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AN INVESTIGATION OF MATHEMATICS AND SCIENCE QUESTIONS IN ENTRANCE EXAMINATIONS FOR SECONDARY EDUCATION INSTITUTIONS IN TURKEY

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Abstract. *This study aimed to investigate LDE mathematics and science questions in terms of cognitive requirements (knowing, applying and reasoning) and structural properties (conceptual, algorithmic and graphical). The methodology adopted in the current study was document analysis. The results of this study indicated that LDE science assessments emphasized conceptual questions, while mathematics questions were more algorithmic in structure. In addition, both mathematics and science items de-emphasized graphical representations. In terms of their cognitive requirements, both science and mathematics LDE items neglected the cognitive domain of reasoning. Moreover, science questions mostly met in the intersection of knowing and conceptual, while mathematics questions often required students to apply knowledge on algorithmic questions. This study also concluded that the distribution of question requirements differed from year to year. Some implications regarding the results included that implementing a nation-wide assessment that neglects graphical representations contradicts the target goal of the mathematics and science programs in Turkey. The fact that the LDE was designed to determine the level of students' learning yet neglects reasoning questions also presents a contradiction to the curricular aims.*

Key words: *cognitive requirements, level determination examination, mathematics and science problems, structural properties.*

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Introduction

In today's world, governments allocate significant portions of their budget to education, raising expectations for educational efficiency, which is typically measured through variables such as classroom materials, quality of teaching, quality of educational environment, and students' beliefs. However, a great deal of emphasis has also been placed on determining students' achievement levels and comparing them from year to year (Berberoglu & Kalender, 2005). Responsible for preparing students for life, schools must teach and improve abilities like problem solving, critical thinking, and reading skills. A higher quality social life is promoted in an educational system that produces academically qualified individuals. While determining and evaluating achievement, countries usually assess their students' performance through standardized national and international examinations. Beside sharing the progress of their students and comparing their results at the international level, most countries, including Turkey, use the examinations for students transitioning to higher educational institutions, like middle school to high school or high school to college. The limited quota of highly regarded high schools causes intense rivalry, and systems have been established to identify the most excellent students.

The level determination examination (LDE) in Turkey is taken by eighth grade graduates seeking entrance to secondary education institutions. New teaching and learning programs at primary education institutions in Turkey became effective in 2004, and in the 2007-2008 academic year, a new system was applied to secondary education (MoNE, 2007a). The main purpose of the new system was to diminish the burden of the entrance examination and emphasize the importance of school itself. The old transition system relied heavily on a placement exam known as Secondary School Placement Exam (SSPE). This test caused anxiety for students and parents: evaluating three years of work through a 120-minute test was not in line with evaluation principles of Turkey's new teaching and learning program, and SSPE only covered some parts of the curriculum, prompting students to neglect uncovered subjects (MoNE, 2007b).

Many comparative studies have investigated examination systems of different countries. Recent studies investigated such factors as achievement in examinations (Incikabi, 2012; Koçkar & Gençöz, 2004), gender related issues (Garner & Engelhard, 1999; Lisle, Smith, & Jules, 2005), reasons for failure (Kim & Dembo, 2000; Kjellström & Pettersson, 2005; Lukacs & Tompa, 2002), and alignment between curriculum and examinations (Azar, 2005; Incikabi, 2011a, b; Liang & Yuan, 2008; Özmen, 2005; Saderholm & Tretter, 2008). The results of these studies address compatibility between content of examinations, curriculum coverage, and classroom instruction, since exam content shapes curriculum by affecting instruction. According to Kim (2005), differences in distribution of the contents in the assessment may cause poor performance, since students tend to disregard topics not emphasized by the examinations. Similarly, Kasanen and Raty (2008) have highlighted how national assessments affect student attitudes towards lessons by causing them to neglect project and performance activities and practice more on question types in the tests. Therefore, test specifications gain importance in evaluating education efficiency.

Test specification plays an important role in interpreting international comparisons based on test scores (Linn, 2003). Over or under-emphasis of certain cognitive processes or topics may be of advantage to some countries (Ben-Simon & Cohen, 2004). Item format also affects achievement (Ben-Simon & Cohen, 2004). Although early versions of international competencies included multiple choice items, current competencies employ a variety of formats (multiple choice, structured response, essay) due to a global demand for authenticity in testing and the desire to assess more complex, higher-order cognitive processes.

Recent studies of question types (Baştürk, 2011; Coştu, 2007, 2010; Erkan Erkoç, 2011; Kim & Pak, 2002; Maloney, 1994) have indicated that the intensity of graphical, conceptual, and algorithmic questions in examinations has changed classroom instruction by affecting both students as learners and teachers as instructors. The studies comparing students' performances on graphical, conceptual and algorithmic questions are very few in number compared to those focusing on the performance on conceptual and algorithmic questions (Coştu, 2007, 2010). Erkan Erkoç (2011) compared pre-service teachers' scores on conceptual, algorithmic, and graphical questions and indicated achievement on conceptual questions. Moreover, Coştu (2007) presented that eleventh-grade students performed better on conceptual chemistry questions than algorithmic and graphical chemistry questions. In another study Çoştu (2010) conducted with twelfth-grade students, algorithmic questions were the only question types with high scores. However, researchers need to initiate studies of national assessments of developing countries such as Turkey in terms of process requirements applied to international competencies and question structures.

Based on above literature, this study aimed to investigate LDE mathematics and science questions in terms of their cognitive requirements (knowing, applying and reasoning) and structural properties (conceptual, algorithmic and graphical). Being in line with the aim, the following research questions were to be sought for answers within the scope of the current study:

- How were various cognitive domains, structural properties, and their intersection distributed in the mathematics questions of LDE?
- How were various cognitive domains, structural properties, and their intersection distributed in the science questions of LDE?

Methodology of Research

In this study, document analysis was applied to LDE mathematics and science questions. Document analysis is known as an effective method for systematic review (Cohen, Manion, & Morrison, 2007).

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Sample of Research

The target was eighth grade LDE questions. A total of 160 questions from the years from 2009 to 2012 (80 for mathematics and 80 for science) were assessed. During the academic year 2007-2008, when the new mathematics program became effective, LDE was applied first to sixth and seventh graders. Thereafter, the secondary institutions selection and placement examination (SSPE) was replaced by the LDE examination for eighth graders.

Procedures

To interpret the LDE science and mathematics questions, four experts (two in the field of mathematics education and two in science examination) convened in two groups. All experts had familiarity and experience with the assessment and its framework. The expert panel members had an opportunity during the opening session to review, classify, and discuss several practice items in order to establish a common understanding of classification procedures. The researchers did not develop the coding themes: they were adapted from the literature (Coştu, 2007, 2010; Erkan Erkoç, 2011; Nakhleh, 1993; Nakhleh & Mitchell, 1993) and Trends in International Mathematics and Science Study (TIMSS) 2011 mathematics and science frameworks (Mullis, Martin, Ruddock, O'Sullivan, & Preuschoff, 2009). Table 1 presents the coding themes and related behaviors/explanations. During coding, the panel members coded each question independently. Coders classified items in the most detailed way possible—ideally, to the objective level, that in cases where items appear to address multiple themes (See Appendix A for sample LDE items and their codings). The initial coder agreement rate was 85 percent for mathematics and 87 percent for science. Each item for which the coders did not agree then was discussed until an agreement was reached on how the item would be coded.

Table 1. Coding categories used in the study.

Categories	Sub-categories	Behaviours
Structural Properties	Conceptual	Use conceptual information regarding the given condition in the question
	Algorithmic	Use algorithmic calculations to reach a numerical value
	Graphical	Interpret/retrieve information from a graphic
Cognitive Requirements (Mathematics)	Knowing	Recall, Recognize, Compute, Retrieve, Measure, Classify/Order
	Applying	Select, Represent, Model, Implement, Solve Routine Problems
	Reasoning	Analyze, Generalize, Synthesize/Integrate, Justify, Solve Non-routine Problems
Cognitive Requirements (Science)	Knowing	Recall, Recognize, Define, Describe, Illustrate with Examples, Demonstrate Knowledge of Scientific Instruments
	Applying	Compare, Contrast, Classify, Use Models, Relate, Interpret Information, Find Solutions, Explain
	Reasoning	Analyze, Synthesize, Integrate, Hypothesize, Predict, Design, Draw Conclusions, Generalize, Evaluate, Justify

Data Analysis

The frequency of cognitive domains and structures of the questions, broken down by examination year, were determined. The interpretation of the analyses is descriptive in nature.

Results of Research

The results of the current study were introduced with regards to the research problems.

LDE Science Questions

Table 2 shows the distribution of LDE science questions based on TIMMS cognitive domains and structural properties. The majority (about 89%) were structured conceptually, while 8 percent were graphical and only a few (about 3%) required algorithmic procedures. Among the cognitive requirements used, knowing and applying were mostly highlighted, with a slight emphasis on knowing. However, only one-tenth of the science questions required reasoning, which is the highest order of and the most complex cognitive domain of all.

Table 2. Distribution of LDE science questions based on TIMSS science cognitive domains and structural properties.

		f	%
Structural Properties	Conceptual	71	88.75
	Graphical	7	8.75
	Algorithmic	2	2.5
Cognitive Requirements	Knowing	38	47.5
	Applying	34	42.5
	Reasoning	8	10

Table 3 shows the distribution of dual qualifications (cognitive and structural) across the science questions in LDE. Almost half were included in the intersection of knowing and conceptual codes, while about one-third placed in the conceptual-applying combination. In addition, the questions in the intersection of conceptual-reasoning, probably the most selective questions in the examinations, covered only one-tenth of the all science items. Moreover, all graphical and algorithmic questions were limited to the cognitive requirement of applying.

Table 3. Distribution of cognitive domains and structural properties in LED science questions.

		Cognitive Requirements		
		Applying	**Knowing**	**Reasoning**
Structural Properties	Conceptual	25 (31.25%)	38 (47.5%)	8 (10.0%)
	Algorithmic	2 (2.5%)	0	0
	Graphical	7 (8.75%)	0	0

Figure 1 shows the percentage distribution of LDE science items across the years in terms of structural properties and cognitive domains. Among structural properties, only the 2010 LDE included algorithmic questions. Moreover, conceptual questions were the most represented (more than 75% per year). Among the cognitive domains, applying and knowing were the most emphasized. Although reasoning questions were included for the last three years, they were few in number compared to other domains.

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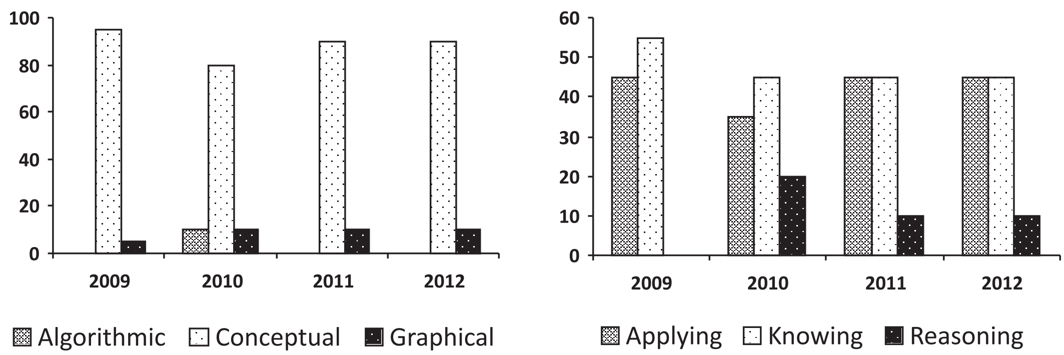

Figure 1. Percentage distribution of question types and cognitive domains from 2009 to 2012.

LDE science questions' coverage of learning areas as stated in the science curriculum in Turkey (MoNE, 2005b) is shown in Table 4. Physical events was the most covered learning area (about 33%) in the science part of the examinations. Except for one physical-event question coded as algorithmic-applying, all other physical-event questions were structured as conceptual questions focused on knowing and applying.

Table 4. Distribution of LDE items in terms of science content domains.

Learning Areas	Qualifications	Knowing	Applying	Reasoning	Total (%)
Physical Events	Algorithmic	-	1	-	26 (32.5)
	Graphical	-	-	-	
	Conceptual	14	11	-	
Matter and Change	Algorithmic	-	1	-	24 (30)
	Graphical	-	4	-	
	Conceptual	12	6	1	
Life and Living Beings	Algorithmic	-	-	-	24 (30)
	Graphical	-	3	-	
	Conceptual	7	8	6	
The Earth and the Universe	Algorithmic	-	-	-	6 (7.5)
	Graphical	-	-	-	
	Conceptual	5	-	1	

The learning areas Matter and Change and Life and Living Beings covered 30 percent each of all science questions. For Matter and Change, LDE questions highly emphasized conceptual questions; there were few graphical and algorithmic questions. Conceptual Matter and Change questions required knowing (mostly), applying (some), and reasoning (only one), whereas graphical and algorithmic questions only called for applying. Life and Living Beings included only conceptual (mostly) and graphical (few) questions. Although the conceptual questions had almost equal distribution among knowing, applying, and reasoning, the graphical questions solely incorporated applying. The Earth and the Universe was least covered (about 8%) and included only conceptual questions categorized under knowing and applying cognitive domains.

LDE Mathematics Questions

The distribution of LDE mathematics questions in terms of TIMSS cognitive domains and structural properties is shown in Table 5. Three quarters of mathematics questions were algorithmic, while 23 percent were conceptual, and only a few (about 3%) graphical. Among the cognitive requirements used during the solution process, more than half of the items (about 56%) required applying, whereas about one-third were categorized as knowing. As with the LDE science questions, few (about 13%) called on reasoning, the highest order of and most complex cognitive domain.

Table 5. Distribution of LDE mathematics questions based on TIMSS science cognitive domains and structural properties.

		f	%
Types of Questions	Algorithmic	60	75
	Conceptual	18	22.5
	Graphical	2	2.5
Cognitive Domain	Applying	45	56.25
	Knowing	25	31.25
	Reasoning	10	12.5

Table 6 shows the percentage distribution of qualifications (cognitive and structural) across the mathematics questions. Almost half of the LDE mathematics items (about 54%) were categorized in the intersection of algorithmic and applying, while a few placed in algorithmic-knowing and conceptual-knowing, each at 15 percent. In addition, questions in the intersection of conceptual-reasoning, probably the most selective questions, covered only about 6 percent of all mathematics items. Moreover, no mathematics item with graphical structure required reasoning.

Table 6. Distribution of cognitive domains and structural properties in LDE mathematics questions.

		Cognitive Requirements		
		Applying	**Knowing**	**Reasoning**
Structural Properties	Algorithmic	43 (53.75%)	12 (15%)	5 (6.25%)
	Conceptual	1 (1.25%)	12 (15%)	5 (6.25%)
	Graphical	1 (1.25)	1 (1.25%)	0

The percentage distribution of LDE mathematics items across the years in terms of structural properties and cognitive domains was presented in Figure 2. Among the structural properties across all years, algorithmic questions were most represented (more than 60% per year). Although conceptual questions were included in each LDE, they were few in number compared to algorithmic questions. On the other hand, few algorithmic questions were included in LDE examinations in 2009 and 2010. Among the cognitive domains, applying was the most emphasized across the years, followed by knowing. Similar to the science section, LDE mathematics sections also de-emphasized the reasoning questions that require a higher order of thinking skills, such as generalizing, justifying, and analyzing.

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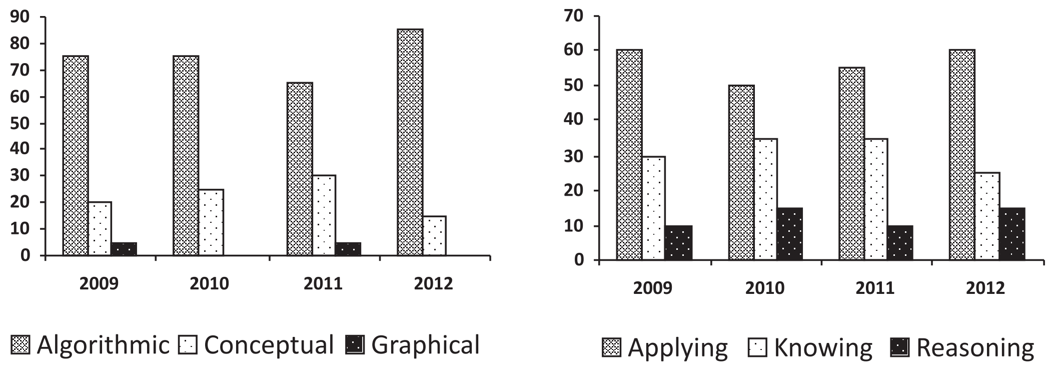

Figure 2. Percentage distribution of question types and cognitive domains from 2009 to 2012.

Table 7 shows the percentage distribution of LDE mathematics questions based on the learning areas as defined by the curriculum in Turkey (MoNE, 2005a). Measurement was the most covered learning area (about 33 percent). Except for two questions coded as conceptual-knowing and conceptual-reasoning, all others were algorithmic questions focused on applying (mostly), reasoning (a few), and knowing (a few) cognitive requirements.

Table 7. Distribution of LDE items in terms of mathematics content domains.

Learning Areas	Qualifications	Knowing	Applying	Reasoning	Total (%)
	Algorithmic	1	21	2	
Measurement	Graphical	-	-	-	26 (32.5)
	Conceptual	1	-	1	
	Algorithmic	1		1	
Geometry	Graphical	-	-	-	14 (17.5)
	Conceptual	7	1	4	
	Algorithmic	5	6	-	
Numbers	Graphical	-	-	-	14 (17.5)
	Conceptual	3	-	-	
	Algorithmic	-	12	2	
Algebra	Graphical	-	-	-	14 (17.5)
	Conceptual	-	-	-	
	Algorithmic	5	4	-	
Probability and Statistics	Graphical	1	1	-	12 (15)
	Conceptual	1	-	-	

Geometry, Numbers, and Algebra covered 18 percent of all mathematics questions. Geometry was the only learning area that emphasized conceptual questions. There were a few algorithmic geometry questions, while no geometry question included use of graphical representations. Conceptual geometry questions required knowing (mostly), reasoning (some), and applying (only one), whereas algorithmic questions required knowing and reasoning. Numbers included mostly algorithmic questions and some conceptual questions. Although the algorithmic questions had almost equal distribution across knowing and applying, the conceptual questions solely called for knowing. Algebra included only algorithmic questions that required applying (mostly) and reasoning (few). Probability and Statistics was the least covered (15 percent) and included mostly algorithmic questions with a few graphical and conceptual questions. The algorithmic and graphical questions were categorized in knowing and applying, while the conceptual question required knowing.

Discussion

This study aimed to provide an analysis of the mathematics and science items included in LDE assessments in Turkey based on (a) cognitive requirements (knowing, applying and reasoning) as defined in TIMSS 2011 and (b) structural properties (algorithmic, conceptual and graphical). The study was limited to 160 questions from the LDE (80 in mathematics, 80 in science).

An overview of results is provided in Table 8. In terms of distribution of structural properties, LDE science assessments emphasized conceptual questions, while mathematics questions were more algorithmic in structure. Both mathematics and science items de-emphasized graphical representations. Van Dyke and White (2004) have stated that graphical interpretation supports abstract thinking skills. Standard examinations such as LDE need to be designed to involve reading, forming, and interpreting graphics (Forster, 2004). A number of studies indicate that students have common deficiencies in these areas (Ates & Stevens, 2003; Beichner, 1994; Berg & Smith, 1994; Kekule, 2008; McDermott, Rosenquist, & van Zee, 1987; Saglam-Arslan, 2009). For example, in his two-stage study that was first performed with 480, then 700 students, Kekule (2008) discovered that students describe graphics as an outline or picture of reality. Berg and Smith (1994) also reported that students perceive graphics as a picture instead of a symbolic depiction of knowledge.

Table 8. Overview of the results.

	Science Questions		Mathematics Questions	
	Emphasized	De-emphasized	Emphasized	De-emphasized
Structural Properties	Conceptual	Graphical Algorithmic	Algorithmic	Graphical
Cognitive Requirements	Knowing Applying	Reasoning	Applying	Reasoning
Dual Qualifications	Conceptual-knowing Conceptual-applying	The others	Algorithmic- applying	The others
Distribution Across Time	Conceptual Knowing Applying	Graphical Algorithmic Reasoning	Algorithmic Applying Knowing	Conceptual Graphical Reasoning

Both science and mathematics LDE items neglected the cognitive domain of reasoning, which requires that students analyze, generalize, synthesize/integrate, justify, or solve non-routine problems (Mullis et al., 2009). Science questions mostly met in the intersection of knowing and conceptual, while mathematics questions often required students to apply knowledge on algorithmic questions. These differences in cognitive balances may affect student performance in other competencies (such as TIMSS) that include more reasoning questions (Ben-Simon & Cohen, 2004). For instance, Çil and Çepni (2012) observed low performance of Turkish students on questions requiring correlational cognitive and hypothetical thinking abilities.

This study found that the distribution of question requirements differed from year to year. Some representation types (such as conceptual in science and algorithmic in mathematics) existed in each assessment, while some (algorithmic in science and graphical in mathematics) were habitually neglected. A similar misbalance was also evident in the distribution of cognitive requirements by each assessment. For example, questions requiring reasoning were not included in 2009 LDE science items and were de-emphasized over the years.

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Conclusions

A general overview of the research findings might lead a conclusion that LDE does not assess students' knowledge in terms of the aspects that were investigated in this study. Taking into account of the complexity of learning process, it is a compulsory need for assessments to interrogate students' learning from different angles. Since, assessments that highlight only one cognitive procedure or consist of one item type would affect classroom instruction, shape the curriculum (Kim, 2005) and cause students' neglecting the other cognitive processes.

Upon consideration of the results of the study, some implications should be taken into account by policy makers and test/curriculum designers. Following the reform movement, the adjusted curriculum in Turkey emphasizes using multiple representations in teaching (MoNE, 2005a, 2005b); however, implementing a nation-wide assessment that neglects graphical representations contradicts the target goal. Moreover, the science and mathematics programs in Turkey put great emphasis on improving students' problem solving and critical, creative, and reflective thinking in line with the behaviors of the reasoning domain as used in this study. The fact that the LDE was designed to determine the level of students' learning yet neglects reasoning questions also presents a contradiction to curricular aims.

The results of this study are beneficial to researchers who investigate national assessments, as well policymakers and curriculum designers who interpret the results of such exams. Further studies investigating the test-curriculum-teaching triangle will reinforce the findings of the current study.

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Appendix A

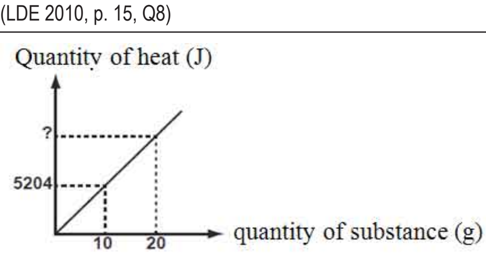
Sample LDE Items

Table 9. Sample codes for selected LDE science items

<table>
<tr><th rowspan="2">Items</th><th colspan="2">Qualification</th></tr>
<tr><th>Structural Properties</th><th>Cognitive Requirements</th></tr>
<tr><td>Some concepts regarding Natural processes and their definitions are as follows:
<table>
<tr><td>• Aftershock
• Foreshock
• Intensity
• Magnitude</td><td>Concepts</td></tr>
<tr><td>• The degree of damage on buildings and people caused by the earthquake.
• Small earthquakes occurring before the main shock.
• The value of the ground motion measured by seismo-graph.</td><td>Definitions</td></tr>
</table>
Which concept does remain outside when the concepts are paired with their definitions?

A) Aftershock B) Foreshock C) Intensity D)Magnitude
(LDE 2012, p. 15, Q7)</td><td>Conceptual</td><td>Knowing</td></tr>
<tr><td>The table shows the running hours (during a month) of a vacuum cleaner having 2000 watt power and an iron having 2200 watt power:
<table>
<tr><th></th><th colspan="2">The running times (hour)</th></tr>
<tr><th></th><th>vacuum cleaner</th><th>iron</th></tr>
<tr><td>1st week</td><td>4</td><td>2</td></tr>
<tr><td>2nd week</td><td>5</td><td>-</td></tr>
<tr><td>3rd week</td><td>2</td><td>5</td></tr>
<tr><td>4th week</td><td>-</td><td>3</td></tr>
</table>
According to table, what was the total electric energy (kwh) consumed by the vacuum cleaner and the iron during this month?

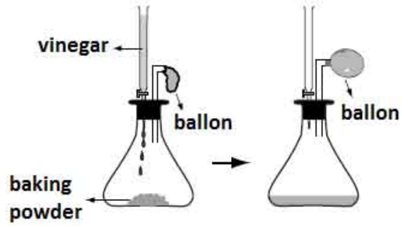
A) 21 B) 22 C) 42 D) 44

(LDE 2010, p. 15, Q8)</td><td>Algorithmic</td><td>Applying</td></tr>
<tr><td>

The graph shows the change in the evaporation point with regard to the quantity of a pure substance that is at the point of boiling temperature. What is the numerical value of "?" given in the graph?

A) (5204/10)·20 B) (5204/10+20)
C) (5204/20) ·10 D) 5204·(10+20)

(LDE 2010, p. 15, Q14)</td><td>Graphical</td><td>Applying</td></tr>
</table>

<table>
<tr>
<td>Gülay, conducting the experiment given below, records her observations and notes the results.


My experiment:
I have added vinegar on baking powder.
My observations:
Balloon was bulged, cap got warmed, and liquid was obtained in the cap.
My results:
....

In this experiment, what result can Gülay reach?
A) Vinegar and baking powder preserved their chemical structure.
B) The amount of baking powder did not change.
C) The vinegar did not react with the baking powder.
D) All liquid that was obtained was vinegar.

(LDE 2010, p. 15, Q10)</td>
<td>Conceptual</td>
<td>Reasoning</td>
</tr>
</table>

Table 2. Sample codes for selected LDE mathematics items.

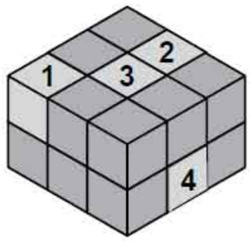
<table>
<tr><th rowspan="2">Items</th><th colspan="2">Qualification</th></tr>
<tr><th>Structural Properties</th><th>Cognitive Requirements</th></tr>
<tr>
<td>Table: Basketball players’ average points per game and average point range
<table>
<tr><th>Name of the player</th><th>Average point per game</th><th>Point range</th></tr>
<tr><td>Cemil</td><td>17</td><td>3</td></tr>
<tr><td>Alper</td><td>17</td><td>15</td></tr>
<tr><td>Hasan</td><td>12</td><td>15</td></tr>
<tr><td>Ali</td><td>12</td><td>3</td></tr>
</table>
Table shows the average points and point range of the players who played the same number of game last year. Which player did score more points with the least changing amount?

Ali B) Hasan C) Alper D) Cemil

(LDE 2009, p. 12, Q16)</td>
<td>Graphical</td>
<td>Knowing</td>
</tr>
<tr>
<td>A bakery sold a total number of 144 patty and pastry during the day and made 144TL profit from the sell. How many pastries have been sold if the price for a patty and a pastry is 50 Kr and 75 Kr, respectively?

80 B) 64 C) 58 D) 44

(LDE 2009, p. 13, Q19)</td>
<td>Algorithmic</td>
<td>Applying</td>
</tr>
</table>

 Taking out which cube do not cause change in the surface area of the solid given in the figure that consists of unit cubes. 1 B) 2 C) 3 D) 4 (LDE 2011, p. 11, Q13)	Algorithmic	Reasoning
A person who investigates which color car has been mostly sold found out that white cars were preferred the most. What measure was utilized to reach this conclusion? Median B) Mode C) Mean D) Range (LDE 2011, p. 11, Q16)	Conceptual	Knowing

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