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GENDER DIFFERENCES IN MATHEMATICAL COMPETITION PERFORMANCE FOR GRADE 4 PUPILS IN LATVIA

Maruta Avotiņa[1], Guna Brenda Pogule[1], Ingrīda Veilande[2]

[1] University of Latvia, Latvia, Faculty of Physics, Mathematics and Optometry
[2] Riga Technical University Latvian Maritime Academy, Latvia

ABSTRACT

There are stereotypes that boys are better than girls at mathematics and other STEM subjects. For example, at the International Mathematical Olympiad, most of the participants are boys, and only some girls qualify for the competition. However, a team (6 secondary school pupils) from Latvia, unlike other countries, almost every year contains a girl participant in this prestigious olympiad. Special competitions and olympiads for girls are organized. The goal is to increase their interest and confidence in mathematics, like the European Girls' Mathematical Olympiad.

To determine whether there are gender differences in Latvia for the primary school pupils in the mathematical problem solving we analyse data obtained in a school year 2021/2022 in the national level mathematical competition "This much or… How much?" in which participated about 3200 pupils from various schools in Latvia. Pupils solved problems ranging in difficulty from multiple choice questions and standard computation tasks to non-standard problems that requires explanations and creative thinking. The main objective of this study is to determine if there are any gender differences in mathematical competition for Grade 4 pupils. In the paper we analyse pupils works and solutions according to mathematical skills necessary in the tasks to find out whether there are gender differences in solving different tasks and what are the strength for each gender. The obtained results could be useful for math teachers so they can differentiate the teaching process and improve each pupil's performance in mathematics, as well as rise pupils interest using non-standard tasks.

Keywords: *mathematics for Grade 4, mathematical olympiad, gender differences in mathematics, mathematical skills, olympiad results*

Introduction

Some theories in the past had tried to describe the differences between genders emphasising the influence of biological factors (Girelli, 2022). It contributed to the strengthening of various stereotypes about masculinity. One of the myths is that

certain parts of the brain function biologically differently between men and women. To measure gender differences in neural processes a group of researchers (Kersey et al., 2019) scanned the brains of young 3 to 10 years old children and adults with functional magnetic resonance imaging. Gathered images were compared among children and adults. Researchers found no evidence of differences in neural functions while children were watching educational videos with mathematical content.

Psychologists, sociologists, and educators have spent decades studying differences between genders' performance in mathematics. As the initial studies focused on the belief that mathematics and science are dominated by males, subsequent research broadens its scope to include various social and cultural aspects (Hana, 2003), such as learning environment, learning ways, and the significance of teachers and parents. Additionally, research has shown that girls experience higher levels of math anxiety than boys (Devine et al., 2012), which is an obstacle to choosing a carrier in the STEM (Science, Technology, Engineering, and Mathematics) field (Daker et al., 2021).

Internationally recognized studies, such as Trends in International Mathematics and Science Study (TIMSS) and Program for International Student Assessment (PISA), have acknowledged that the achievement gap between boys and girls in mathematics is minimal. TIMSS 2019 reported that in half of all 58 participating countries, boys outperform girls in Grade 4, although the differences were negligible (Mullis et al., 2020). Whereas pupils from 27 countries presented gender equity in mathematics achievement on average. According to the PISA assessments the differences between 15-year-old participants were not significant in a vast majority of countries (OECD, 2016). Notable differences were observed among top-performing pupils, with boys outperforming girls (OECD, 2019).

Ellison and Swanson (2010) drew attention to gender inequity at mathematics competitions in the USA. They analysed data from the American Mathematical Competitions for high school students in 2007. These competitions are organised in several levels, at the first level 44% of participants were girls. Only those students who scored at least 100 were invited to take part at the next level. Only 25% of pupils who scored 130 were girls. To get to the highest level, knowledge beyond the standard secondary school curriculum is necessary. Researchers suggest that a change in government policy is necessary to motivate girls to learn mathematics at a higher level.

When it comes to the most prestigious event in mathematics, the International Mathematical Olympiad (IMO), girls comprise a small portion of all the participants. Hoyos (2019) analysed the percentage of girls at the IMO, determining that from 1959 till 2022 only about 10% of all the contestants were girls. Only 3.6% of all gold medallists at the IMO were girls. Hoyos guessed that the discrepancy is caused by young women`s lack of interest in the most competitive levels of mathematics. However, a relatively high number of girls from Latvia were included in teams from 2000 to 2022 (see Table 1). Considering that each team has a maximum of 6 members, during this period Latvian teams have included 16% girls who also have won awards (see Table 2).

Table 1 Number of girls included in the teams of IMO (2000–2022)

Country	Girls	Country	Girls
Finland	21	Norway	14
Latvia	**20**	Germany	8
Estonia	18	China	3
Sweden	18	USA	3
Lithuania	13	Poland	2

Table 2 Awards of female contestants from Latvia

Year	Contestant	Award
2022	Komisarova Milana	Honourable mention
2021	Oliņa Līva	Bronze medal
2017	Upīte Agnese	Bronze medal
2012	Ošiņa Ilze	Honourable mention
2009	Ozola Ieva	Honourable mention
2000	Koroļova Aleksandra	Bronze medal

For various fields of natural sciences, economics, engineering, and other fields to develop more comprehensively and to reduce gender gap, it is necessary to involve more women in these fields. There are a lot of young talented girls that should be motivated to study more STEM subjects. Numerous math competitions are therefore held specifically for girls (Veilande, 2018). The European Girls' Mathematics Olympiad (EGMO), which began in 2012 at Murray Edwards College in Cambridge, is one of these significant events. This olympiad has similar rules and similar difficulty as the IMO. The results indicate that girls can be as high achieving as boys.

The rapid development of STEM fields contributes to creation of new jobs. It is crucial to give women access to high-quality education and to encourage them to pursue careers in STEM professions to ensure that there are adequate workers in these fields of science and engineering (Ghasemi et al., 2019). For instance, Lazio and Ford Jr acknowledged that there are millions of unfilled STEM jobs which hinders economic development in the USA (Lazio & Ford Jr, 2019).

According to the economic survey of Latvia given by OECD (OECD, 2022), Latvia has further challenges because its population is declining. The study highlights poor basic digital skills and high rates of student dropouts in higher education which indicates a lack of workforce skills. Quite a few students choose to learn STEM subjects. According to the official statistics of Latvia (Official Statistics Portal Database, 2022) many young people study humanities and health science (see Figure 1). The number of men who choose to study STEM subjects is more than twice as high as the number of women. In 2022, a survey questionnaire for grade 7 to 12 pupils was developed to determine conditions in the learning environment that can predictably affect the academic achievements of girls in Latvia (Daniela et al., 2022).

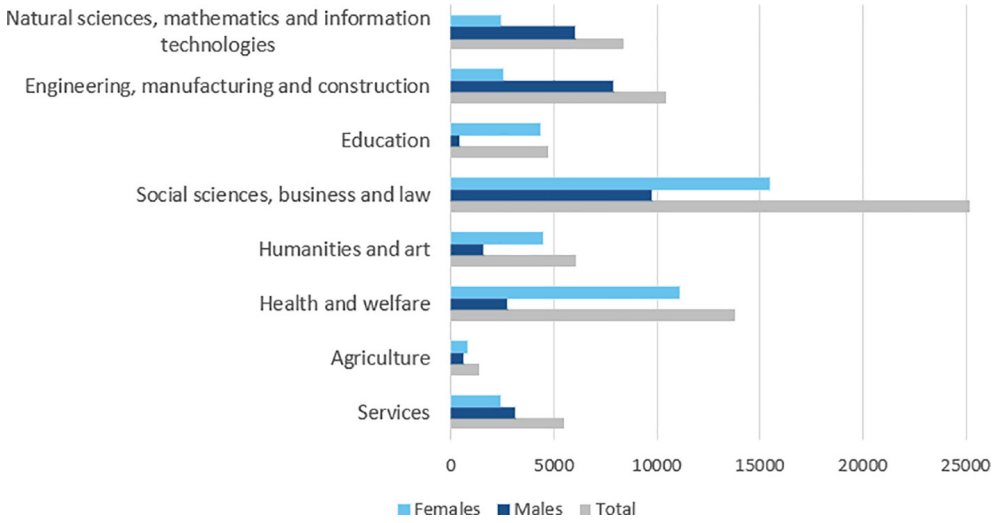

Figure 1 Enrolment in higher education institutions and colleges grouped by sex, mode of studies, and discipline (at the beginning of school year) 2022

Methodology

The research subject of this paper is the gender differences in mathematical performance in the national level mathematical contest "This much or… How much?" for Grade 4 pupils in a school year 2021/2022. We use secondary data collection to analyse pupils' scores in rounds 1 to 3 using data received from participating schools from different regions in Latvia as well as qualitative data analysis such as pupils' solutions of round 4 problems accordingly to mathematical skills used in solutions to see whether there are gender differences in pupils' performance and what skills and tasks are better done by each gender. In total, there are 3256 participant results analysed in this paper.

Results

This section is divided into two parts. In the first part, we describe and analyse gender differences in the first three rounds of the mathematical contest "This much or… How much?", the second part is dedicated to the analysis of some mathematical skills for girls and boys according to tasks of the round 4 of the contest.

A mathematical contest "This much or… How much?" for Grade 4 pupils was established in 2004 because there was a necessity for a contest in which could participate pupils from Grade 4 since mathematical olympiads in Latvia are organized starting from Grade 5 pupils. The contest is organized by the University of Latvia A. Liepa's Correspondence Mathematics School and has 4 rounds that include tasks that are intended as an introduction to mathematical olympiad problems. Pupils solve problems of various difficulty levels, from multiple-choice questions and standard computation tasks to non-standard problems that require reasoning and creative thinking. Every pupil is

welcome to participate in the first three rounds, which are held in schools. However, the fourth round is held in regional centres, and students who performed best in the first three rounds are invited. Pupils` works (round 1 to 3) are evaluated by maths teachers according to common criteria, the fourth round is evaluated by the organizers. Further, we analyse data from the mathematical competition "This much or… How much?".

Pupils Results in Round 1, Round 2 and Round 3

In this section we analyse girls' and boys' results in the first three rounds of the contest "This much or… How much?". There are no significant differences between the number of girls and boys that participate in the contest (see Table 3). Since there were 8997 girls and 9462 boys in Grade 4 in Latvia in 2021 (Official Statistics Portal Database, 2021), we may conclude that both genders are equally interested in this mathematical competition.

The contest problem sets have different types of tasks (A. Liepas Correspondence Mathematics School, 2023). In each round tasks from all main subbranches of mathematics (algebra, geometry, combinatorics, number theory) are included. The first round consists of single-choice answer tasks, the second round is single-choice answer tasks and open questions and in the third round, there are only open questions. The average results in these rounds (see Table 4) show that boys are better at single-choice tasks (in almost all tasks of round 1 the boys scored higher, see Table 5), but in round 2 and round 3, the average results have no significant differences.

Table 3 Number of participants in rounds 1 to 3

	Participants	Girls	Boys
Round 1	2144	47 %	53 %
Round 2	2535	49 %	51 %
Round 3	1821	50 %	50 %

Table 4 Average points obtained by pupils in rounds 1 to 3

	Average points	Average points (girls)	Average points (boys)	Problem type
Round 1	16.4 (max 48)	15.5	17.2	Single-choice questions
Round 2	14.1 (max 38)	14.2	14.1	Single-choice questions and open questions
Round 3	8.14 (max 25)	8.1	8.2	Open questions

Table 5 Percent of pupils who solved the task correctly in rounds 1 to 3

		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
R1	Girls	54	24	45	29	33	8	28	22	24	34	
	Boys	57	28	47	33	41	10	36	22	27	37	
R2	Girls	88	61	52	20	77	50	15	18	4	19	15
	Boys	90	60	59	26	72	50	15	17	4	16	13
R3	Girls	35	16	11	8	9	2	14	12	78		
	Boys	41	18	11	11	9	2	17	13	70		

Although average results are relatively equal there are several tasks that show gender differences in performance. In the first three rounds, boys outperformed girls in 17 tasks, while girls outperformed boys in 6 tasks and the results were equal in 7 tasks (see Table 5). Although boys solved more tasks correctly, in many of them the difference between the performance of boys and girls is not significant, only 1%-2%.

The tasks with the biggest differences between girls' and boys' performance are analysed next. All these tasks can be found in Appendix I. It can be observed that boys are more likely than girls to answer correctly single-choice questions and tasks involving real-life problems and tasks with practical context. Girls performed better in tasks that require them to carefully study task criteria and complete only what was requested. For example, in R2 P5, where girls outperform boys by 5% (see Table 5), it was necessary to read the data accurately from the given graph. However, no additional data operations were required for the task. Similarly, in R3 P9, girls perform 8% better, which required pupils to follow the instructions of the task accurately, without delving into any real-life problem.

Tasks in which boys perform better involve real-life problems and practical context. Pupils must complete numerous operations to obtain the correct answer in these tasks. This requires delving into the task's context and understanding the meaning of each number. The differences in results and the most common mistakes made in these tasks are described further.

- The boys performed 4% better in R1 P4. Girls were more likely than boys to select the incorrect option E (see Figure 2, where the correct answer is given in brackets). The error could have resulted from counting congruent triangles and selecting the answer whose denominator contains the number of triangles.
- In R1 P5, 4% more girls than boys selected the incorrect option A. This can be calculated by subtracting 10 from 12, ignoring the fact that half-litre bottles are provided instead of one-litre ones.
- The most frequently wrong response in R1 P7 is C (6% more for girls than boys). Although the question asks by how much the temperature has increased, answer C gives the exact temperature of one day. To acquire the correct answer, students must do various things, including not just reading the data from the graph for both days, but also evaluating the difference between them.

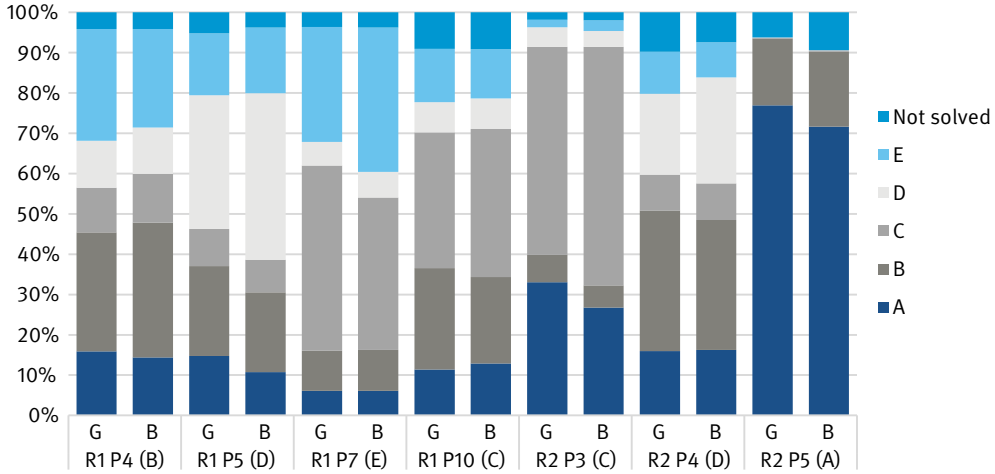

Figure 2 Percent of selected answer choices for some tasks of the round 1 and round 2

- In R1 P10, 4% more girls than boys selected the incorrect option B. The task's question contains the phrase "white shirt," and the number in response B matches the number of white shirts. Finding just one number in the text, as in previous tasks examined here, is not enough.
- In R2 P3, the most frequently incorrect response is C (6% higher for girls than boys). The error may have been caused by oversimplifying the task. The divisibility of 70 by 7 is obvious.
- The most frequently picked wrong answer in R2 P4 is C (6% more for girls than boys). It can be obtained by adding the numerators and denominators of all fractions in the text. There could be two issues: a lack of ability to add fractions or a lack of understanding of the task's context.
- R3 P1 is an open question, and 6% more boys than girls correctly answered it. Although the problem is brief, the solution entails several steps, including expressing an hour in minutes and calculating the value of the required fraction.

It can be observed that girls are more prone than boys to select wrong responses whose values can be acquired by performing a single operation on provided numbers – reading values from a graph or finding them in the text, adding or subtracting given numbers. The task's context and complexity, which require more than one operation, are not recognized by girls more often than boys.

Pupils Results in the Round 4

According to the pupils' performance in the first three rounds, at least one pupil from each participating school is invited to participate in round 4. Since boys' results in the first three rounds were better, the number of boys invited to round 4 was greater (233 boys and 183 girls). As well as in the average result of round 4, boys outperformed girls (average number of points for boys is 20.5, but for girls, it is 19.2 out of 47).

Mathematical skills are conceptualized as a separate area that includes verbal components (number knowledge, counting, computation, and reasoning) and nonverbal components (math notation, reasoning in time and space, and computation) (Miller, 2004). Mathematical skills are not only related to topics taught in mathematics lessons but also include practical skills and abilities that are considered useful in everyday life and for different professions. Next, we analyse some tasks of round 4 according to the main mathematical skills necessary in each task where differences in gender performance were observed previously. See the contest problem set in Appendix II.

Problem 1 is a task where pupils must demonstrate their numeracy skills by dividing two numbers in which girls scored higher than boys (71% of girls made computation correctly contrary to 65% boys) and is shown in Figure 3. The task required accurate computing by employing a school-taught algorithm. The main mistake for each gender was missing 0 in the result. When analysing pupils' solutions, it was discovered that girls checked the accuracy of the answer more frequently by using the opposite operation.

Problem 2 is a task where pupils must show their understanding of time calculations and an analogue clock. Boys solved this problem significantly better than girls (see Figure 4), although the main mistakes were similar for all pupils. Girls more briefly described and explained their solutions, whereas boys' solutions were shorter and they more often wrote only an answer.

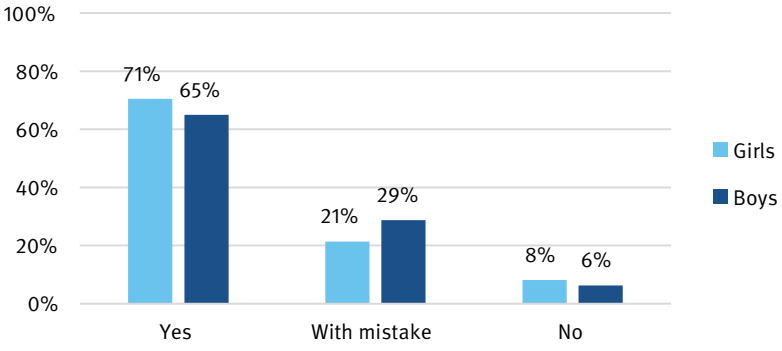

Figure 3 Girls and boys' numeracy skills in problem 1

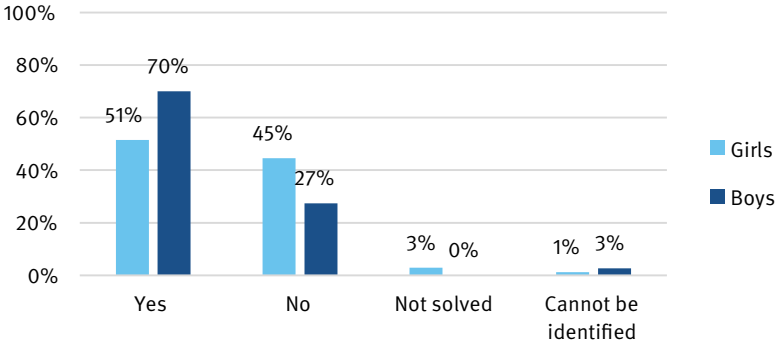

Figure 4 Girls' and boys' time calculation skills in problem 2

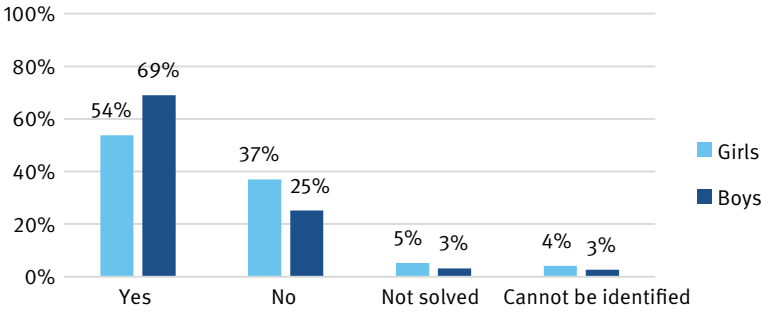

Figure 5 Girls' and boys' abstract thinking skills in problem 4

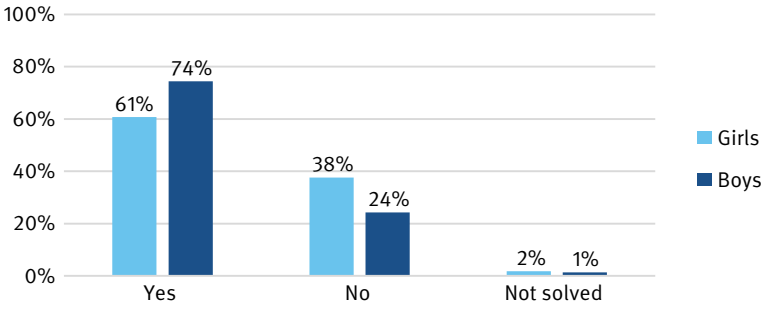

Figure 6 Girls' and boys' money conversion skills in problem 5

Problem 4 is a task where abstract thinking is needed because a pupil must think about all possible 2-number combinations and find a counterexample. Boys showed a more general view in solving this problem, while girls wrote a few examples that met the required conditions and did not think about whether the statement is true for all numbers (see Figure 5). Abstract thinking is very crucial in learning mathematics since properties, ideas, and concepts must be generalized without being tied to a specific example.

At a young age, pupils must learn to deal with tasks that involve units of measure, because it will be necessary in their daily lives. Problem 5 checks whether a pupil understands the difference between cents and euros and knows how these units are related. Boys performed better than girls in this task (see Figure 6), the main mistake was an incorrect conversion of EUR 20 to 200 cents. However, girls communicated more about their mathematical reasoning than boys. While girls made some arithmetic mistakes, their solutions were better and more well-organized.

Reading skills are the basis for solving any problem. In problem 6 reading and the accuracy of it was the key to the correct solution. Girls outperformed boys in this task (see Figure 7). Although the task only required colouring the given figure according to the requirements, more than half of the pupils, due to the lack of thorough reading, cannot solve the problem correctly. Analysing the correct solutions, we did not notice any algorithms for how pupils got the necessary colouring, only one girl showed how she decided which squares to colour (see Figure 8).

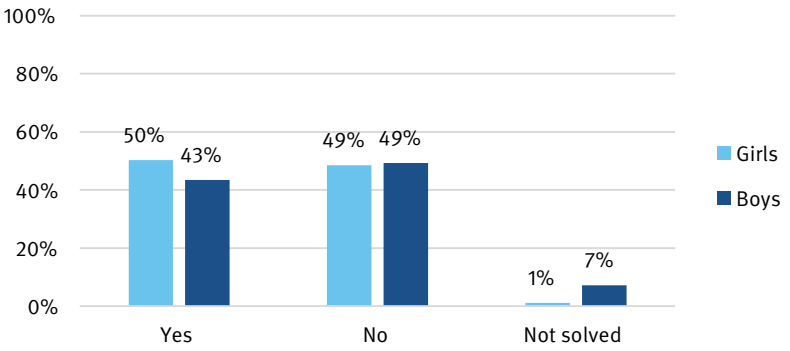

Figure 7 Girls' and boys' reading skills in problem 6

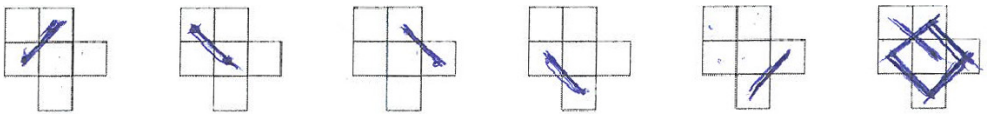

Figure 8 Girl's solution of problem 6

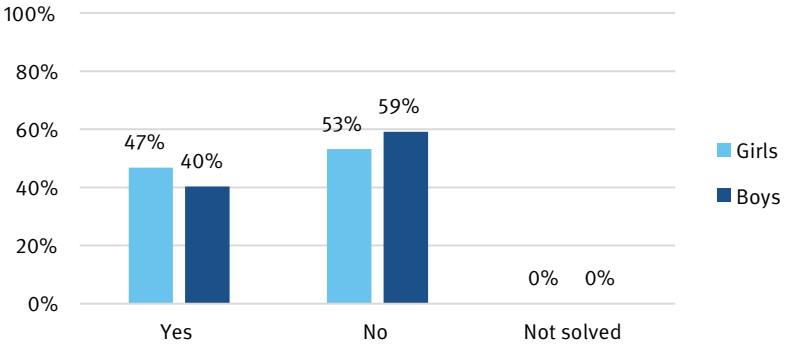

Figure 9 Girls and figurative thinking skills in the problem 11

Figurative thinking provides a means of finding the patterns that give meaning to experience and involves the visual process of seeing correspondences of shape or function (Smolucha & Smolucha, 2012). Figurative thinking is the main type of thinking in preschool ages and the development of it is crucial since it will be hard to solve complex problems in the future if one has no ability to manage pictures. Problem 11 requires building a figure from given shapes and in this problem girls' performance was better than boys' (see Figure 9). This task is a good example of how to develop pupils' figurative thinking.

The obtained data do not show a significant difference between the performance of boys and girls in the contest "This much or… How much?" for Grade 4 pupils in the school year 2021/2022.

The previously covered observations are consistent with the findings of the Progress in International Reading Literacy Study (PIRLS), where it was acknowledged that girls had higher average achievement in reading than boys in the fourth grade. The results of the contest confirm that reading and comprehension of a text are important and necessary for correct problem solving, not only in standard situations during everyday lessons but also in mathematical contests that require non-standard thinking. Girls got better results in solving these types of tasks where careful reading and thorough work was all that was needed for a correct solution. Boys did better at solving tasks with a practical context and use of mathematics in real-life situations. This implies that boys are more interested in practical subjects. It must be recognized that both girls and boys are equally interested in solving exciting mathematical problems.

Conclusions and Discussion

The article analysed Grade 4 pupils' performance in a mathematical contest in Latvia. We can see that there is no significant difference between the performance of boys and girls when it comes to their scores or solutions. When it comes to multiple-choice questions and tasks with a practical context that require more than one operation, boys fare somewhat better. However, girls are better at tasks that require careful work and reading skills. Both genders are equally interested in entering competitions, so it is important for teachers as well as for parents and society to keep this interest in the future by motivating and supporting pupils.

In mathematics lessons, teachers should place emphasis on mathematical literacy for pupils to develop their reasoning capabilities and to learn how to structure their solutions so that they are easy to read.

Discussions should be started in several directions:

- The stereotype that girls cannot be good at mathematics or in the field of STEM must be eliminated and a significant role can be played by social media and public beliefs and statements.
- To motivate both girls and boys to learn mathematics and other STEM subjects special supporting materials for teachers must be developed containing more real-life and practical problems that would be challenging and interesting for pupils.
- Interest clubs for teachers and outdoor activities for pupils should be organised to disseminate information, exchange views, and motivate pupils to choose to learn STEM subjects in the future.

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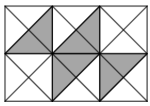
Appendix I

Some Tasks of the Round 1 to 3 of the Contest "This much or... How much?"

R1 P4 A rectangle is divided into equal triangles, what part of the rectangle is coloured?

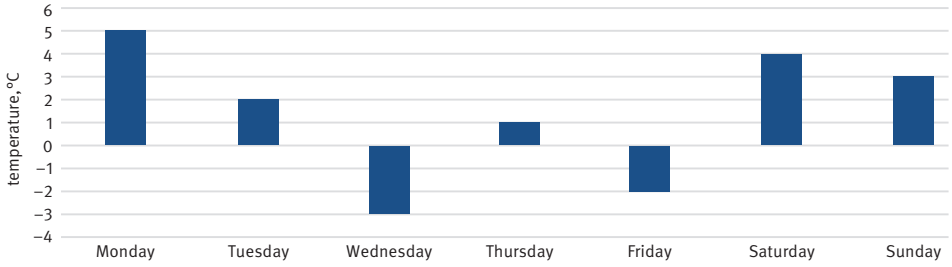


A $\frac{1}{4}$ **B** $\frac{1}{3}$ **C** $\frac{1}{2}$ **D** $\frac{2}{3}$ **E** $\frac{7}{24}$

R1 P5 10 half-litre bottles of water were poured into a 12-litre bucket. How many more such bottles of water need to be poured to fill the bucket?

A 2 **B** 7 **C** 12 **D** 14 **E** other number

R1 P7 The graph shows the average air temperature during the nights of the second week of October. By how many degrees was Saturday night warmer than Wednesday night?



A by 1°C **B** by 3°C **C** by 4°C **D** by 6°C **E** by 7°C

R1 P10 On a dark autumn evening, the electricity went out in the whole town, and John's house was completely dark. On this evening, John must perform at an orchestral concert, so he needs to bring a suit and a white shirt. John knows that he has 6 white, 4 black and 5 red shirts in his wardrobe. What is the smallest number of shirts he needs to take out of his wardrobe to make sure he has a white shirt?

A 1 **B** 6 **C** 10 **D** 11 **E** 15

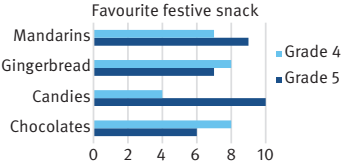
R2 P3 What is the largest number divisible by 7 that is less than 100?

A 70 **B** 97 **C** 98 **D** 99 **E** 105

R2 P4 On Monday it snowed $\frac{1}{5}$ of a centimetre, on Tuesday it snowed $\frac{3}{10}$ of a centimetre and on Wednesday it snowed $\frac{1}{10}$ of a centimetre. What is the thickness of the snow on Thursday morning if we know that it did not snow overnight and did not melt on any day?

A $\frac{5}{10}$ cm **B** $\frac{5}{25}$ cm **C** $\frac{5}{5}$ cm **D** $\frac{6}{10}$ cm **E** 5 cm

R2 P5 Which table shows the same data as the chart?



A

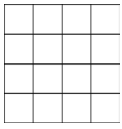
Favourite festive snack		
Snack	Grade 4	Grade 5
Mandarins	7	9
Gingerbread	8	7
Candies	10	4
Chocolates	8	6

B

Favourite festive snack		
Snack	Grade 4	Grade 5
Mandarins	7	9
Gingerbread	8	7
Candies	4	10
Chocolates	8	6

R3 P1 (*2 points*) How many seconds is one-twelfth of an hour?

R3 P9 (*2 points*) In a given table, colour some of the boxes so that there are exactly two coloured boxes in each row and in each column of the table!



Appendix II

The Round 4 Tasks of the Contest "This much or... How much?"

1. (*2 points*) Calculate 2020 ÷ 20.

2. (*3 points*) How many minutes will have passed from today at 20:22 until 02:10 tomorrow?

3. (*4 points*) How many natural numbers are greater than 20 + 22 and less than 20 × 22?

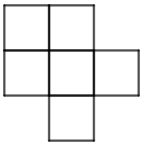
4. (*4 points*)

a) Is the sum of two equal numbers always greater than the number itself?

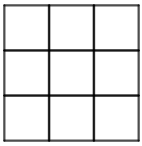
b) Is the product of two equal numbers always greater than the number itself?

5. (*5 points*) Jane has several 5-cent coins with a total value of 20 euros and several 2-cent coins with a total value of 50 euros. How many coins does Jane have?

6. (*6 points*) In how many ways can you paint two squares in a black colour in the given figure so that they share a vertex but not an edge?



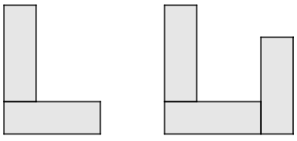
7. (*3 points*) From 24 cm long string Nick made a net consisting of 9 squares 1 cm × 1 cm (see the net in the picture). How long does Nick need to make a similar net consisting of 20 × 20 boxes of the same size?



8. (*4 points*) All 42 students from the village go to an art school or a music school (some go to both). It is known that there are as many students in the art school as there are only in the music school. It is also known that twice as many students go to both schools at the same time as there are students who go only to the art school. How many students go to both the art school and the music school?

9. (*6 points*) Ann wrote a two-digit number on a piece of paper. Then she divided this number by 5 and subtracted 5 from the result. What number could Ann have written on the page? Find all the possible numbers!

10. (*6 points*) The shapes in the picture are made of equal rectangles. The perimeter of the figure in *A* is 58 cm and the perimeter of the figure in *B* is 85 cm. What is the perimeter of each of the rectangles used?



11. (*4 points*) Create a rectangle using two figures *A* and four figures *B*!