International Journal of Education and Practice
2013 Vol. 1, No. 5, pp. 51-63
ISSN(e): 2310-3868
ISSN(p): 2311-6897
DOI: 10.18488/journal.61/2013.1.5/61.5.51.63

REPRESENTATION OF SCIENCE PROCESS SKILLS IN THE CHEMISTRY CURRICULA FOR GRADES 10, 11 AND 12 / TURKEY[1]

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ABSTRACT

In one study conducted in Turkey, Berberoğlu et al. (2002) stressed that methods of designing and implementing especially laboratory experiments should inevitably be focused on developing one's higher-level mental skills. It was suggested in a study by Koray et al. (2006) entitled as "Conditions of Representing Science Process Skills in 9th grade Chemistry Course Books and Chemistry Curriculums" that scientific process abilities should be given more place in Chemistry curriculums. In this study, conditions of representing science process skills in 10th grade, 11th grade and 12th grade Chemistry curricula were analysed. Related programs were studied by document analysis method. As a result, representations of basic level and advanced level abilities in above-mentioned programs were year ten, year eleven and year twelve respectively, and it can be inferred that the emphasis in the programs underlined by educators were not disregarded.

Keywords: Chemistry education, Science process skills, The chemistry curricula for grades 10, 11 and 12.

Received: 12 June 2013/ **Revised:** 17 July 2013/ **Accepted:** 20 July 2013/ **Published:** 23 July 2013

1. INTRODUCTION

Science provides a network analysis of the world that surrounds us; in addition, it makes an attempt to explain and describe certain aspects of our universe. (ATS, 2011). Life in modern societies relies on science and its techniques. Any education system should provide citizens with a scientific culture that allows a successful integration into and a decent adaptation to working life. Thanks to this culture, learners gain words, knowledge and scientific skills required for their daily lives. (CS, 2011). Moreover, it presents learners with the ability;

- not to miss out on scientific knowledge conveyed by the media,

[1] This study is the expanded version of the oral presentation in the Turkish II. National Congress of Chemistry Education/Turkey.

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- to understand the relationship among technology, society and science,
- to confront those problems that occur in the fields of health and environment and to take responsible decisions,
- to be aware of bioethical, economic and social problems,
- to evaluate science and scientists in reference to their contribution to the mental development of humanity, and
- to gain a scientific attitude and adopt experimental approach for more autonomy. (CS, 2011).

Physical sciences "define the nature of knowledge as the process of thinking, understanding current body of knowledge and generating new knowledge". (Tan and Temiz, 2003). The aim of science education is "to raise all humans as scientifically literate and help them to understand how scientists discover theories". (Aktamış and Ergin, 2007). In order to realize these aims in science education, the triangle of teachers, students, and curricula should not be ignored. (McMinn *et al.*, 1994). Curriculum plays a pivotal role in this triad. It is without doubt that a well-designed curriculum will enhance the efficiency of teaching. (Ayas *et al.*, 1994).

The notion of curriculum is expressed by educationalists in the form of a prescription for learning. (Taba, 1962; Oliver, 1971). One of the essential components of the prescription is the science process skills. Efficient teaching, or the efficiency of teaching, can be facilitated through learners being enabled to gain the science process skills, one of the educational attainments stipulated in the curriculum.

The science process skills (SPS) are the thinking skills that we use to create knowledge, to reflect on problems and to formulate results. (Lind, 1998). It has been reported that the SPS helps learners understand Physical Sciences. (Çepni *et al.*, 1996; Harlen, 1999). Furthermore, it has been maintained that the basis of learning how to recognize, define and, to some extent, solve individual and social problems is learning how to gain the science process skills. (Aktamış and Ergin, 2007). In this way, individuals can use the SPS for identifying the problems in their daily lives and overcoming them via appropriate hypotheses. (Liang, 2002).

The common instruments of science are knowledge and skills required to carry out research. Of these instruments, skills are classified as follows. (Padilla *et al.*, 1984; IQST, 2006):

- American Association for the Advancement of Science (AAAS) classified scientific process skills as basic scientific process skills and complementary scientific process skills. The former involves observation, classification, data recording, measurement, using space/time relationships, using numbers, inference, and prediction. On the other hand, the latter includes changing and controlling variables, interpreting data, hypothesizing, operational definitions, using data and formulating models, and experimenting. (Padilla *et al.*, 1984).
- Nevertheless, Improving Quality of Science Teacher Training in European Cooperation-constructivist approach- (IQST) classifies the science process skills under two headings, namely basic process skills and higher-level process skills. The former involves observation, classification, communication, measurement, prediction and inference.

(Teaching The Science Process Skills: TTSPS; Padilla, 1990; IQST, 2006). In contrast, the latter includes identification, manipulation, interpretation, operational definition, formulation of models, experimentation, construction of hypotheses and drawing conclusions. (IQST, 2006).

Science classes are eminently suitable for teaching how to conduct scientific research. These are, physics, chemistry, and biology classes at high school level, and science classes at primary school level. The aims of science education that have recently been in practice are listed as students' learning i) how to do scientific research while learning science, ii) science history in suitable science topics, and iii) ways of gaining knowledge while carrying out scientific research. Science teachers are provided with two hours of coursework each week to realize these aims. (Bağcı Kılıç, 2003). As for scientific research, it is taught in a variety of courses.

"The most suitable course for teaching scientific research is science. It presents itself in the courses physics, chemistry and biology in high school, and science in primary school. It is more plausible to allocate two hours to science teachers and, therefore, to enable students to learn scientific research while learning science, to learn the history of science in appropriate units, and to learn ways of accessing knowledge while conducting scientific research. In fact, these are objectives of science education as emphasized recently." (Bağcı Kılıç, 2003)

In today's world marked by the information age, all activities used for learning and teaching are crucial. (Yanpar, 2007). These activities should focus on the science process skills, which are emphasized as important learning products in the educational process. (Harlen, 1999). "The educational process is always updated in a way that will enable individuals to catch up with the world, and proves to be a pioneering factor in the process of change. The tendency has shifted to training students in a way that will enable them to access knowledge, to distinguish what knowledge is necessary, and to generate new knowledge on the basis of the knowledge they have accessed." (Başbay, 2008). This is only possible through higher-level process kills. (Koray *et al.*, 2006). What is prevalent in this tendency is constructivism and learner-centeredness. In constructivism, a learner is in the center and builder of his/her own knowledge as well as participating in preparing it. (Piaget, 1926);(Gustave, 2003). As stated by Mark Twain, education is not to fill up one's memory, but to develop his/her brain (Felsefe Kulübü). Philosophical and emotional ointments flow through a developed brain. They represent themselves in the form of science or arts. Whereas science increases one's philosophical depth in his/her own consciousness, arts increase his/her emotional depth. (Aydın, 2010)

All these objectives can only be realized through higher-level mental skills put forward by Koray *et al.* (2006). In other words, "they can be fulfilled with synthesis, internalizing values and adaptation, three skills in cognitive, affective and psychomotor domains of Bloom's taxonomy respectively." (Aykaç *et al.*, 2006).

In one study conducted in Turkey, Berberoğlu *et al.* (2002) stressed that methods of designing and implementing especially laboratory experiments should inevitably be focused on developing one's higher-level mental skills.. It is stated that in order to achieve this, in other words, to develop students' both scientific process skills and creating thinking skills is possible through focusing more on open-ended experiments and activities that improve creativity. Aktamış and Ergin (2007).

The study conducted by Koray *et al.* (2006) stated that more scientific process skills were to be featured in the chemistry curriculum in order to help students grasp concepts, adopt attitudes, and improve skills related to chemistry class

Aydın (2009) found that the chemistry curriculum for grade nine in Turkey could satisfactorily represent basic process skills, but this was not the case for higher-level process skills.

2. PROBLEM STATEMENT

Whether science is fully understood or not is determined through measuring scientific process skills. (Harlen, 1999). However, in the secondary school chemistry curricula (new), forming or investigating single relationships between scientific process skills and content attainments is stated to be unnecessary (Milli Eğitim Bakanlığı [MEB], 2007). On the other hand, the National Sciences Teachers Association underlined that a reasonable part of science curricula should focus on the science process skills. (Padilla, 1990). All things considered, the present study is of major importance.

3. CONCEPTUAL FRAMEWORK

In one study, Dönmez and Azizoğlu (2010) recommended that the skill objectives should be emphasized in teachers' books and that they should cover the science process skills to be used by teachers when necessary during lecturing. Considering these recommendations and the fact that learning these skills can eliminate the idea that Physical Sciences are based on memorization. (Harlen, 1999), it is essential that these skills should be incorporated into the curriculum. According to Harlen (1999), these skills are learning products that are vital to the educational process. Furthermore, these products are actually methods and techniques by which scientists can have access to and process knowledge. (Gagne, 1965). With these methods and techniques, people identify their daily problems and solve them through appropriate hypotheses. (Liang, 2002). It is context-based learning that uses current issues interesting students as course contents (Salters-Nuffield Advanced Biology) (SNAB). It is a way of learning derived from socio-cultural constructivism. (Baker *et al.*, 2007). Learners adopting this learning approach develop their own scientific process skills. (Sözbilir *et al.*, 2007). It was put forward that teacher candidates could use inquiry-based approach to improve the aforementioned skills. (Budak and Köseoğlu (2007).

In Turkey, it is important to determine whether the chemistry curricula, started to be developed in 2007 reportedly on the basis of constructivism (Yaşar *et al.*, 2011), have been designed in a way that will develop higher-level cognitive skills. That is because a curriculum based on constructivism should be designed in a way that will make learning permanent and develop higher-level cognitive skills. (Şaşan, 2002). For all these reasons, the present study is of major importance.

4. THE PURPOSE OF THE STUDY

The purpose of the present study is to reveal the extent to which the science process skills are represented in the Chemistry Curricula for Grades 10, 11 and 12.

4.1 Study Questions

In the country studied,

1. what is the extent to which the science process skills are represented in the Chemistry Curriculum for Grade 10?
2. what is the extent to which the science process skills are represented in the Chemistry Curriculum for Grade 11?
3. what is the extent to which the science process skills are represented in the Chemistry Curriculum for Grade 12?

5. METHODOLOGY

The Chemistry Curricula for Grades 10, 11 and 12. (MEB, 2008; 2009a; 2009b) were analyzed through document analysis. It is one of the most significant techniques commonly used in social sciences. Document analysis is designed "to identify the existence of certain words or concepts in a text or set of texts". (Büyüköztürk *et al.*, 2008). In other words, it is the process by which one collects recordings or documents relevant to the study and codes and analyses them in accordance with a particular system. (Çepni, 2009). That is, it involves an analysis of written materials on the target phenomenon or phenomena. (Yıldırım and Şimşek, 2005). Therefore, document analysis is commonly used in qualitative studies. Accordingly, the technique was used in the present study to analyze the words included in the educational attainments and activities in the units of the Chemistry Curricula for Grades 10, 11 and 12 as well as sample assessment questions at the end of each unit. (MEB, 2008; 2009a; 2009b).

In this analysis, valid and reliable question types were used. (Turgut *et al.*, 1997). These question types and the science process skills represented are presented in Appendix. (Turgut *et al.*, 1997). In reference to the list of questions used as the measurement instrument, an analysis was made of the words included in the educational attainments and activities in the units of the Chemistry Curricula for Grades 10, 11 and 12 as well as every single assessment question at the end of each unit. In this way, it was possible to determine which word or question represented a particular science process skill in the best way possible.

In Turkey, the Chemistry Curricula, which started to be developed in 2007, are based on "constructivism". (Yaşar *et al.*, 2011). Therefore, the curricula were analyzed in reference to the science process skills adopted by the IQST-Improving Quality of Science Teacher Training in European Cooperation-constructivist approach.

A sample assessment question included in the Chemistry Curriculum for Grade 10 is presented below. (MEB, 2008). It is followed by an analysis of the question in reference to the question type-science process skill relationship tested by Turgut *et al.* (1997).

Question: Mixtures
The science process skill represented: Observation
Question. Compare and contrast the substances in terms of CCI_4 (carbon tetrachloride) and water solubility. (MEB, 2008).

	CCI_4	H_2O	Reason
C_6H_{14} (hexane)			
$NaHCO_3$ (sodium bicarbonate)			
HCI (Hydrochloric acid)			
I_2 (Iodine)			
CH_3OH (Methanol)			

Figure. Sample Assessment Question in the Chemistry Curriculum for Grade 10 and the Science Process Skill Represented

Analysis of the Question: It seems that there is a parallel between the first question type (Appendix) -science process skill relationship tested by Turgut *et al.* (1997) and the question type-science process skill presented above.

This is supported by the similarity between the question by Turgut *et al.* (1997) "*In what ways did you compare and contrast the objects?*" and the statement included in the curriculum "*Compare and contrast the substances in terms of* CCI_4 *(carbon tetrachloride) and water solubility.*"

6. FINDINGS

As a result of the analysis carried out, it was determined how scientific process skills were reflected in the Chemistry Curricula for Grades 10, 11 and 12 (Table 1, 2 and 3).

Table-1. Scientific Process Skills (SPS) and their reflection in the Chemistry Curricula for Grades 10.

SPS	Basic Process Skills							Higher-Level Process Skills						
Grade 10	1- Observation	2- Classification	3- Communication	4- Measurement	5- Prediction	6-Inference	7- Identification	8- Manipulation	9- Interpretation	10-Operational Definition	11-Formulation of Models	12-Experimentation	13-Construction of Hypotheses	14-Drawing Conclusions	Total
T*	6	-	1	5	9	15	-	3	1	34	31	43	7	24	179
%	*3.3*		*0.6*	*2.8*	*5.0*	*8.4*		*1.7*	*0.6*	*19.0*	*17.3*	*24.0*	*3.9*	*13.4*	*100*
O**	20.1							79.9							100

*Total, ** Mean Percentage

While the basic process skills are represented by 20.1% in the Chemistry Curriculum for Grade 10, the higher-level process skills are represented by 79.9% in the curriculum (Table 1). Whereas inference, prediction, observation, measurement and communication are represented by 8.4%, 5.0%, 3.3%, 2.8% and 0.6% respectively, experimentation, operational definition, formulation of models, drawing conclusions, construction of hypotheses, manipulation and interpretation are represented by 24.0%, 19.0%, 17.3%, 13.4%, 3.9%, 1.7% and 0.6% respectively.

Table-2. Scientific Process Skills (SPS) and their reflection in the Chemistry Curricula for Grades 11.

SPS	Basic Process Skills								Higher-Level Process Skills						
Grade 11	1- Observation	2- Classification	3- Communication	4- Measurement	5- Prediction	6-Inference	7- Identification	8- Manipulation	9- Interpretation	10-Operational Definition	11-Formulation of Models	12-Experimentation	13-Construction of Hypotheses	14-Drawing Conclusions	Total
T*	11	-	-	5	3	7	-	2	-	28	1	17	-	33	*107*
%	*10.3*			*4.7*	*2.8*	*6.5*		*1.9*		*26.2*	*0.9*	*15.9*		*30.8*	*100*
O**				24.3							75.7				100

*Total, ** Mean Percentage

While the basic process skills are represented by 24.3% in the Chemistry Curriculum for Grade 11, the higher-level process skills are represented by 75.7% in the curriculum (Table 2). Whereas observation, inference, measurement and prediction are represented by 10.3%, 6.5%, 4.7% and 2.8% respectively, drawing conclusions, operational definition, experimentation, manipulation and formulation of models are represented by 30.8%, 26.2%, 15.9%, 1.9% and 0.9% respectively.

Table-3. Scientific Process Skills (SPS) and their reflection in the Chemistry Curricula for Grades 12.

SPS	Basic Process Skills								Higher-Level Process Skills						
Grade 12	1- Observation	2- Classification	3- Communication	4- Measurement	5- Prediction	6-Inference	7- Identification	8- Manipulation	9- Interpretation	10-Operational Definition	11-Formulation of Models	12-Experimentation	13-Construction of Hypotheses	14-Drawing Conclusions	Total
T*	3	2	-	-	6	4	2	2	1	3	2	6	-	10	*41*
%	*7.3*	*4.9*			*14.6*	*9.8*	*4.9*	*4.9*	*2.4*	*7.3*	*4.9*	*14.6*		*24.4*	*100*
O**				36.6							63.4				100

*Total, ** Mean Percentage

While the basic process skills are represented by 36.6% in the Chemistry Curriculum for Grade 12, the higher-level process skills are represented by 63.4% in the curriculum (Table 3). Whereas prediction, inference, observation and classification are represented by 14.6%, 9.8%, 7.3% and 4.9% respectively, drawing conclusions, experimentation, operational definition, identification-manipulation-formulation of models, and interpretation are represented by 24.4%, 14.6%, 7.3%, 4.9% and 2.4% respectively.

6.1 Limitations

The focus of the study was limited to the curricula in Turkey

7. CONCLUSIONS AND DISCUSSION

A discussion is made on the science process skills in the Chemistry Curriculum for Grades 10, 11 and 12 in reference to Tables 1, 2 and 3, which show the extent to which the basic process skills and higher-level process skills are represented, as well as on percentages in descending order of prominence. According to the results, the basic process skills are represented by 20.11% in the Chemistry Curriculum for Grade 10 whereas the higher-level process skills are represented by 79.89% in the curriculum. In addition, the basic process skills are represented by 24.30% in the Chemistry Curriculum for Grade 11 while the higher-level process skills are represented by 75.70% in the curriculum. Finally, the basic process skills are represented by 36.59% in the Chemistry Curriculum for Grade 12 whereas the higher-level process skills are represented by 63.41% in the curriculum.

In the Curricula of Chemistry Class for Grade 10, while basic process skills are listed from most to the least as *inference*, *prediction*, *observation*, *measurement*, *communication*, and *classification*, high-level process skills are ordered as *doing an experimentation*, operational definition, formulation of models, drawing conclusions, construction of hypotheses, manipulation, interpretation and identification.

In this curriculum, it is seen that of the basic skills, *making an inference* is the most prominent one, while doing *an experiment* is the leading skill in the high-level process skills. *Making an inference* is defined as making statements on the causes of the events that happened before based on observations. (MEB, 2004), while doing an experiment is stated to be the process of changing and controlling variables.(Tan and Temiz, 2003).

These findings indicate that the emphasis laid on laboratory experiments as stated by Berberoğlu *et al.* (2002) has not been ignored in this curriculum. The study conducted by TIMSS in 1999 reported that the science curriculum in Turkey aimed to teach all the topics in the fields of world science, life science, physics, chemistry, environmental science (TIMSS., 1999). However, when the data collected from teachers and students were analyzed, it was determined that the aforementioned country was one of the countries where the least number of experiments were carried out in science classes compared to other countries (Australia, England, Israel, Malaysia, The United States of America). (TIMSS., 1999).

In the Chemistry Curriculum for Grade 11, the basic process skills are as follows in descending order: observation, inference, measurement, prediction, and communication-classification. On the other hand, the higher-level process skills are as follows in descending order: *drawing conclusions*, operational definition, experimentation, manipulation, formulation of models, identification-interpretation - construction of hypotheses.

The prominent skills in the curriculum are "observation" as a basic process skill and "drawing conclusions" as a higher-level process skill. Observation and drawing conclusions are methods and techniques that scientists use for accessing and processing knowledge. (Gagne, 1965). Observation is also defined as using senses to collect information about an object or event. (Padilla, 1990). In other words, observation is a basic science process skill. Using our sense organs, we observe events and objects, and learn how the world around us is (TTSPS). "Science starts with observation" and drawing conclusions is "interpreting the results of an observation or experiment and making judgments. (Tan and Temiz, 2003).

In the Chemistry Curriculum for Grade 12, the basic process skills are as follows in descending order: prediction, inference, observation, classification, and measurement-communication. On the other hand, the higher-level process skills are as follows in descending order: *drawing conclusions*, experimentation, operational definition, identification – manipulation - formulation of models, interpretation and construction of hypotheses".

The prominent skills in the curriculum are "prediction" as a basic process skill and "drawing conclusions" as a higher-level process skill. Prediction is stating an opinion as to future events or expected situations on the basis of certain data. (Tan and Temiz, 2003). Besides, prediction is involved in stating the result of a future event based on a design. (Padilla, 1990). In other words, it is forming an opinion as to potential future results on the basis of observation, inference and experimentation. (MEB, 2004).

It should be noted here that the prominent higher-level process skill in the Chemistry Curriculum for both Grades 11 and 12th is "*drawing conclusions*".

In conclusion, the extents to which the basic process skills and higher-level process skills are represented in the curricula are as follows in descending order: the Chemistry Curriculum for Grade 10, the Chemistry Curriculum for Grade 11 and the Chemistry Curriculum for Grade 12. It is clear that the designers of the curricula have not neglected the emphasis stated by certain educationalists. (Berberoğlu *et al.*, 2002; Koray *et al.*, 2006; Aydın, 2009).

The reason why it is clear that the emphasis has not been overlooked in the curricula is that the chemistry curricula in Turkey, which are based on constructivism. (Yaşar *et al.*, 2011), have been designed in a way that will promote higher-level cognitive skills. These skills can be listed as follows: distinguishing, imagination, inquisition, creative thinking, and reasoning. (MEB, 2006). These play an importance role in designing and designing is the format which is realized in mind. (Kaya *et al.*, 2010). Having acquired the mental processes that are pointed out, students may develop a sense of responsibility in their own learning. (Çepni *et al.*, 1996). In this way, learners can be enabled to gain the skills that scientists use during their studies. (Lind, 1998).

7.1 Suggestions

Further studies could draw conclusions as to the development level of the country studied in reference to the science process skills identified.

In addition, they could compare and contrast PISA and TIMSS with a consideration into these conclusions and the science process skills in the chemistry curricula used in other countries.

Funding: This study received no specific financial support.

Competing Interests: The author declares that there are no conflicts of interests regarding the publication of this paper.

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Appendix. Question Types and Science Process Skills Represented*

Question No	Question Type	Science Process Skills
1	*In what ways did you compare and contrast the objects?*	*observation*
2	By which characteristic did you classify these objects?	classification
3	How do you calculate the area of this habitat?	measurement
4	How would you put these geometric figures in order in accordance with their area?	number/space relationships
5	Considering all the data, which brand seems to be the best one to purchase?	data transfer/recording
6	If a candle burns for 12 to 14 seconds in one-liter jar, how long do you estimate it will burn in a two-liter jar?	Prognosis/ Prediction
7	What causes the candle to get extinguished?	inference
8	According to the graph, how does the density of rocks change depending on depth?	data interpretation
9	If you attempt to dissolve a soluble aspirin in water with varying temperatures, what are the variables that are changed or react to change?	defining variables
10	Considering the relevant variables, what are the factors in the length of a shadow? What affects the growth rate of a plant?	formulation of hypotheses
11	If you are searching for the size and germination time of a seed, what are the variables that are changed or react to change in the experiment?	operational definition
12	How is each changed variable defined?	using and controlling variables
13	After turning a container to different shapes, how would you define the object in the container?	using data /formulation of models
14	At what altitude does a glass marble have the greatest potential (hidden) energy?	decision-making
15	What affects the distance that a rubber band can cover?	experimentation

*(Turgut *et al.*, 1997)