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| Research Article / Araştırma Makalesi |

Analysis of the Mathematics Questions in 2021 High School Entrance Exam According to Learning Areas and the MATH Taxonomy

2021 Liselere Giriş Sınavı (LGS) Matematik Sorularının Öğrenme Alanlarına ve MATH Taksonomisine Göre Analizi

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Keywords

1.Mathematics Education
2.MATH Taxonomy
3.Learning area
4.High School Entrance Exam (LGS)

Anahtar Kelimeler

1.Matematik Eğitimi
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Abstract

Purpose: The study was carried out to examine the mathematics questions in the 2021 High School Entrance Exam (LGS) regarding learning areas and the MATH Taxonomy's groups and categories for cognitive processes. In addition, math questions in 2018, 2019, and 2021 LGS were compared based on learning areas and MATH taxonomy.

Design/Methodology/Approach: Learning areas were coded as "learning areas" and "linked learning areas." In the context of cognitive processes, the exam questions were classified according to the groups and categories of the MATH Taxonomy developed explicitly for mathematics. The research was designed as document analysis, one of the qualitative research designs.

Findings: It was found that the questions in 2021 LGS were taken from all learning areas of secondary school mathematics and the number of questions was compatible with the learning areas in the curriculum. It was seen that many questions addressed more than one learning area, and the learning areas were related to each other. When the questions in 2021 LGS were examined in the context of cognitive processes according to the MATH taxonomy, it was found that there were questions from groups B and C, mostly C, and no questions from group A. The questions in 2018, 2019, and 2021 LGS were also compared in this study. It was found that the learning areas generally had a similar distribution, and when compared in terms of MATH taxonomy, the questions' level increased as the years progressed.

Highlights: MATH Taxonomy, explicitly developed for mathematics, is vital in examining mathematics questions according to cognitive processes. It was observed that the questions were not directed to a single learning area and that the learning areas were related to each other. Coding in the form of a learning area-linked learning area is essential.

Öz

Çalışmanın amacı: Bu çalışma, 2021 Lise Giriş Sınavında (LGS) yer alan matematik sorularının öğrenme alanları ve MATH Taksonomisinin bilişsel süreçlere yönelik grupları ve kategorileri açısından incelenmesi amacıyla yapılmıştır. Ayrıca 2018, 2019 ve 2021 LGS'de yer alan matematik soruları öğrenme alanları ve MATH taksonomiye dayalı olarak karşılaştırılmıştır.

Materyal ve Yöntem: Öğrenme alanları "öğrenme alanı" ve "bağlantılı öğrenme alanı" olarak kodlanmıştır. Bilişsel süreçler bağlamında, sınav soruları matematik için özel olarak geliştirilen MATH Taksonomisinin gruplarına ve kategorilerine göre sınıflandırılmıştır. Araştırma nitel araştırma desenlerinden doküman incelemesine dayalı olarak yürütülmüştür.

Bulgular: 2021 LGS'deki soruların ortaokul matematiğinin tüm öğrenme alanlarından alındığı ve soru sayılarının öğretim programındaki öğrenme alanları ile uyumlu olduğu tespit edilmiştir. Birçok sorunun birden fazla öğrenme alanına hitap ettiği, öğrenme alanlarının birbiriyle ilişkili olduğu görülmüştür. 2021 LGS'de yer alan sorular MATH taksonomisine göre bilişsel süreçler bağlamında incelendiğinde, B ve C gruplarından çoğunlukla C olmak üzere soruların olduğu, A grubundan ise hiç soru bulunmadığı tespit edilmiştir. Bu çalışmada 2018, 2019 ve 2021 LGS arasında karşılaştırma da yapılmış olup, öğrenme alanlarının genel olarak benzer bir dağılıma sahip olduğu; MATH taksonomisi açısından karşılaştırıldığında ise yıllar geçtikçe soruların seviyesinin arttığı sonucuna ulaşılmıştır.

Önemli Vurgular: Matematik sorularının bilişsel süreçlere göre incelenmesinde matematiğe özel olarak geliştirilen MATH Taksonomi kullanımının önemli bir rolü vardır. Soruların tek bir öğrenme alanına yönelik olmadığı, öğrenme alanlarının birbiri ile ilişkili olduğu görülmüştür. Öğrenme alanı-ilişkili öğrenme alanı şeklindeki kodlamanın önemli olduğu düşünülmektedir.

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INTRODUCTION

In order to measure how many education and training goals are reached, it is necessary to measure and evaluate the behavioral changes in students (Baykul, 2000). The National Council of Teachers of Mathematics (NCTM, 2000) defines evaluation as a tool for improving students' learning and a valuable tool for making teaching decisions. The evaluation process is monitored by computer programs and by executive controls on individuals (Woolfolk, 1993).

Evaluation can be formative and summative. Formative evaluation is a planned process designed to constantly check students' comprehension of educational activities (Popham, 2008). On the other hand, summative evaluations are cumulative assessments that produce a specific score, such as final exams or standardized tests. In sum, while summative evaluation gives a snapshot of what the student knows at a particular moment, formative assessment is like a movie that presents the active status of the student's thinking and reasoning.

The measurement and evaluation process has a significant role in monitoring, controlling, and improving the functioning of an education system (Demirel, 2006). Measurement and evaluation are essential for education in measuring the students' success and the functioning of the teaching methods (Ministry of National Education, 2018). In mathematics teaching, measurement and evaluation contribute to determining the targeted learning outcome level, revealing misconceptions, and increasing performance (Alkan, 2008). Exams are the primary measurement tools used in determining these characteristics of the education system in Turkey. In Turkey, the measurement and evaluation process is carried out in two ways, locally and centrally (Çepni et al., 2003).

The Ministry of National Education and OSYM (Student Selection and Placement Center) conducts the central assessment and evaluation process to place students in a higher education institution. Until 1997, the exams were offered as OGES (transition system to secondary education institutions). These exams were offered under different names over the years to the students for the transition from secondary school to high schools, such as Secondary Education Institutions Exam (OKS) until 2009, the Placement Exam (SBS) until 2013, and the Exam for Transition from Basic to Secondary Education (TEOG) until 2017. The High School Entrance Exam (LGS) has been used since 2018.

The quality of the questions is essential for the central exams to be successful. The variations in the cognitive levels of the questions are the leading factor affecting this quality. Bloom's Taxonomy is the most widely used taxonomy to determine the cognitive level (Bloom, 1956). According to Bloom's taxonomy, mental development consists of the following six levels, from simple to complex: knowledge, comprehension, application, analysis, synthesis, and evaluation (Tan & Erdoğan, 2004). Bloom's taxonomy was updated under "Revised Bloom's Taxonomy" to address the deficiencies in taxonomy and meet the needs of developing education programs. In the revised taxonomy, the levels "evaluation" and "synthesis" changed places, and the hierarchy between all the levels was removed. Although Bloom's taxonomy can be used in any field, Smith et al. (1996) developed a new taxonomy only for the mathematics course using an approach different from that of Bloom. This taxonomy is the Mathematical Assessment Task Hierarchy (MATH) (Smith et al., 1996). The MATH taxonomy was developed to correctly classify the mathematical questions and test the skills and concepts (Smith, 2010). The MATH taxonomy supports deep learning and enables us to understand whether students learn superficially or deeply. This can be realized by asking questions in line with the categories in the MATH taxonomy (Smith et al., 1996). The MATH taxonomy provides a control to determine whether the student's knowledge, skills, and abilities are measured (Wood et al., 2002). The evaluation focuses primarily on exams. While a narrow skill area is often measured in exams, the MATH taxonomy aims to broaden the skill areas assessed (Smith et al., 1996). A broader and deeper learning experience can be offered to students via the MATH taxonomy (Ball et al., 1998). The MATH taxonomy allows to determine the students' levels of mathematical knowledge and broaden their learning areas. Math taxonomy consists of three main groups and eight subcategories (Table 1).

Table 1. Groups and categories of each group in MATH Taxonomy

Group A	Group B	Group C
A1 - Factual Knowledge and Fact Systems	B1 - Information Transfer	C1 - Justifying and Interpreting
A2 - Comprehension	B2 - Application in New Situations	C2 - Implications, Conjectures, and Comparisons
A3 - Routine Procedures		C3 - Evaluation

Group A requires superficial learning, whereas groups B and C require deep learning (Wood et al., 2002).

Categories in Group A: A1 - Factual Knowledge and Fact Systems: This category includes remembering a formula, knowledge, or specific definition. A2 - Comprehension: This category includes recognizing the examples and counterexamples of an objective or function related to mathematics and comprehending the importance of symbols in formulas. A3 - Routine Procedures: This category includes the exercises, sample questions, and daily routine procedures done by students in the classroom.

Categories in Group B: B1 - Information Transfer: This category includes the ability to transform information from one format to another, from verbal to quantitative, from quantitative to verbal, and transform quantitative data to graphic one. B2 - Application in New Situations: This category refers to the ability to choose and apply appropriate methods or information in new situations.

Categories in Group C: C1 - Justifying and Interpreting: This category refers to the student's ability to justify or interpret a result given by someone else or reached by the student. C2 - Implications, Conjectures, and Comparisons: This category covers the student's ability to make conjectures and comparisons about a given situation or a situation found by the student, to justify or prove it, and to draw implications about it. C3 - Evaluation: This category refers to the ability to judge the value of data and materials given for a purpose based on specific criteria (D'Souza & Wood, 2003).

In this study, the groups and categories of the MATH taxonomy were referenced in determining the cognitive levels of the mathematics questions in LGS-2021.

Uğurel et al. (2012) analyzed the mathematics questions in OKS, SBS, and TIMSS using the framework of MATH taxonomy. They reported that the categories with the highest number of questions were B1 in SBS-6, A3 in SBS-7, B1 and A3 in SBS-8, B2 in OKS, and A3 in TIMSS. In their study examining the math questions in the 2013 Spring ALES (Academic Personnel and Postgraduate Education Entrance Exam) according to the MATH taxonomy, Aliustaoğlu and Tuna (2016) reported that the highest number of questions was from the category A3 in the Quantitative-1 Test and the category C2 in the Quantitative-2 Test. On the other hand, Esen (2018) examined the mathematics questions in ALES from 2006 to 2013 according to the groups and categories in the MATH taxonomy and the mathematics learning areas and asserted that the categories B1 and B2 had the highest number of questions and the group A had the least number of questions. İltuş (2019) used the MATH taxonomy to examine the mathematics questions in the Teaching Subject Matter Knowledge Test of KPSS (Public Personnel Selection Exam) since 2013 and reported that the majority of the questions were from the group A. Gürbüz (2021) analyzed the limit-continuity and derivative-integral questions in the university entrance exams in Turkey between 1966 and 2019 according to the MATH taxonomy and reported that the limit-continuity and derivative-integral questions were asked the most from the group A and the least from the group C.

Similar to the studies by İltuş (2019) and Gürbüz (2021), Aygün et al. (2016) examined 939 math questions in the 6th, seventh, and 8th-grade exams according to the MATH taxonomy. They asserted that the majority of the questions were from group A (routine procedures and basic skills), there were fewer questions from group B (higher-order thinking skills), and there were almost none from group C (the highest-order thinking skills). Moreover, Gürbüz (2021) asserted that, as the year progressed, a decrease was observed in the number of questions from group A and an increase in the number of questions from groups B and C.

In the study carried out by Erdoğan (2020), it was noted that the questions in the mathematics subtests of 2016-2017 TEOG were mostly from the category A3 (Routine Procedures) of the MATH taxonomy. Erdoğan (2020) also reported that the correct answers were mainly in group A and the least correct answers were in group C. In her master's thesis, Farımaz (2020) compared 2018 and 2019 LGS questions as cognitive processes according to the groups and categories of the MATH taxonomy and concluded that 2018-LGS contained the most questions from the category C2, while the 2019-LGS from the category B2. She also reported that in 2018-LGS, the percentage of the questions from group A was close to that of those from group C, and the percentage of the questions from group B was low. In 2019-LGS, the percentage of the questions from group B was the highest, followed by groups A and C, in order of percentage. As for the distribution of the questions by learning areas, it was reported that the 2018 LGS contained questions mainly from the learning area "Geometry and Measurement" and no questions from the learning area "Data Processing."

On the other hand, the 2019 LGS was reported to contain questions from all learning areas. When the literature was examined, some studies were related to using MATH taxonomy at the undergraduate level (Bennie, 2013; Blanco et al., 2009). This study also examined the textbooks according to the MATH taxonomy and reported that the 2017-2018 mathematics textbook included questions from category A1 and the 2018-2019 mathematics textbooks mostly from category A3. In addition, Wong and Kaur (2015) examined mathematics questions in Singapore secondary schools within the scope of the MATH taxonomy. At the end of the research, they concluded that the mathematics questions in secondary schools were mainly asked in group A and category A3 among group A. On the other hand, it was observed that fewer questions were asked from the groups B and C.

With the advent of twelve-year-compulsory education in the 2012-2013 academic year, the Ministry of National Education (MoNE) revised the mathematics curriculum (Evirgen, 2014). The objective of this revised curriculum was to make students gain skills in information and communication technologies, psychomotor and affective skills, and reasoning and mental skills (MoNE, 2013). This objective was pursued in the curriculum revised in the 2018-2019 academic year. The new curriculum was created to provide meaningful and permanent learning, enable the use of metacognitive skills, and design education within the framework of skills (MoNE, 2018). The Secondary School Mathematics Curriculum includes five learning areas: numbers and operations, algebra, geometry and measurement, data processing, and Probability. LGS covers only the questions from the 8th-grade mathematics. Topics of the learning areas in 8th-grade mathematics are as follows. i. Numbers and Operations: factors and multiples, exponential expressions, and square root expressions; ii. Algebra: algebraic expressions and identities, linear equations, and inequalities; iii. Geometry and Measurement: triangles, congruence and similarity, transformation geometry, and geometric bodies; iv. Data Processing: data analysis; and v. Probability: the Probability of occurrence of simple events.

At this grade, there are 52 learning outcomes in these learning areas, and the time allocated for them is 180-course hours. When the curriculum was analyzed in terms of the learning outcomes and the time allocated for them, their distribution was found to be as follows: Numbers and Operations (Learning outcome: 30.77%; Recommended time: 27.78%); Algebra (Learning outcome: 25%; Recommended time: 30.56%); Geometry and Measurement (Learning outcome: 30.77%; Recommended time: 28.33%); Data Processing (Learning outcome: 3.85%; Recommended time: 6.67%); Probability (Learning outcome: 9.62%; Recommended time: 6.67%) (MoNE, 2018).

Research Questions

Research Questions of the study are as follows:

1. What is the distribution of the math questions in 2021 LGS by learning areas?
2. What are the distributions of the math questions in 2018, 2019, and 2021 LGS by learning areas?
3. What is the distribution of the math questions in 2021 LGS by the groups and categories in the MATH taxonomy?
4. What are the distributions of the math questions in 2018, 2019, and 2021 LGS by the groups and categories in the MATH taxonomy?

Purpose of the Study

The purpose of this study was to analyze the math questions in 2021 LGS by the MATH taxonomy and learning areas and to compare the results with those of 2018 and 2019.

Significance of the Study

Exams are expected to include questions that measure different levels of thinking and serve their purpose (Aliustaoğlu & Tuna, 2016). The questions prepared for an exam should enable students to think at a higher level. The MATH taxonomy was designed for the field of mathematics education in order to develop high-order thinking skills (Dost et al., 2011). New-generation questions are asked in LGS (Atasoy, 2019; Ünal, 2019) to ensure a high-order mental process. In the present study, the new generation questions were analyzed using the MATH taxonomy and attempted to determine whether they involve a high-order mental process. Therefore, this study is essential for the exams to be prepared in the coming years. This study is also essential in providing information to LGS question writers, teachers, and students about the structure of new-generation questions. The learning areas examined the distribution of LGS questions in this study. By doing so, a tool was offered for curriculum writers to see the accordance of the exams with the curriculum. Moreover, the analyzes in this study include the place of questions in more than one learning area, which helps to see the relationship between learning areas.

Limitations and Assumptions of the Study

• The questions in the study are limited to those in 2021 LGS math exam.

• The study was limited to the groups and categories in the MATH taxonomy and the learning areas in the secondary school math curriculum.

• In LGS 2020, the questions were only from the learning outcomes of the 1st semester due to the onset of the COVID-19 pandemic; so, LGS 2020 was not included in the comparison.

• The questions in LGS 2018 and 2019 were classified based on Farımaz's (2020) master's thesis and compared with those in LGS 2021 in terms of learning areas.

METHOD

The document analysis method was used in this descriptive study to analyze the mathematics questions in the High School Entrance Exam (LGS), administered to 8th-grade students in 2021, according to the learning areas and cognitive processes. Document analysis is the examination and analysis of documents containing information about a phenomenon at hand (Yıldırım & Şimşek, 2013).

The research data consisted of the mathematics questions in the quantitative section of 2021 LGS. These questions were obtained from the web page of the General Directorate of Measurement, Evaluation, and Examination Services, Ministry of National Education. There were 20 “new generation questions” in the exam, and exam booklet A was used in the study.

In the study, the distribution of the questions was revealed according to the learning areas. Since the questions included more than one learning area, the coding was done as "learning area" and "linked learning area." The questions were examined regarding cognitive processes using the groups and categories in the MATH taxonomy. According to the reliability formula of Miles-Huberman (1994), the researchers’ opinions showed an agreement of 85%, 90%, and 85% in pairs. The researchers conducted joint studies on each coding that lacked a consensus, ultimately achieving a consensus.

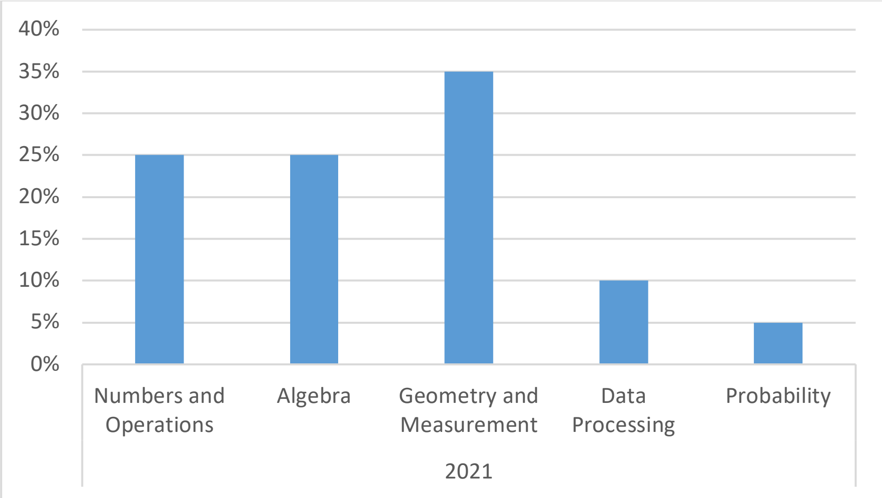
Since the research is based on document analysis, no ethics committee approval was required.

RESULTS

This part of the study presents the results obtained from the data of the study.

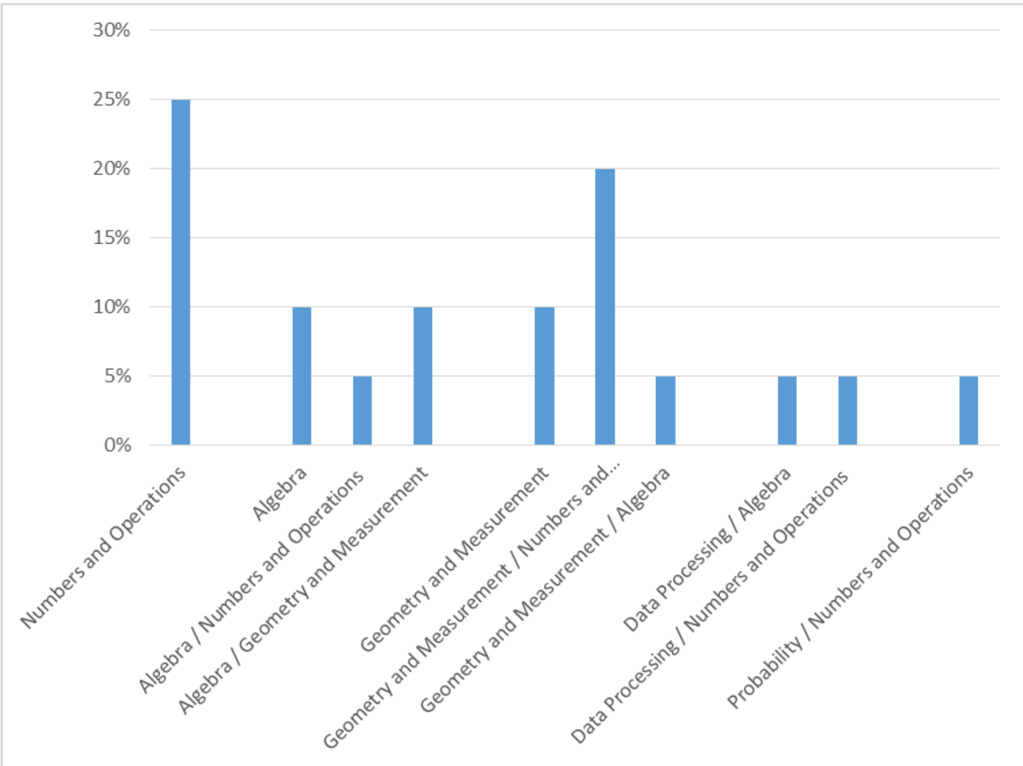
Analysis of the Data Associated with the First Sub-Question

Graph 1 shows the results for the first sub-question of the research, that is, “What is the distribution of the math questions in 2021 LGS by learning areas?”



Graph 1. Percentage distribution of the math questions in 2021 LGS by learning areas

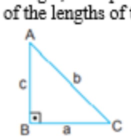
As can be seen in Graph 1, the learning area “geometry and measurement” (35%) was found to have the highest number of questions in 2021-LGS, followed by “numbers and operations” (25%), “algebra” (25%), “data processing” (10%), and “probability” (5%). Graph 2 shows the distribution of the mathematics questions in 2021 LGS by learning areas and linked learning areas. If the question is directly related to a single learning area, it is coded with that learning area. However, if it was related to another learning area linked to a specified learning area, then it was coded with two learning areas.

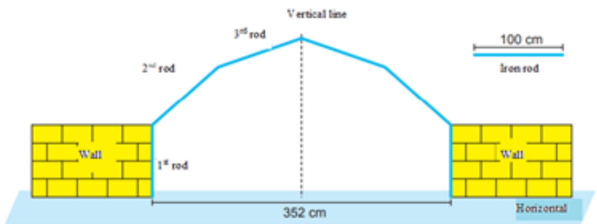


Graph 2. Percentage distribution of the math questions in 2021 LGS by learning areas and linked learning areas

In order to better understand the coding, Table 2 gives some examples of how the math questions in 2021 LGS were coded according to the learning areas and the linked learning areas. As seen in Graph 2, all the questions (25%) in the learning area “numbers and operations” were found to be directly related to this learning area alone. On the other hand, while some of the questions in the learning area “algebra” (25%) were found to be directly related to this learning area alone (10%), some others were related to the learning areas “geometry and measurement” (10%) and “numbers and operations” (5%) as well as the learning area “algebra.” As for the learning area “geometry and measurement,” which had the highest number of questions (35%), some of the questions were found to be directly related to this learning area alone (10%). Most of them were related to the learning area “numbers and operations” (20%), and a minority of them to “algebra” (5%). Moreover, it was found that the questions in the learning area “data processing” (10%) were found to be related to the learning areas “algebra” (5%) and “numbers and operations” (5%), and the question in the learning area “probability” (5%) was found to be related to the learning area “numbers and operations” (5%).

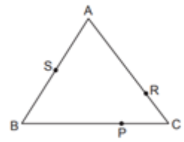
Table 2. Examples of coding and interpretation for the mathematics test questions in 2021 LGS according to the learning areas

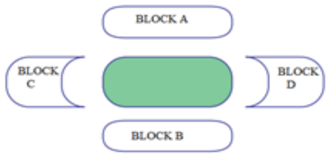
<table>
<tr><th>Learning Areas</th><th>Linked Learning Areas</th><th>Explanations for the coding of learning areas</th><th>Sample Mathematics Questions from 2021 LGS (Translation)</th></tr>
<tr><td>Numbers and Operations</td><td></td><td>This question involves operations on exponential numbers; therefore, it was coded in the learning area “numbers and operations.”</td><td>a≠0 and m, n are integers.
$a^n . a^m = a^{n+m}$ and $\frac{a^m}{a^n} = a^{m-n}$
In the table below, there are exponential numbers with a base of 2 and different exponents, and E and F are one of these numbers.
<table><tr><td>Column I</td><td>Column II</td></tr><tr><td>2^{-1}</td><td>2^{-2}</td></tr><tr><td>E</td><td>F</td></tr><tr><td>2^3</td><td>2^1</td></tr></table>The product of 3 exponential numbers in the Column I is equal to a perfect square positive integer and the product of those in the Column II is also equal to a perfect square positive integer.
So, what is the least possible value of E + F?
A) 33 B) 17 C) 9 D) 3</td></tr>
<tr><td>Algebra</td><td>Geometry and Measurement</td><td>This question asks the slope and requires the knowledge about Pythagorean theorem; therefore, it was coded in the learning areas “algebra” and the linked learning area “geometry and measurement.”</td><td>Slope is the ratio of the vertical length to the horizontal length.
The hypotenuse of a right triangle is the side opposite the right angle. In a right triangle, the square of the length of the hypotenuse equals the sum of the squares of the lengths of the other two sides.


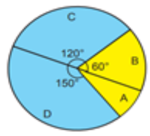
$a^2 + c^2 = b^2$
The gate of a park is modelled as follows.


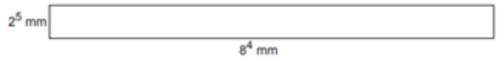
In order to build the gate, 6 iron rods with a length of 100 cm will be spliced as seen in the model above. The length of the gate is 352 cm. The vertical line in the model splits the gate into two equal parts. The 1st rod is perpendicular to the surface. The 2nd rod has a slope of 75%.
So, what is the slope of the 3rd rod?
A) $\frac{7}{24}$ B) $\frac{3}{10}$ C) $\frac{5}{12}$ D) $\frac{1}{2}$</td></tr>
</table>

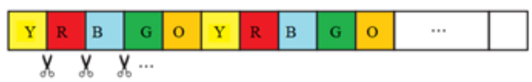
<table>
<tr><th>Learning Areas</th><th>Linked Learning Areas</th><th>Explanations for the coding of learning areas</th><th>Sample Mathematics Questions from 2021 LGS (Translation)</th></tr>
<tr><td>Geometry and Measurement</td><td></td><td>This question involves the triangle inequality; therefore, it was coded in the learning area “geometry and measurement.”</td><td>Efe will use an inelastic rope to put in order the angle measures of the triangle ABC.


When Efe puts one end of the rope on;
• the corner A and superpose it on [AB] and [BC], the other end of the rope reaches P,
• the corner B and superpose it on [BC] and [CA], the other end of the rope reaches R,
• the corner C and superpose it on [CA] and [AB], the other end of the rope reaches S,


If BP > AS> CR, what is the correct order of the internal angle measures of the triangle ABC?
A) $m(\hat{A}) > m(\hat{C}) > m(\hat{B})$ B) $m(\hat{B}) > m(\hat{C}) > m(\hat{A})$
C) $m(\hat{C}) > m(\hat{B}) > m(\hat{A})$ D) $m(\hat{A}) > m(\hat{B}) > m(\hat{C})$</td></tr>
<tr><td>Data Processing</td><td>Algebra</td><td>This question involves the ability to interpret tables and circle graphics and use algebra; therefore, it was coded in the learning area “data processing” and the linked learning area “algebra.”</td><td>

The figure above is the seating plan of a stadium. 80% of the tickets of the match is sold. The table below shows the ticket prices for each block, and the graph below shows the distribution of the unsold tickets by block.
Table: Ticket Prices by Block
<table><tr><th>Blocks</th><th>Price of one ticket (TL)</th></tr><tr><td>A</td><td>20</td></tr><tr><td>B</td><td>20</td></tr><tr><td>C</td><td>10</td></tr><tr><td>D</td><td>10</td></tr></table>
Graph: Distribution of the unsold tickets by block


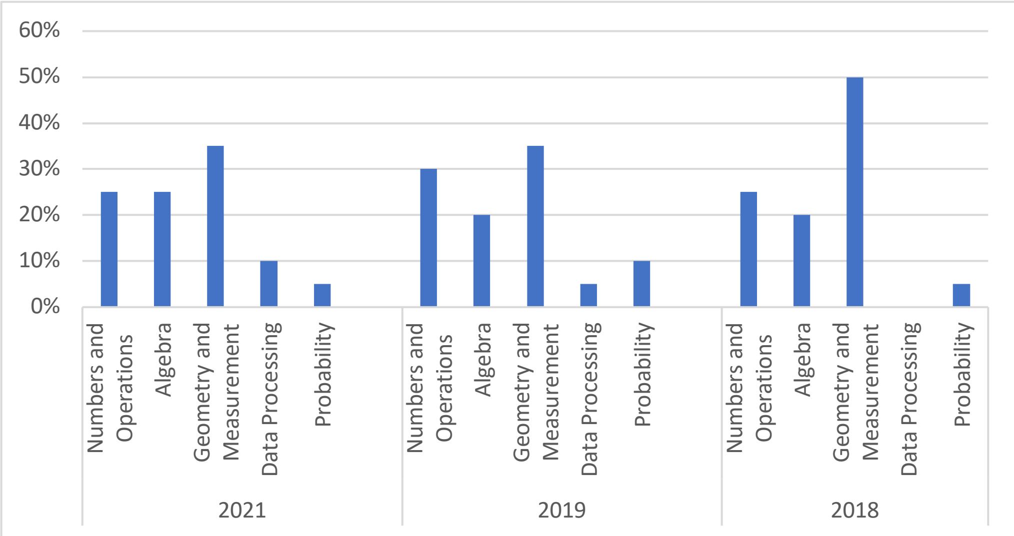
If the total price of the unsold tickets is 15000 TL, what is the number of tickets put up for sale for this match?
A) 5000 B) 6000 C) 7200 D) 8400</td></tr>
<tr><td>Probability</td><td>Numbers and Operations</td><td>This question involves the ability to calculate probability and use the exponential numbers; therefore, it was coded in the learning area “probability” and the linked learning area “numbers and operations.”</td><td>a≠0 and m, n are integers.
$\frac{a^m}{a^n} = a^{m-n}$ and $(a^n)^m = a^{n.m}$
Probability of occurrence of an event = the number of favorable outcomes / the total number of possible outcomes
The figure below shows a rectangular cardboard with the lengths of 2^5 and 8^4.


This cardboard is cut into equal squares with a length of 2^5 and colored in yellow, red, blue, green, and orange in a pattern. Then, all the square cardboards are put in a bag.


What is the probability that a randomly selected square cardboard is red?
A) $\frac{25}{128}$ B) $\frac{1}{5}$ C) $\frac{13}{64}$ D) $\frac{7}{32}$</td></tr>
</table>

Analysis of the Data Associated with the Second Sub-Question

Graph 3 shows the results for the second sub-question of the research, that is, "What are the distributions of the math questions in 2018, 2019, and 2021 LGS by learning areas?"

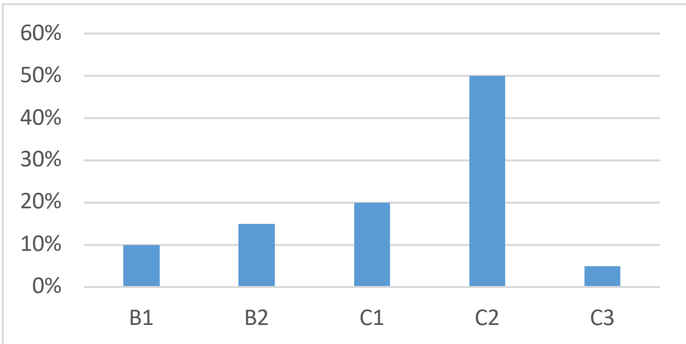


Graph 3. Distributions of the math questions in 2018, 2019, and 2021 LGS by learning areas

As can be seen in Graph 3, the learning area "geometry and measurement" was found to have the highest number of questions in 2018, 2019, and 2021 with 50%, 35%, and 35%, respectively. This learning area was followed by "numbers and operations" and "algebra." While the percentage of the questions from the learning area "numbers and operations" in 2019 was slightly higher than that in 2019 and equal to that in 2021. The learning areas "data processing" and "probability" were found to have the least number of questions. No questions were asked from the learning area "data processing" in 2018, and its percentage was low in 2019 and 2021 (5% and 10%, respectively). Similarly, the percentage of the learning area "probability" was also low in 2018, 2019, and 2021 (5%, 10%, and 5%, respectively).

Analysis of the Data Associated with the Third Sub-Question

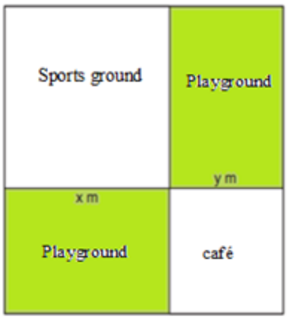
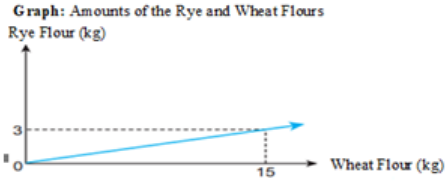
Graph 4 shows the results for the third sub-question of the research, that is, "What is the distribution of the math questions in 2021 LGS by the groups and categories in the MATH taxonomy?"



Graph 4. Distribution of the math questions in 2021 LGS by the categories of MATH taxonomy

As can be seen in the Graph 4, the math questions in 2021 LGS were mostly from the category C2 (50%), followed by the categories C1 (20%), B2 (15%), B1 (10%), and C3 (5%). There were no questions from the category A. In order to better understand the coding, Table 3 gives some examples of how the math questions in 2021 LGS were coded according to the groups and categories in the MATH taxonomy.

Table 3. Examples of coding and interpretation for the mathematics test questions in 2021 LGS according to the MATH Taxonomy

The Math Questions in 2021 LGS (Translation)	MATH Taxonomy Category	Explanation for Coding
The figure below shows a square plot. A square part (with a length of x m) of this plot is planned as a sports ground, and another square part (with a length of y m) is planned as a café. The remaining parts are left for playground.  So, what is the algebraic expression in m^2 for the sum of the areas of the parts left for playground? A) xy B) 2xy C) 3xy D) 4xy	B1 - Information Transfer	This question requires the ability to transform the model into algebra (Transforming information from one form to another)
In a bakery, a mixture of rye flour and wheat flour is used to bake bread. The graph below shows the linear relationship between the amounts of the rye and wheat flours in this mix. **Graph:** Amounts of the Rye and Wheat Flours  The rye and wheat flours were confused with one another and a mixture of 120 kg was prepared. Only wheat flour will be added to the mixture in order to correct this mistake and ensure a linear relationship between the amounts of rye and wheat flours shown in the graph. So, how many kilograms of wheat flour should be added to the mixture? A) 120 B) 380 C) 480 D) 520	B2 - Application in New Situations	This question asks how the linear relationship can be restored after the flours are misused. So, the question requires the ability to see the constant ratio based on the linear relationship and to make a calculation for the new situation (Applying appropriate methods or information to new situations).

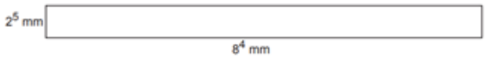
<table>
<tr><th>The Math Questions in 2021 LGS (Translation)</th><th>MATH Taxonomy Category</th><th>Explanation for Coding</th></tr>
<tr><td>

$a \neq 0$ and m, n are integers.

$\frac{a^m}{a^n} = a^{m-n}$ and $(a^n)^m = a^{n.m}$

Probability of occurrence of an event = the number of favorable outcomes / the total number of possible outcomes

The figure below shows a rectangular cardboard with the lengths of 2^5 and 8^4.



This cardboard is cut into equal squares with a length of 2^5 and colored in yellow, red, blue, green, and orange in a pattern. Then, all the square cardboards are put in a bag.

What is the probability that a randomly selected square cardboard is red?

A) $\frac{25}{128}$ B) $\frac{1}{5}$ C) $\frac{13}{64}$ D) $\frac{7}{32}$

</td><td>C1 - Justifying and Interpreting</td><td>This question requires the ability first to find the probability value, then make a transition to all possible situations by using the exponential numbers (128 possible situations), and finally to interpret how many pieces will be red in all possible situations by making use of the pattern (Justifying and Interpreting).</td></tr>
<tr><td>

a, b are natural numbers.

$a\sqrt{b} = \sqrt{a^2 b}$

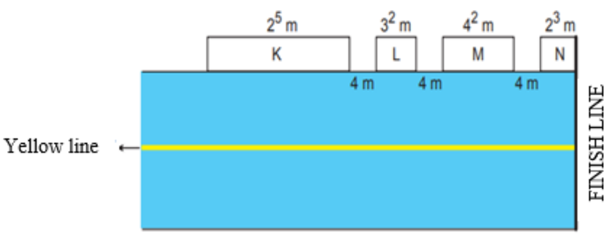
The figure above shows a circle cardboard with a diameter of KL and a 10 cm ruler. When the point 2 on the ruler is put on the point K, the point L corresponds to somewhere between 6 and 7, more close to 7.

So, what is the possible length of the line KL in cm?

A) $2\sqrt{5}$ B) $2\sqrt{6}$ C) $3\sqrt{3}$ D) $4\sqrt{3}$

</td><td>C2 - Implications, Conjectures, and Comparisons</td><td>When the operations are performed in the question, it is found that the length of the line segment KL is between 4 and 5. Based on the conjecture that it should be closer to 5, it is decided which length can be a possible option (implication, conjecture, and comparison).</td></tr>
<tr><td>

The figure below shows a rectangular running track and the rectangular tribunes K, L, M, and N placed on the long length of this running track. The finish line and one of the sides of the tribune N is linear. The lengths of one side of the tribunes and the distances between the tribunes are given in the figure. The yellow line is parallel to the long side of the running track.



While one of two athletes running on the yellow line towards the finish line passing in front of the tribune K, there is a distance of 46 m between this athlete and the leading athlete.

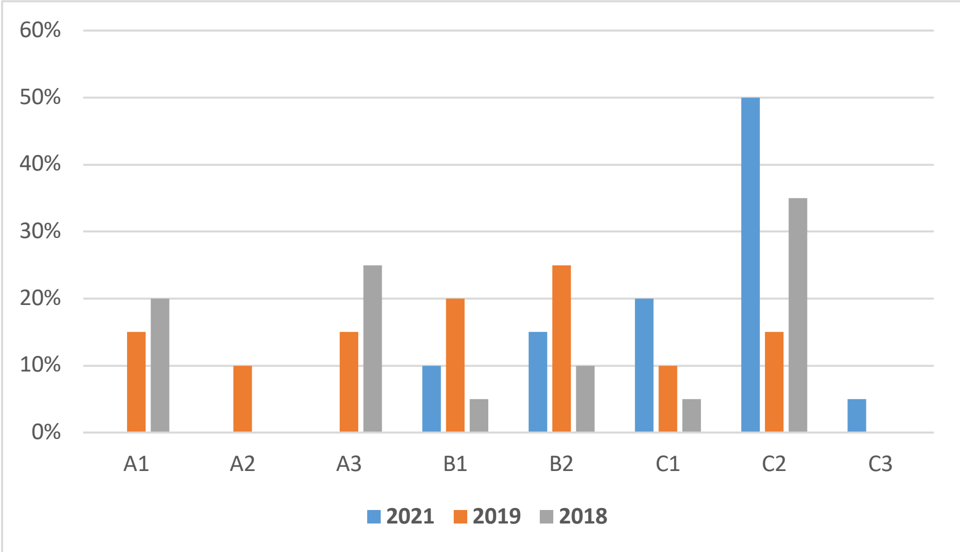
So, which of the following is absolutely wrong about the location of the leading athlete?

A) Crossed the finish line
B) In front of the tribune M
C) Between the tribune L and M
D) In front of the tribune L

</td><td>C3 - Evaluation</td><td>The question requires the ability to make a judgment based on the given information (Evaluation).</td></tr>
</table>

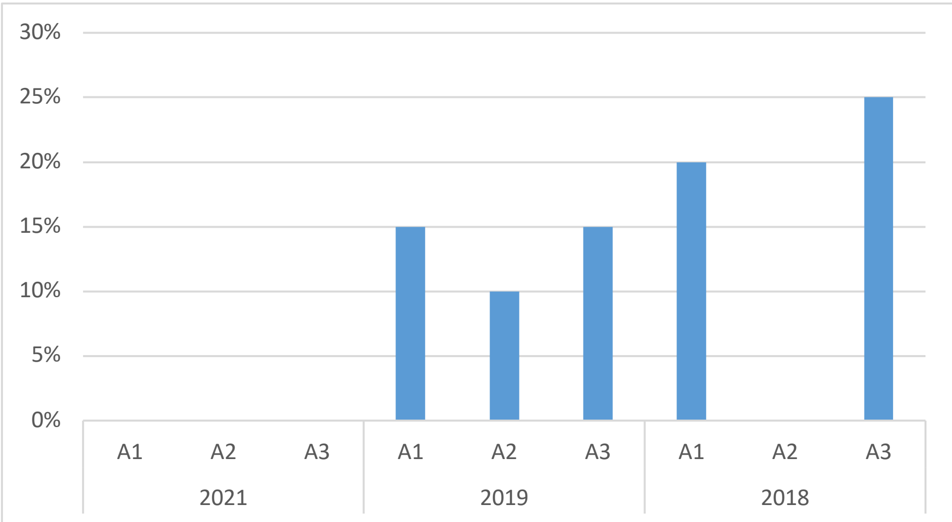
Analysis of the Data Associated with the Fourth Sub-Question

Graph 5 shows the results for the fourth sub-question of the research, that is, “What are the distributions of the math questions in 2018, 2019, and 2021 LGS by the groups and categories in the MATH taxonomy?”



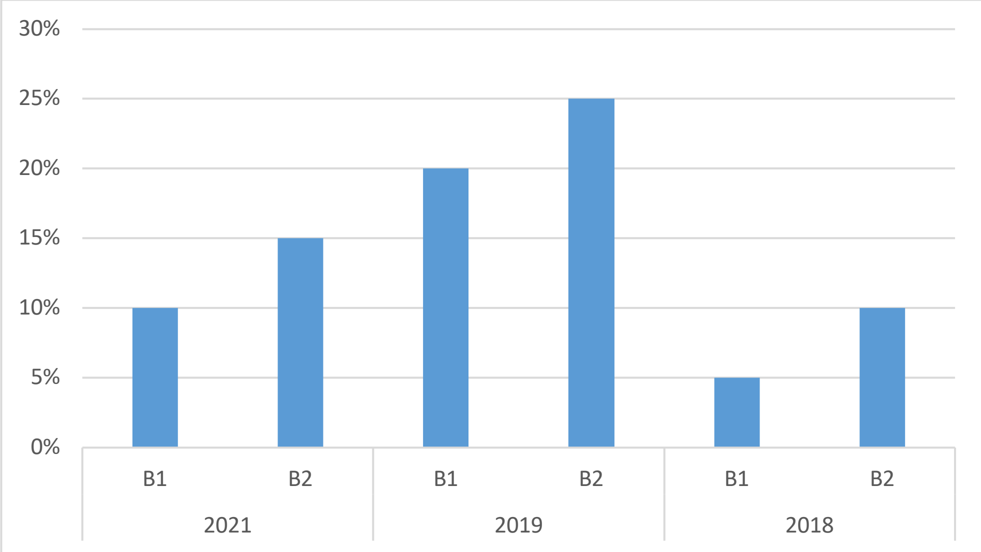
Graph 5. Distributions of the math questions in 2018, 2019, and 2021 LGS by the groups and categories in the MATH taxonomy

Graph 5 shows the distribution of the groups and categories of MATH taxonomy for 2018, 2019, and 2021. The groups A, B, and C were analyzed separately in order to examine how the distribution of the groups of the MATH taxonomy changed over the years. Graph 6 shows the distribution of the questions from the group A by years.



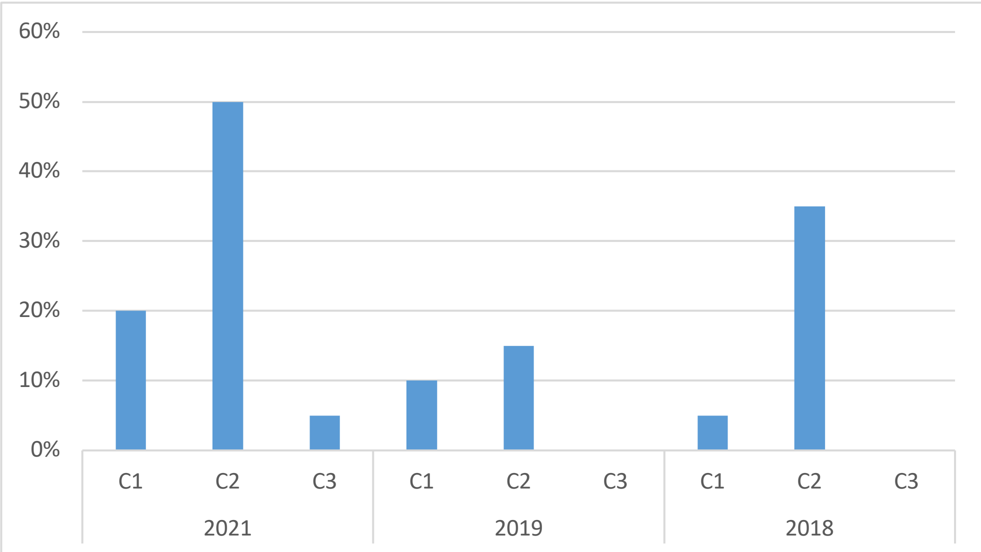
Graph 6. Distributions of the math questions in 2018, 2019, and 2021 LGS by the categories of the group A of the MATH taxonomy

As can be seen in the Graph 6, 45% of the mathematics questions in LGS 2018 and 40% of those in LGS 2019 were from the categories of the group A. In 2021, there were no questions from any category of the group A. When the questions from the group A in 2018 and 2019 were analyzed, it was found that the categories A3 and A1 were dominant. Graph 7 shows the distribution of the questions from the group B by years.



Graph 7. Distributions of the math questions in 2018, 2019, and 2021 LGS by the categories of the group B of the MATH taxonomy

As can be seen in the Graph 7, 15%, 45%, and 25% of the mathematics questions in LGS 2018, 2019, and 2021 were from the categories of the group B, respectively. The percentage of the questions from the category B2 was found to be higher than that of those from the category B1 in all three years. Graph 8 shows the distribution of the questions from the group C by years.



Graph 8. Distributions of the math questions in 2018, 2019, and 2021 LGS by the categories of the group C of the MATH taxonomy

As can be seen in the Graph 8, 40%, 25%, and 75% of the mathematics questions in LGS 2018, 2019, and 2021 were from the categories of the group C, respectively. In 2021, a significant increase was observed in the number of the questions from the category C. Moreover, while there were no questions from the category C3 in 2018 and 2019; for the first time, LGS included a question from the category C3 in 2021. When the percentages of the questions from the categories C1 and C2 were compared, it was found that the percentage of those from the category C2 was higher than that of those from the category C1 in all three years.

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

In this study, the math questions in 2021 LGS were examined in terms of their distribution by the groups and categories of the MATH taxonomy and the learning areas, and then the result was compared with those of 2019 and 2018 LGS. First of all, when the mathematics questions in 2021 LGS were analyzed in terms of their distribution by the learning areas, it was found that the questions were mainly from the learning area “geometry and measurement,” followed by “numbers and operations,” “algebra,” “data processing,” and “probability.” It can be asserted that this distribution is generally compatible with the learning outcome related to each learning area in the secondary school mathematics curriculum and the time allocated for teaching that learning outcome. The learning areas “data processing” and “probability” were found to have a minor share in the curriculum in terms of both the number of learning outcomes and the allocated time. The learning areas “geometry and measurement,” “numbers and operations,” and “algebra” were found to have a similar share in terms of the distribution of the learning outcomes in the curriculum and the allocated time for them.

In this study, if a math question in 2021 LGS involved more than one learning area, these additional areas were considered “linked learning areas.” As a result of the analysis, it was found that most of the questions related to the learning area “geometry and measurement” were also related to “numbers and operations,” and some of them to “algebra.” Similarly, the questions related to “algebra” were found to be also related to “geometry and measurement” and “numbers and operations.” Erdoğan (2020) examined the relationship between mathematical skills and mathematics learning areas and reported that students who correctly answered the questions related to the learning areas "numbers and operations" and "algebra” also had a high ratio of correct answers in the questions related to the learning area "geometry and measurement.” This result supports the existence of a link between the learning areas. The same applies to the learning areas of “data processing” and “probability.”

On the other hand, it was found that the questions directly coded in the learning area “numbers and operations” were not related to other learning areas. For example, a question about exponential numbers directly involves only the learning area of “numbers and operations.” However, the link between “geometry and measurement” and “numbers and operations” is essential. For example, a question related to “geometry and measurement” requires the ability to use the Pythagorean theorem and the knowledge of exponential numbers from the learning area “numbers and operations.” Based on these results, we believe the link between learning areas should be considered in the teaching process. A question can involve more than one learning area; therefore, learning areas should not be considered in isolation.

When the distributions of the mathematics questions in 2021, 2019, and 2018 LGS were compared in learning areas, they were found to have a similar distribution. In all three years, the learning area “geometry and measurement” was found to have the most number of questions, and the learning areas “data processing” and “probability” the least. The learning areas “numbers and operations” and “algebra” were found to have a very close or equal number of questions. It can be asserted that this is generally in harmony with the secondary school mathematics curriculum. These three learning areas have a similar distribution in the curriculum and the LGS questions examined in this study. However, it was found that the percentage of the questions from the learning area "geometry and measurement” was more than its share in the curriculum.

Another point to be noted here is the interrelationship between the learning areas. A question related to “geometry and measurement” also involves other learning areas; therefore, this distribution has no problem. Ekinci and Bal (2019) also reported that the distributions of questions in 2018 and 2019 LGS were similar in learning areas, which was in harmony with the curriculum.

On the other hand, the mathematics questions in 2018 LGS did not involve all learning areas, but those in 2019 and 2021 did. Ekinci and Bal (2019) and Farımaz (2020) also reported the same result for 2019. This result shows that 2019 and 2021 LGS were more aligned with the curriculum than 2018 LGS. Based on the analysis of the questions in 2018 and 2019 LGS, Farımaz (2020) asserted that the number of questions related to the learning areas “data processing” and “probability” should be increased in future exams. However, the number of questions is in harmony with the curriculum; therefore, it can be asserted that there is no need to increase the number of questions. On the other hand, based on the analysis of the questions in 2021 LGS in terms of linked learning areas, it can be asserted that more associations should be built between the learning areas “data processing” and “probability” and the other learning areas. Once this association is built, the learning areas “data processing” and “probability" will be covered by more questions.

When the math questions in 2021 LGS were examined in terms of the groups and categories in the MATH Taxonomy, it was found that there were questions from groups B and C but not from group A. Group C was found to have the most number of questions, with the category C2 (Implications, Conjectures, and Comparisons) having the highest number of questions. Based on these results, the math questions in 2021 LGS were mainly from the higher levels of the MATH taxonomy. When the distributions of the math questions in 2018, 2019, and 2021 LGS were compared in terms of the groups and categories in the MATH taxonomy, it was found that the number of questions from group C increased as the years progressed. Only LGS 2021 included questions from category C3. The previous studies on TEOG (the former equivalent of LGS) reported that the questions from group C needed to be more present in TEOG. The recent increase in the number of questions from group C supports that as the years have progressed, more importance has been attached to measuring the students’ high-level skills. Farımaz (2020) asserted that no questions from category C3 were included in the 2018 and 2019 LGS, and this category was neglected. This need was fulfilled in 2021. Similar to the results of the present study, Gürbüz (2021) also reported a decrease in the number of questions from group A and an increase in those from groups B and C.

The share of the mathematics questions from category C was the highest in 2021 LGS, and there were no questions from category A. This means that students were faced with questions that required them to use their high-order thinking skills. This result was in line with that reported by Ekinci and Bal (2019). They analyzed the math problems in the 2018 LGS using the revised Bloom’s Taxonomy. They reported that the math problems in LGS aimed at measuring students' high-order thinking skills, such as evaluation and interpretation. According to the MATH taxonomy, the math questions in 2021 LGS measure high-order thinking skills, and we believe that such questions will contribute to the development of students’ mathematical thinking. Asking questions that do not require students to use their higher-order thinking skills will lead them to think more superficially (Selçuk, 2000).

LGS 2021 included fewer questions from group B than LGS 2019 but more than LGS 2018. The reason for this was the increase in the number of questions from group C. In other words, LGS 2021 included more questions from the top level of the taxonomy than the others. As for the questions from group A, it was found that no questions were included in 2021, and the numbers of questions were similar in 2019 and 2018, but there were fewer questions in 2019 than in 2018. This shows that the number of questions from group A decreased over the years while the number of questions from higher-level groups increased. Compared to years, more importance has been attached to measuring high-level skills.

Students in Turkey take the international exams held by Trends in International Mathematics and Science Study (TIMSS) and the Program for International Student Assessment (PISA). The structure of TIMSS and PISA exam questions requires students to have high-level skills in problem-solving, such as creative thinking, logic and judgment, reasoning, mathematical communication, correct use of mathematical language, and strategy building (Taş et al., 2016). The TIMSS and PISA results show that Turkey is not sufficiently successful in this regard. There are many reasons for this failure, and one of them is that students do not encounter such questions sufficiently and are not used to them (Aydoğdu İskenderoğlu & Baki, 2011). When the distribution of LGS questions in the MATH taxonomy is analyzed by years, an increase is observed in the number of questions measuring high-level skills (categories B and C). We think that the increase in the number of questions from categories B and C will make the students more used to these types of questions, and this will contribute positively to the success of Turkey in the TIMSS and PISA exams held in the coming years.

One of the particular objectives of the secondary school mathematics curriculum in Turkey is to provide the following skills to students: mathematical literacy, associating mathematical concepts, problem-solving, reasoning, expressing mathematical language correctly and appropriately, using metacognitive knowledge and skills, making generalizations, expressing mathematical concepts using different representations, and communication (MoNE, 2018). Similarly, NCTM (2000) asserts that besides students' success, their skills, such as applying mathematics in daily life, problem-solving, reasoning, self-confidence in mathematics, and communication about mathematics should also be measured. In other words, students must have higher-order thinking skills and apply them to problems. According to the MATH taxonomy, the number of questions measuring higher-order thinking skills in LGS has increased in recent years. This overlaps the objectives of the secondary school mathematics curriculum and NCTM, which is a positive development.

Based on the results of the research, we recommend that:

- the central exams be analyzed according to the MATH taxonomy in order to understand the question structures that can measure more than one knowledge and skill,
- the textbooks be prepared in a way to include the higher-order thinking skills of the MATH taxonomy,
- the teachers be trained on how to prepare questions that involve the higher-order skills of the MATH taxonomy,
- the linked learning areas should be considered in future studies on coding learning areas.

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Statements of publication ethics

We hereby declare that the study has not unethical issues and that research and publication ethics have been observed carefully.

Researchers’ contribution rate

The study was conducted and reported with equal collaboration of the researchers.

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