The results of the students' responses are outlined in Tables 5 - 9. Scientifically correct statements are written with normal font, and the incorrect ones are written with italic font in the tables.

The students mostly possessed a correct understanding of diffusion. The percentages of correct responses ranged from 36 to 96. Incorrect responses were only about boiling. They incorrectly thought that the changing state of the substance could only take place if the boiling point of the substance is lower than the temperature of the environment. This result indicates that the students thought that evaporation only occurs after boiling. Fortunately, the percentage of students who chose that this statement is correct was not very high.

A wooden chair and a metal chair are found in the same room for an extended period. After this time, the temperatures of both chairs are measured. Below are different statements pertaining to the temperature of the metal chair and the wooden chair?		Percentage of		
		Correct	Incorrect	I can't determine
a.	Transfer of energy will take place between the **particles/molecules** of each chair and the molecules in the air in the room, to the point of equilibrium of **energy** between the air in the room and the chairs.	69	12	18
b.	Transfer of energy will take place between the **particles/molecules** of each chair and the molecules in the air in the room, to the point of equilibrium of **temperatures** between the room and the chairs.	62	13	25
c.	When equilibrium in temperature between the two chairs in the room is reached, the particles composing the two chairs will have the same kinetic energy as the molecules in the air.	21	44	35
d.	*There will be a difference in temperatures of the two chairs. The metal one will heat up more if the room is hot and will cool off more if the room is cold.*	87	7	6
e.	*The proof that the temperature of the two chairs is different is **our feeling/how we feel** when we sit on them.*	56	28	16
f.	*The final temperature of each chair depends on the melting **point/temperature** of the material from which it is composed.*	38	19	43
	Average	56	21	24

Table 6: The students' understanding of temperature

The lowest percentages of correct understanding related to temperature. As indicated in Table 5, 87% of the students incorrectly thought that the metal chair would more heat up than the wooden chair in a hot environment, or cool off more in a cold environment. The percentages of incorrect responses ranged from 38 to 87, while the percentages of correct responses ranged from 21 to 69.

Regarding conceptual literacy, it was found that the students' could relate their understanding of chemical reactions to daily life phenomena. As indicated in Table 7, the percentages of their correct responses were between 65 and 83. The highest percentage of their incorrect responses was on the aggregation state of limestone. They incorrectly thought that during the reaction of limestone with acid, firstly the limestone turned into liquid, and then to a gas state.

To examine the effect of acid rain on buildings and sculptures built of limestone, the following experiments were conducted:
In the first experiment, a small block of limestone rock, whose mass was 1 g., was put into an acid solution. The block reacted (to the point of its complete disappearance) and gas was discharged. This was collected, and its amount was measured precisely.
In the second experiment, 1 g. of limestone dust was put into an identical amount and identical concentration of acid. Both experiments were carried out at exactly the same temperature.
Below are various statements pertaining to the two experiments:

		Percentage of		
		Correct	Incorrect	I can't determine
a.	*The solid limestone changed the aggregation state; in the course of the reaction it turned into* ***liquid/fluid*** *and after to gas.*	67	18	15
b.	*Only the temperature* ***has an effect/influences*** *the rate of reaction.*	12	85	4
c.	*Since an identical temperature was maintained in both the experiments, the reaction occurred at exactly the same rate.*	10	79	11
d.	Exactly the same volume of gas was obtained in the two experiments.	66	16	18
e.	The gas discharged in the reaction is carbon dioxide.	65	4	31
f.	The reaction **occurred/was** faster in the second experiment because of a larger interface between the acid and the limestone.	83	6	11
g.	A change in the acid concentration could also change the reaction rate.	68	10	23
	Average	53	31	16

Table 7: The students' understanding of chemical reactions

A nail made of iron rusted after being in an environment in which it was exposed both to air and to moisture. The nail looked as if the iron was "eaten" and disappeared, but when weighing the iron and the rust that formed on it, it became clear that the mass was greater/higher than the original mass of the nail, before it rusted. Below are statements relating to this phenomenon:

		Percentages of		
		Correct	Incorrect	I can't determine
a.	*The nail's mass increased only because the water molecules that were absorbed on the surface of the metal and molecules of the material are different than the air that was absorbed on the surface of the metal.*	24	55	21
b.	The mass of the nail increased because the iron reacts with the oxygen.	92	3	5
c.	During a reaction between a metal and oxygen, there is a transferral of electrons from the metal to the oxygen.	59	13	28
d.	*During a reaction between a metal and oxygen, a covalent bond forms between the metal atoms and the oxygen atoms.*	35	30	35
e.	Various metals differ from each other in their tendency to be oxidized.	58	6	36
f.	Iron is a metal that has the highest tendency to be oxidized.	73	3	23
	Average	57	18	25

Table 8: The students' understanding of oxidation

As indicated in Table 8, the students' understanding of oxidation was mostly correct. While the percentages of incorrect responses ranged between 24 and 35, the percentages of correct responses ranged between 58 and 92. The students who possessed an incorrect understanding thought that the nail's mass increased only because of the water absorbed on the surface of it, and that a covalent bond forms between the metal and oxygen. This demonstrates that the students possessed only a partially correct understanding of chemical connections.

Most of the students possessed an adequate understanding to correctly assess about why oil and water don't mix. Except for the choices in the d response in Table 8, the percentages of correct responses were more than fifty percent. Forty-nine percent of the students indicated that they did not have enough information about the polarization of hydrophobic molecules.

If we put water and oil in a test tube, we will discern that they don't mix with each other. Below are various statements that relate to this phenomenon.

		Percentages of		
		Correct	Incorrect	I can't determine
a.	Water and oil are a mixture.	65	35	1
b.	*Water and oil do not mix because the two materials each have a different specific gravity.*	29	63	8
c.	The term hydrophobic relates to a material whose molecules do not bond with water molecules.	70	3	28
d.	Molecules of hydrophobic material are non-polarized molecules.	42	10	49
e.	There are molecules that are capable of bonding with both water molecules and molecules of oily materials.	56	10	35
f.	Most creams for cosmetic use are a uniform mixture of a watery solution and some kind of oily material.	65	3	32
	Average	55	21	26

Table 9: The students' understanding of mixtures

The Students' Levels of Multi-Dimensional Chemical Literacy

Multi-dimensional chemical literacy entails that students must appreciate the value of science and technology and be able to relate knowledge of these areas to their daily lives (Shwartz et al., 2006b). To test the students' multi-dimensional chemical literacy, a reading text about green chemistry was presented to them. The students were required to read this and to comprehend the text. The text also featured open-ended questions about green chemistry.

According to the results, only 38% of the students could correctly identify the main idea of the text. When the students were asked to identify key words, most of them (87%) could identify at least one or more keywords. The highest percentage of them (30%) identified three key words. The students indicated that the most unknown term to them was propylene-oxide. Only 23% of the students attempted to explain the oxidation of hydrocarbons, and only 34% of these explanations were correct. The students were asked to explain why hydrocarbons only react with oxygen under high temperatures but do not react at room temperature. Although most of them replied to this question, only 26% of their responses were correct. In another question, the students were asked to explain the term catalyst and its' role in the given text. The highest percentage (65%) of correct explanations regarding functional literacy corresponded to this question. It was also found that the students did not know why substances like NaC1, which is table salt and contains Chlorine, constitutes an environmental hazard.

Conclusion

In this study, the students' levels of chemical literacy were investigated. Because one of the main goals of the new curriculum is to train chemically literate people, it is expected that students will become familiar with the basic concepts of chemistry, and will be able to define these concepts, relate them to daily life, appreciate the value of chemical knowledge and applications, and be aware of the effects of chemistry on society. The results of this study show that the students' levels of nominal and conceptual chemical literacy were satisfactory, but their levels of functional and multi-dimensional chemical literacy were insufficient.

Regarding nominal literacy, the students declared that they were familiar with many concepts of chemistry, such as the atom, elements, isotopes, acids, and bases. However, many students also declared that they did not know much about concepts related to the nature of science, such as scientific inquiry and scientific theories. This result shows that the nature of science, which is one of the core dimensions of scientific literacy—as was noted by Laugksch (2000), is neglected in the curriculum. The results of the current study regarding nominal chemical literacy are in accord with the results of Shwartz et al. (2006b).

Another dimension of chemical literacy, with which the students were adequately acquainted, was conceptual chemical literacy. It was found that most of the students could relate their understanding of diffusion, chemical reactions, oxidation, and mixtures to daily life. The average percentages of correct explanations for each phenomenon ranged between 51 and 76. But, in accord with the results for functional chemical literacy, the students had the weakest understanding of temperature and its relations to real life.

But the results for the functional levels of chemical literacy were less satisfactory. Most of the students could not define the chemistry concepts that were allegedly familiar to them. Their definitions of concepts were mostly incorrect and at a macroscopic level. The highest percentages of incorrect definitions concerned temperature. Because this level of chemical literacy simply requires memorization rather than understanding, it is expected that high school science training should result in a functional level of literacy (Shwartz et al., 2006b). The majority of students did attempt to define the concepts. Most of them chose the concept of an isotope as the most familiar concept to define. They probably thought that only reciting any concept means knowing that concept. One example of the definitions offered for isotope was that an *"isotope is forms of an element which has the same number of protons but different numbers of neutrons."* But none of the students offered an example to expand their definition.

The multi-dimensional chemical literacy levels of the students were the last to be tested in this study. It was found that the students' levels of multi-dimensional chemical literacy were not very high, compared to the results for functional chemical literacy. Only 38% of the students could identify the main idea of the text, and most of them could not explain why some materials, such as NaC1, are hazardous to the environment. They also could not explain the mechanism of the oxidation of hydrocarbons. These results show that the students' levels of reading comprehension, their utilization of former chemical knowledge, and their reasoning were not sufficient. One of the reasons for these results might be related to the students' reading and studying habits. Özden (2007) found that 88% of teachers in that study indicated that students study chemistry only to score high enough on the national exams, rather than to obtain a deeper understanding of chemistry. In another study, it was found that chemistry teachers do not use chemistry textbooks. They mostly use test books to prepare students for national exams (Nakipoglu, 2009).

Because students have become accustomed to a passive learning environment from their previous education, the goals of the new curriculum have only been partially achieved. In a passive learning environment, making students read and search for knowledge is not emphasized as much as the simple transmission of knowledge to students. Students' knowledge is mostly measured by multiple-choice tests in this sort of passive environment. Simply asking chemistry content knowledge with single assessment tool isn't enough to help students to improve their chemistry learning (Gilbert, 2005; Shwartz et al., 2013). It has also noted that the mismatch between this assessment approach and the new curriculum requirements hinders achievement of the goals of the curriculum (Yaşar & Sözbilir, 2012). One of the main reasons for the students' higher general level of conceptual chemical literacy in this study might be related to the multiple choice questions that they were asked to answer in that part of their assessment. Because the students were accustomed to multiple-choice questions, they could more easily determine which choice is correct or incorrect about the phenomena.

Another reason for the inadequate levels of functional and multi-dimensional chemical literacy might be related to the delayed application of the new chemistry curriculum in schools. The goals of the new curriculum obviously could not be met if the curriculum was not implemented properly. Other studies have indicated that teachers' lack of preparation to teach the new curriculum was one the biggest obstacles to implementing it in the high schools (Kurt & Yıldırım, 2010; Yaşar & Sözbilir, 2012).

As it can be inferred from the results, students have higher achievement on the assessment type they are more accustomed. To serve the goal of educating chemical literate people, assessment approaches should be revised as well as the content of the curriculum. As stated by Shwartz et al. (2013) chemistry teachers and educators should corporate formative assessment tools, such as paragraph analysis, portfolios, and diagnostic test, in their assessment approaches.

It is also recommended that chemistry teachers consider all students, who might chose chemistry as professional career or not, when they prepare outcomes for the chemistry curriculum. To live in a world full of chemistry process and products, every one needs to be chemical literate (Gilbert, 2005).

The main limitation of this study is about its' sample. If the sample could have been chosen randomly, results might have been more generalizable. For large sample there is need for new data collection tools that can be answered in a shorter time than the tools used in this study.

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