Analysis of Turkish high-school physics-examination questions according to Bloom's taxonomy*

Serhat KOCAKAYA[1,3] and Selahattin GÖNEN[2]

[1]Yüzüncü Yil University, Education Faculty
Department of Physics Education
Zeve Campus, VAN, TURKEY
E-mail: kocakaya@yyu.edu.tr

[2]Dicle University, Education Faculty
Department of Physics Education
Campus, DIYARBAKIR, TURKEY
E-mail: sgonen@dicle.edu.tr

[3]Correspondence author

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Abstract

The purpose of this study was to analyse and compare the physics questions of the university entrance exam (OSS) with those asked at exams at different schools in Turkey in terms of the levels of cognitive domain of Bloom's Taxonomy. The study was carried out in four types of high schools (student age: 14–17): 'Ordinary', 'Vocational, 'Anatolian'and 'Science' from Diyarbakır, with 19 physics teachers. It was found that 72.5 per cent of the questions were of the lower-order cognitive skills (LOCS) type. Statistical tests showed that the question types were related to school type ($P<0.001$). On the other hand, about half of the questions asked in the university entrance examination (OSS) were of the higher-order cognitive skills (HOCS) type 50.9 per cent and of the lower-order cognitive skills (LOCS) 49.1 per cent. This contradiction causes a problem between the assessment at high school and that at the OSS.

Keywords: Bloom Taxonomy, physics education, higher-lower order cognitive skills

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 the effectiveness of students and teachers (Rosenshine, 1971). In this process, first, it is necessary to test the targeted behaviour by using measurement tools that have high validity and reliability. If we are not clear about the expected behaviour for the students to reach, we can not measure the targeted behaviour. Consequently, the first step in any assessment process is to define students' behavioural changes. Therefore, 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 measurement tools, oral examinations are known as qualitative tools (Cohen & Manion, 1998).

Physics teachers usually apply written exams to find out whether students learn the content and scientific facts of physics. To assess physics teaching at all types of high school, it is important to determine the quality of questions asked at school exams.

Physics is known as a difficult lesson to comprehend by most students. As a result, success of students is rather low on physics questions asked in high school and OSS (Çepni&Azar, 1998; Çepni, Özsevgeç & Gökdere, 2003). Because physics teachers think that physics is difficult to understand as a lesson, they generally ask lower-order and superficial questions. In fact, according to studies related with the subject, questions consist of 80 per cent reminding(Karamustafaoğlu, Sevim, Karamustafaoğlu & Çepni, 2003; Köse, 1999; Crocks, 1998; Gall, 1984). Lower-order questions neither develop intelligence capacity of students nor lead them learning parrot fashion. The students attending a high school, as a result of not meeting questions which need to be thought (thinking with possibilities, thinking imaginably, and correlational thinking), often could not answer them in OSS. Physics questions asked are expresed on the basis of analysis, problem solving on commentary and they can be solved by students who can understand events conceptionally, think analytically and have the ability to solve problems and practicing.

If our aim is to make students solve higher-order physics questions in OSS and encourage them to improve their system of thinking, We should provide them with appropriate education. The consideration made according to the level of students at schools brings out their real mental skills.

The most common criteria used when analysing the instructional objectives and questions is Bloom Taxonomy (BT), developed by Benjamin Bloom and known by his name. BT asserts to prepare questions for measuring thinking skills of students (Çepni, 2003; Çepni at al., 2007).

The main purpose for determining success of students has to be determining and developing their level of cognitive progress by asking well prepared questions. According to BT, cognitive levels are arranged in order, from simple to complex: knowledge level, comprehension level, application, analysis, synthesis and evaluation level. As stated by Çepni (2003) and Çepni&Azar(1998), students might be at difference cognitive levels. The quality of the questions asked on exams contributes to creativeness of students and their criticism ability.

According to Çepni et al. (2003 and 2007), existing teachers do not make appropiriate determinations on mental developmental characteristics of students. Therefore, many successful students at high school fail on OSS. According to Azar (1998), the teachers in secondary schools do not have enough experience of asking questions by considering BT. Moreover, the cognitive levels of physics questions on OSS are needed to be investigated.

HOCS items are defined as quantitative problems or qualitative conceptual questions, unfamiliar to the students, requirine 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). 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 physics questions asked in exams at different schools in a province of Turkey, in terms of the levels of cognitive domain of BT. This Taxonomy has been used mostly in designing questions which help teachers to measure students' thinking abilities (Colletta & Chiappetta, 1989).

Purpose

The purposes of this study were:

1- To compare the cognitive levels of questions asked at high school physics exams and OSS according to BT.

2- To determine the differences at the level of asked questions at high school and OSS exams.

Method

The study was carried out in seven high schools (student age: 14-17) in the province *Diyarbakır* in Turkey: three 'Ordinary' high schools, two 'Vocational and Commercial' high schools; one 'Anatolian' high school and one 'Science' high school, which were randomly chosen in Diyarbakır. Ordinary High Schools (OHS) are well known as *public high school* and students are enrolled to these high schools 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) and Science High Schools (SHS) accept students by means of a nation-wide selection examination (LGS\OGS). 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. Besides, there is not one SHS in every cities because of its elite.

Eight hundred seventy six (876) written-exam questions asked by 19 physics teachers in these schools during two academic terms of 2005 were collected by the researchers. These questions were analysed in terms of the stages of the cognitive domain. 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, the authors and the other physics education expert have analysed each question according to Bloom's Taxonomy. It was found that these three academicians had a high consensus on the levels of the questions. Afterwards, OSS questions were also classified according to the cognitive levels of BT. Both the frequencies of the cognitive levels of physics exam questions and the OSS physics questions in 2005 were compared as of years. Finally, the significance of connections between OSS (2005) and high school physics questions was researched by statistical analyses.

Findings and Results

Table I gives the distribution of 876 questions according to school type and to cognitive level. Only about 27.5 per cent of the questions asked were at the higher levels of cognitive domain (analysis, synthesis and evaluation levels). On the other hand, about 20.2 per cent of the questions were at low levels: 6.3 per cent at the knowledge and 13.9 per cent at the comprehension level. The other 52.3 per cent were at the application level. These conclusions are also supported by previous work which demonstrated that most traditional examinations are of the LOCS type (Hand, Prain & Wallace, 2002; Nakhleh, 1993; Zoller, 1993; Çepni et al., 2003; Karamustafaoglu et al., 2003; Köğce, 2005).

Table I *Distribution of Exam Questions According to School Type and Cognitive Level.*

School Types	OHS		VCHS		AHS		SHS		Total	
Question Levels	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**
Knowledge	33	9.6	20	8.9	-	0.0	2	1.2	55	6.3
Comprehension	77	22.4	29	12.8	2	1.5	14	8.1	122	13.9
Application	171	49.7	147	65.0	56	42.1	84	48.4	458	52.3
Analysis	26	7.6	8	3.5	63	47.4	50	28.9	147	16.8
Synthesis	33	9.6	20	8.9	8	6.0	19	11.0	80	9.1
Evaluation	4	1.1	2	0.9	4	3.0	4	2.4	14	1.6
Total	344		226		133		173		876	

Questions asked are related to school types: the observed $\chi 2$ statistic assumes the value 207.36, which exceeds the critical value (37.69) ($p < .001$). Questions at the knowledge level were especially asked at OHS and VCHS. These types of questions were rarely asked at AHS and SHS. Comprehension level questions were asked mostly at Ordinary High Schools (OHS). On the other hand, the application level questions were asked more at VCHS (in order that it is a school that bases on practice). Finally, questions at analysis, synthesis and evaluation levels, which require students to think scientifically, were rarely asked at all at OHS and VCHS; in addition, these types of questions were mostly used in AHS and SHS. It is evident that AHS and SHS teachers tend to set more HOCS-type questions, while the teachers in the other types of schools tend to set LOCS-type questions. It is worth noting that it has been found that the students who were successful in university entrance exams were especially graduated from AHS (Köse, 1999) and SHS. This may be due to the high success of the AHS and SHS students in the OSS exams. Figure 1 shows graphically this percentage of high schools physics questions level.

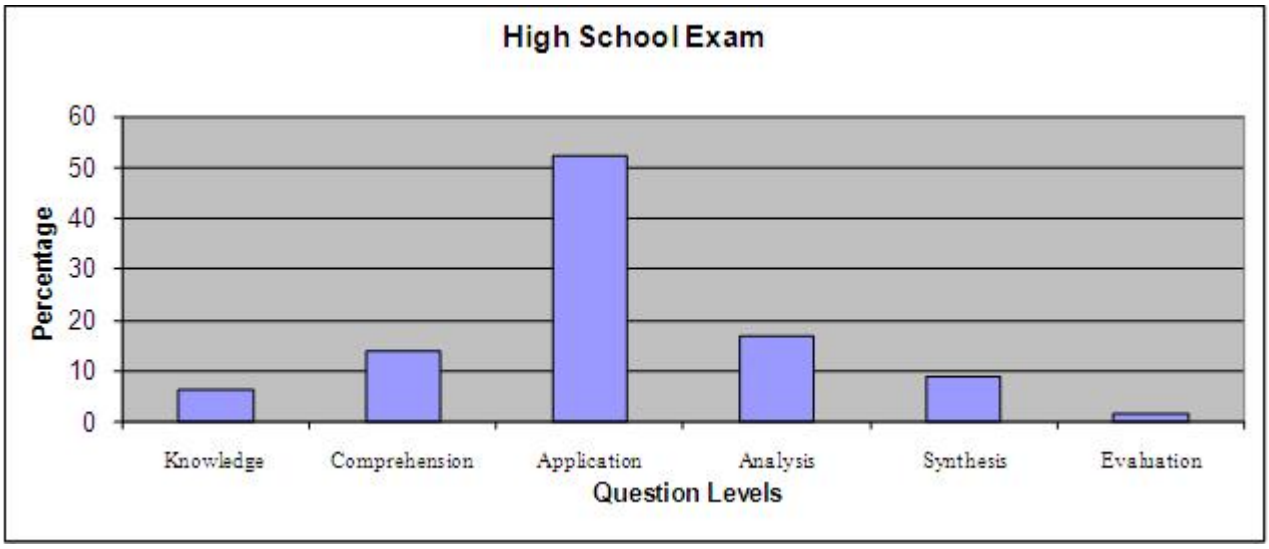

Figure 1 *Examining The School Physics Questions Levels According to Their Cognitive Level.*

OSS physics questions were examined according to their levels of cognitive progress and frequencies of cognitive level of questions were calculated and are presented in Table II as of years.

Table II *Distribution of The OSS Physics Questions According to The Cognitive Level as to Years.*

Years	**2000***		**2001***		**2002***		**2003***		**2004**		**2005**		**Total**	
Questins Level	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**
Knowledge	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Comprehension	0	0.0	0	0.0	1	5.3	0	0.0	3	15.7	0	0.0	4	3.5
Application	9	47.4	10	52.6	12	63.1	12	63.1	4	21.2	5	26.3	52	45.6
Analysis	10	52.6	7	36.8	5	26.3	5	26.3	9	47.4	13	68.4	49	43.0
Synthesis	0	0.0	2	10.6	1	5.3	1	5.3	0	0.0	0	0.0	4	3.5
Evaluation	0	0.0	0	0.0	0	0.0	1	5.3	3	15.7	1	5.3	5	4.4
Total	19		19		19		19		19		19		114	

*Azar(2005)

When researchers have examined the OSS questions between the years of 2000–2005, as seen in Table II, it is observed that 3.5 per cent were at comprehension level, 45.6 per cent at application level, 43.0 per cent at analysis level, 3.5 per cent at synthesis level and 4.4 per cent at evaluation level. Figure 2 shows graphically this percentage of OSS physics questions level.

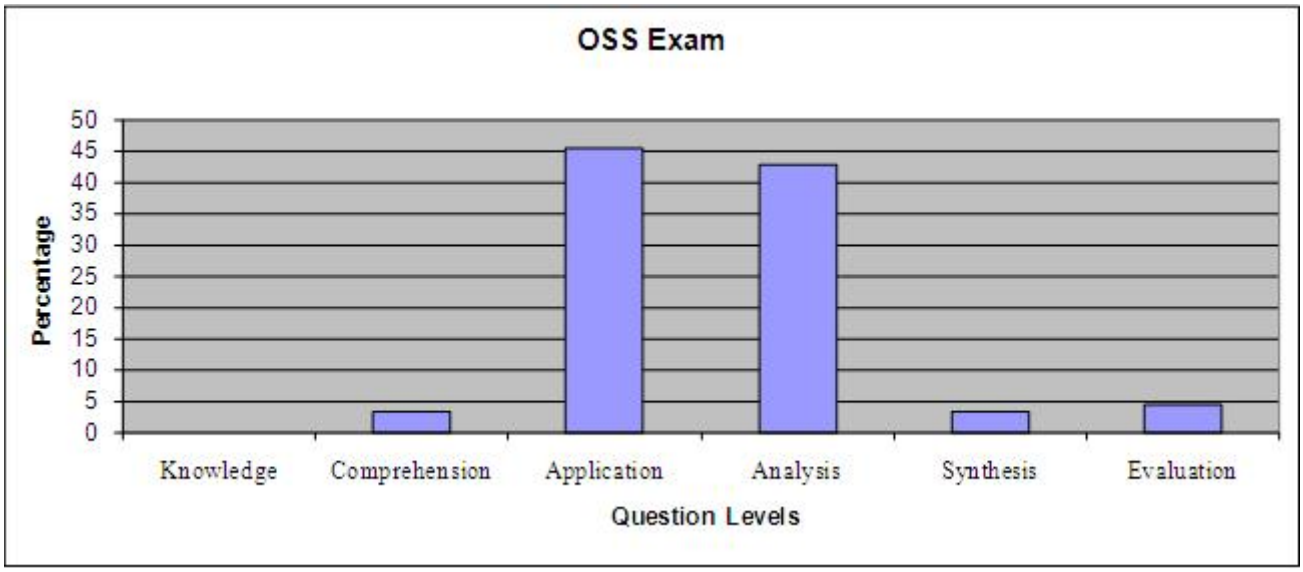

Figure 2 *Examining OSS Physics Questions Levels According to Their Cognitive Development Level*

An analysis was performed on OSS physics questions and high school physics questions according to levels of LOCS. The resuls are given in Table III.

Table III A*nalysis OSS Physics Questions and High School Physics Questions According to Levels of LOCS.*

	Knowledge		Comprehension		Application	
	f	%	f	%	f	%
High School Questions	55	6.3	122	13.9	458	52.3
OSS exam Questions	0	0.0	4	3.5	52	45.6
Total	55		126		510	

OSS physics questions and high school physics questions were analysed according to their levels of HOCS. The resuls are given in Table IV.

Table IV *Analysis OSS Physics Questions and High School Physics Questions According to Levels of HOCS.*

	Analysis		Synthesis		Evaluation	
	f	%	f	%	f	%
High School Questions	147	16.8	80	9.1	14	1.6
OSS exam Questions	49	43.0	4	3.5	5	4.4
Total	193		87		19	

Figure 3 shows graphically both percentage of high schools and OSS physics questions level.

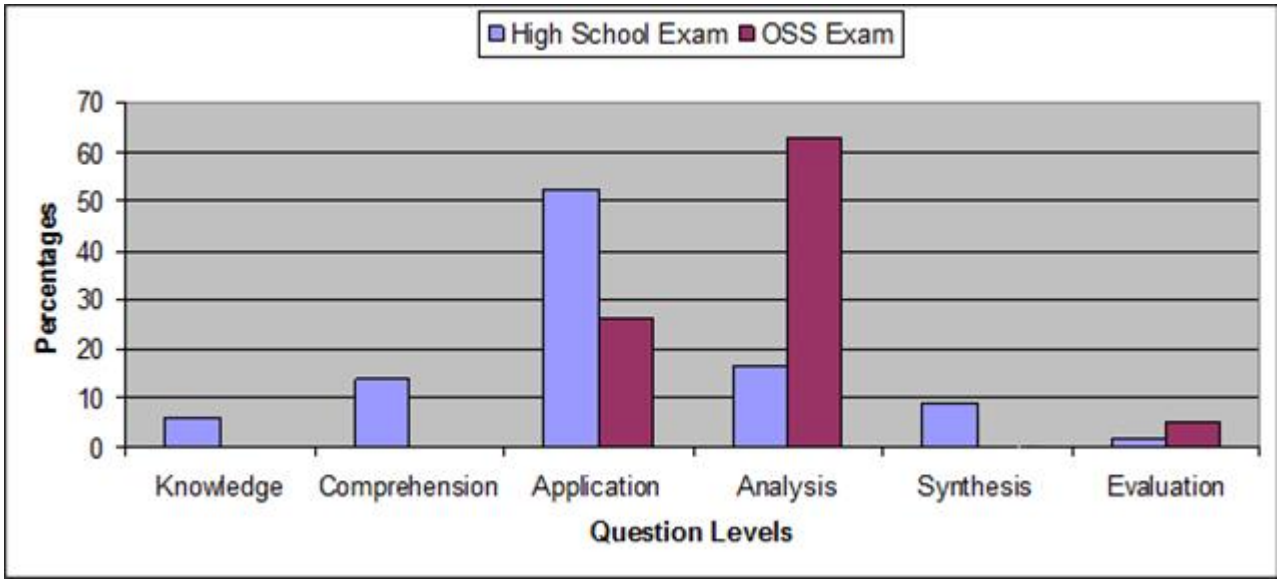

Figure 3 *The Levels of OSS (2005) and High School Physics Questions According to BT.*

Conclusion and Recommendations

According to the findings from this research, it can be understood that teachers involved in this study use questions at application level to determine students' achievements mostly. On the other hand, OSS exam comprising application and analysing cognitive level questions mostly (Table III, Tablo IV, Figure 3 and Azar, 2005).

Examination questions at application and lower levels of Bloom's Taxonomy were prepared to measure students' understanding of concepts, and applying level of physical 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 the application level, could be at knowledge or comprehension level. Also, researchers concluded that the questions examined were not suitable for students to perceive the basic concepts in physics, assimilate and interpret the physical events, and connect them with daily events and needs. This situation directs students to memorise the science concepts without understanding their real meaning.

Although the majority of the high school students take lower scores from the physics exams, these results 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-examination of concepts (Tezbaşaran, 1994). However, it has been reported that students who have high academic achievement in science lessons were not capable of dealing 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:

- Physics teachers should take into consideration students' cognitive (developmental) level. For to do it; they have to control their cognitive levels with short quizes which has to applicate in short durations (for exp. Every two weeks).

- 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 of planning and executing physics lessons, as well as preparing appropriate questions for various cognitive levels.

- Teachers should prepare exam questions in collaboration with their colleagues.

- Universities having specialists in physics education should give seminars and in-service courses on preparing physics lessons and questions.

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Appendix

Examples and Analysis of Questions

Researchers found that chemistry exam questions could be included 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.

Question: *Can you define what is an atom?*

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.

Question*: When a mechanical or electromagnetic wave goes from one medium to another, it undergoes a change in*

(a) amplitude only; (b) both speed and wavelength; (c) speed only;

(d) wavelength only.

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

Question: *Two identical conducting spheres, A and B, carry equal electric charge. They are separated by a distance much larger than their diameter and exert an electrostatic force F on each other. A third identical conducting sphere C is initially uncharged and far away from A and B. Sphere C is then brought briefly into contact with sphere A, then with sphere B, and finally removed far away. The electrostatic force between A and B is now*

(a) 3F=8 ; (b) F=2 ; (c) F=4 ; (d) F=16 .

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.

Question: *In the circuit below, we increase the resistance R_2.*

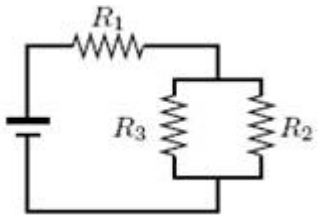
If I_j is the current through resistor R_j (j = 1; 2; 3), then

(a) I_1 and I_2 both increase;

(b) I_1 decreases and I_2 increases;

(c) I_1 and I_2 both decrease;

(d) I_1 increases and I_2 decreases.



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 synthesized or problems are solved.

Question: *Design an experiment which can be use to find friction constant of a surface?*

6- Evaluation. Questions at this level require students to make judgements about the value or merit 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.

Question: *Describe the effects of radioactivity on atoms. Explain your answer.*