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ANALYSIS OF TURKISH HIGH-SCHOOL CHEMISTRY-EXAMINATION QUESTIONS ACCORDING TO BLOOM'S TAXONOMY

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ABSTRACT: Improving students' conceptual understanding depends on the question types asked in exams by the teachers. In the related literature, in order to analyse the cognitive levels of the questions, Bloom's Taxonomy has been mostly used. The aim of this study was to analyse and compare the chemistry questions asked in exams at different schools in two cities in Turkey in terms of the levels of cognitive domain of Bloom's Taxonomy. The study was carried out in three types of high schools (student age: 14-17): 'Ordinary', 'Anatolian', and 'Vocational', from the cities of Trabzon and Amasya, with 17 chemistry teachers in 2000-01. 403 questions set in school examinations were analysed. It was found that 96% of the questions were of the lower-order cognitive skills (LOCS) type. Statistical tests showed that the question types were related to school type. On the other hand, more than half of the questions asked in the university entrance examination (OSS) were of the higher-order cognitive skills (HOCS) type. This contradiction causes a problem between the assessment at high school and that at the OSS. Recommendations for overcoming this problem are made. [*Chem. Educ. Res. Pract.*: 2003, *4*, 25-30]

KEY WORDS: a*ssessment; chemistry examination questions; high-school examinations; university entrance examinations; Bloom's Taxonomy; lower-order cognitive skills (LOCS); higher-order cognitive skills (HOCS); Turkey*

INTRODUCTION

Education is a process that aims at changing an individual's behaviour. Some of the important aims of science education are to provide students with lasting learning of scientific concepts, and improve their thinking skills (Saunders & Shepardon, 1987). Planning, teaching, and assessment stages have been used in order to achieve these aims. Assessment is a crucial stage in determining whether students' conceptual development has reached higher order cognitive skills (HOCS) or not.

Assessment aims to make judgements and decisions about students' and teachers' effectiveness (Rosenshine, 1971). In this process, first, it is necessary to test the targeted behaviour by using measuring tools that have high validity and reliability. If we are not clear about the expected behaviour for the students to reach, we cannot measure the targeted behaviour. Consequently, the first step in any assessment process is to define students' behavioural changes. So, a comparison should be made between expected and observed outcomes. For this, written examinations, multiple-choice tests, and oral examinations can be used. While written and multiple-choice tests are accepted as quantitative measuring tools,

oral examinations are known as qualitative tools (Cohen & Manion, 1998). Chemistry teachers usually apply written exams to find out whether students learn the content and scientific facts of chemistry. To assess chemistry teaching at all types of high school, it is important to determine the quality of questions asked in school exams.

HOCS items are defined as *quantitative problems or qualitative conceptual questions, unfamiliar to the students, that require for their solution more than knowledge and application of known algorithms ... Such an application may further require (partially or fully) the abilities of reasoning, decision-making, analysis, synthesis, and critical thinking* (Zoller & Tsaparlis, 1997, p.118). In order to improve the quality of teaching, it is widely believed that one must be able to set good/proper questions. Teachers who set HOCS questions foster interaction between themselves and their students (Brualdi, 1998).

The purpose of this study was to analyse and compare the chemistry questions asked in exams at the different schools in two cities of Turkey, in terms of the levels of cognitive domain of Bloom's Taxonomy. This Taxonomy has been used mostly in designing questions which help teachers to measure students' thinking abilities (Colletta & Chiappetta, 1989).

METHOD

The study was carried out in eight high schools (student age: 14-17) in the cities of *Trabzon* and *Amasya* in Turkey: three 'Ordinary' high schools, three 'Vocational and Commercial' high schools and two 'Anatolian' high schools. Ordinary High Schools (OHS) are well known as *general lycees* and students are enrolled to these lycees without any entrance examinations. Vocational and Commercial High Schools (VCHS) usually accept students who try to enter profession early without graduating university. Anatolian High Schools (AHS) accept students by means of a nation-wide selection examination (LGS). Usually, bright pupils are able to enrol these schools. Almost in each city there is one AHS. However, in big cities there are more than one AHS.

Trabzon is a big city in the North Black Sea region, with a population of *ca.* two hundred thousand people in the city centre. Its socio-economic statue is accepted as over medium. Amasya is a small city at the middle of the Black Sea region, with approximately fifty thousand people in the city centre. Its socio-economic statue is considered to be as medium. The economies of these cities are mostly based on agriculture. All types of high schools exist in both cities, while student success rates on the university entrance examination (OSS) is under the average, in comparison with the other cities in Turkey.

Four hundred and three (403) written-exam questions asked by 17 chemistry teachers in these schools during two academic terms were collected by the researchers. These questions were analysed in terms of the stages of the cognitive domain (Colletta & Chiappetta, 1989). Cognitive behaviour consists of cognitive skills and related activities. According to Bloom's Taxonomy of educational objectives, the cognitive domain is organised into six levels: knowledge, comprehension, application, analysis, synthesis and evaluation (Bloom, 1956). Aims and questions classified according to levels of cognitive domain, together with comments on each question are summarised in the Appendix.

In the analysis process, each of the authors individually analysed each question according to Bloom's Taxonomy. It was found that the authors had a high consensus on the levels of the questions (Judd, Smith & Kidder, 1991). Statistical analyses were carried out using the SPSS statistical software.

RESULTS AND COMMENTS

Table 1 gives the distribution of the 403 questions according to school type and to cognitive level. Only about 4% of the questions asked were at the higher levels of cognitive domain (analysis, synthesis and evaluation levels). On the other hand, about 60% of the questions were at low levels: 27.8% at the knowledge and 28.5% at the comprehension level. Another 39.7% were at the application level. These conclusions are also supported by previous work which demonstrated that most traditional examinations in chemistry are of the LOCS type (Zoller, 1993; Nakhleh, 1993).

TABLE 1. *Distribution of exam questions according to school type and cognitive level.*

School Types	OHS		VCHS		AHS		**Total**	
Question Levels	f	%	f	%	f	%	**f**	**%**
Knowledge	24	18.6	73	46.2	15	12.9	**112**	**27.8**
Comprehension	45	34.9	45	28.5	25	21.6	**115**	**28.5**
Application	59	45.7	38	24.1	63	54.3	**160**	**39.7**
Analysis	1	0.8	2	1.2	5	4.3	**8**	**2.0**
Synthesis	-	0.0	-	0.0	5	4.3	**5**	**1.2**
Evaluation	-	0.0	-	0.0	3	2.6	**3**	**0.8**
Total	**129**		**158**		**116**		**403**	

Questions asked are related to school types: the observed χ^2 statistic assumes the value 74.91, which exceeds the critical value (16.81) ($p < .01$). Questions at the knowledge level were especially asked at Vocational and Commercial High Schools (VCHS). These types of questions were rarely asked at Anatolian High Schools (AHS). Comprehension level questions were asked mostly at Ordinary High Schools (OHS). On the other hand, the application level questions were asked more at AHS, somehow less so at OHS, and much less at VCHS. (Actually, the majority of the questions at AHS were at the application level.) Finally, questions at analysis, synthesis and evaluation levels, which require students to think scientifically, were not asked at all at OHS and VCHS; in addition, these types of questions were very little used in AHS. Similar results have been found in other studies (Çepni & Azar, 1998). It is evident that AHS teachers tend to set more HOCS-type questions, while the teachers in the other types of schools tend to set LOCS-type questions. Note that it has been found that the students who were successful in university entrance exams were especially graduated from AHS (Köse, 1999). This may be the reason of the high success of the AHS students in the OSS exams.

Table 2 gives the distribution of the 403 questions according to school type and city. Although it appears that there are some differences between cities as well as school type in terms of levels of the questions, an independent two-tailed *t*-test showed no statistically significant differences ($t = .003$).

DISCUSSION AND RECOMMENDATIONS

Examination questions at application and lower levels of Bloom's Taxonomy were prepared to measure students' understanding of concepts, and applying level of chemical reactions into problems and teaching formula. However, whether the questions examined in this study were new for students or they had come across them before the exams is not known. Consequently, some questions accepted as at the application level, could be at knowledge or comprehension level. Also, we concluded that the examined questions were not

TABLE 2. *Distribution of the questions analysed according to school type and city.*

Question levels	TRABZON						AMASYA						**TOTAL**			
	OHS		VCHS		AHS		OHS		VCHS		AHS		**Trabzon**		**Amasya**	
	f	%	f	%	f	%	f	%	f	%	f	%	**f**	**%**	**f**	**%**
Knowledge	15	19.1	26	53.1	7	14.9	9	17.7	47	43.1	8	11.6	**48**	**27.6**	**64**	**28.0**
Comprehension	25	32.2	12	24.5	11	23.4	20	39.2	33	30.3	14	20.2	**48**	**27.6**	**67**	**29.3**
Application	37	47.4	10	20.4	23	48.9	22	43.1	28	25.7	40	58.0	**70**	**40.2**	**90**	**39.4**
Analysis	1	1.3	1	2.0	3	6.4	-	0.0	1	0.9	2	2.9	**5**	**2.9**	**3**	**1.3**
Synthesis	-	0.0	-	0.0	2	4.3	-	0.0	-	0.0	3	4.4	**2**	**1.2**	**3**	**1.3**
Evaluation	-	0.0	-	0.0	1	2.1	-	0.0	-	0.0	2	2.9	**1**	**0.5**	**2**	**0.9**
TOTAL	**78**		**49**		**47**		**51**		**109**		**69**		**174**		**229**	

suitable for students to perceive the basic concepts in chemistry, and assimilate and interpret the chemical events, and connect them with daily life events and needs. This situation directs students to memorise the science concepts without understanding their real meaning (Çepni, Ayas, Johnson & Turgut, 1997; Ayas & Demirbaş, 1997).

Although the majority of the high school students take high marks from the chemistry exams, these results do not reflect the real achievement on HOCS. Because, if students answer successfully many questions at OSS exams, they can be accepted as successful students in the Turkish context. In Turkey, the majority of the questions asked in the OSS exams, which have a turning point in students' life, require analytic thinking and cross-examinination of concepts (Tezbaşaran, 1994). However, it has been reported that students who have high academic achievement in science lessons were not capable to deal successfully with many questions at the OSS exams (Morgil & Bayan, 1996).

Based on the results of this study, the following recommendations can be made, with the aim to contribute to improving students' thinking abilities and ultimate achievement:

- Chemistry teachers should take into consideration students' cognitive (developmental) level.
- Teachers should ask HOCS type questions such as: *Ionisation potential refers to the energy required to remove an electron from an atom. The first ionisation potential refers to the energy required to remove the first electron, the second potential refers to the removal of the second electron, etc. Which of the following two would you expect to have a higher ionisation potential: a sulphur atom or a phosphorus atom? Explain.* (Zoller, Fastow, Lubezky & Tsaparlis, 1998).
- In student teachers' undergraduate programs, theoretical and practical training should be provided that will make students capable to plan and execute chemistry lessons, as well as to prepare appropriate questions for the various cognitive levels.
- Teachers should prepare exam questions in collaboration with their colleagues.
- Universities having specialists in chemistry education should give seminars and in-service courses on preparing chemistry lessons and questions.

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APPENDIX: EXAMPLES AND ANALYSIS OF QUESTIONS

We found that chemistry exam questions could be sorted into each of the six classifications of Bloom (Colletta & Chiappetta, 1989; Gronlund, 1995). During analysis of the questions, the following criteria were used.

1.- Knowledge. Questions on the knowledge level require the students to remember facts they have already learned and recall these as they have been learned.

Aim: *To be able to define the concept of compound.*
Question: *Can you define what is a compound?*

2.-Comprehension. Students must be able to rephrase information using their own statements and translate knowledge into new context and interpret graphs, tables, charts and cartoons.

Aim: *To be able to explain the variation of the electron affinity of the elements.*
Question: *Explain how the electron affinity of the elements varies in the periodic table.*

3- Application. Students are required to identify the relevant information and rules to arrive at a solution and solve problems using known algorithms.

Aim: *To be able to calculate the pressure of each gas in a mixture in a closed vessel.*
Question: *What is the partial pressure of each gas in a mixture that contains 40 g He, 56 g N_2, and 16 g O_2, if the total pressure of the mixture is 5 atm?*

4- Analysis. The analysis level requires that students separate an idea into its parts or elements and demonstrate an understanding of the relationship of the parts to the whole.

Aim: *To be able to separate mixtures.*
Question: *Propose a method to separate each of the following mixtures:*
a) blood b) unrefined petroleum c) iron -sulphur (in powder form) mixture.

5- Synthesis. Questions on synthesis level permit students to devise ways to design experiments and test hypotheses. Students may be required to write a paper and a report in which ideas are synthesised or problems are solved.

Aim: *To be able to propose a method in order to find the formulas of organic compounds.*
Question: *Describe an experiment in order to find the formulas of organic compounds.*

6- Evaluation. Questions at this level require students to make judgements about the value or merits of an idea, purpose, solution to a problem, procedure, method or product. This level requires students to use the other five levels of the taxonomy to varying degrees.

Aim: *To be able to explain the effects of radioactivity on human health and environment.*
Question: *Describe the effects of radioactivity on human health and environment. Explain your answer.*

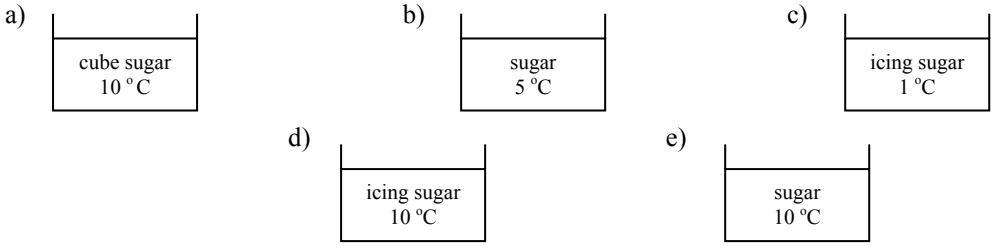
- Two examples of HOCS type questions asked in the OSS are given below.

1. Which events given below encountered in daily life are not related to dissolution of gases? (OSS-1998)

a) If a glass bottle filled with a fizzy drink is heated too much, its top blows up.
b) When a bottle filled with a fizzy drink is left in an icebox, it cracks.
c) When a bottle filled with a fizzy drink is opened, gas bubbles are generated.

d) Cool water is better environment for growing fish than warm water.
e) When divers dive in deep sea, the concentration of nitrogen in their blood increases.

2. To the following containers that contain each an equal amount of water, the same amount of sugar is added. In which container the dissolution is the fastest? (OSS-2001)



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