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THE GENDER GAP IN LOWER SECONDARY SCHOOL PHYSICS COMPETITIONS: CONSIDERING NUMERIC AND SYMBOLIC PROBLEMS

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Abstract. *Noticing the inconsistency in previous studies of gender differences in learning physics, it was determined to check whether a gender gap exists in a relatively large sample of competitors (N = 12,966) from Serbia. The aim of the research presented here was to analyze the achievements of male and female lower secondary school students, competitors in physics, at all rounds of the physics national competitions in Serbia. The population of respondents consisted of 3,392 competitors in the school year 2015/2016, 4404 in 2016/2017, and 5170 in 2017/2018. Participants were grouped by gender. The results of the analyses, based on a t-test with a confidence level of 95% and a = 0.05, support the hypothesis that there is a statistically significant gender gap in favor of male participants at municipal and district rounds of competitions. However, the obtained results show a lack of difference in achievements at the state competition level. In general, at each subsequent level of competition, the gender gap decreases. In addition to the observed differences at the three levels of competition, the similarities in the achievements of male and female students on certain problems were also analyzed.*

Keywords: *gender gap, physics competition, symbolic problems, problem solving*

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Introduction

Students' education in natural sciences is found to be of great importance for their understanding of natural phenomena well-known from their daily lives (Schilhab, 2021). It can be expected that competitors in physics, chemistry, biology, or mathematics usually show an increased level of interest in these disciplines already at the first level of education, i.e., in the lower secondary school, 12-14 years old. Meanwhile, increasing students' interest in studying natural disciplines, especially female students, remains a great challenge for the modern educational system (Brewe & Sawtelle, 2016; Prelić et al., 2022). Dziob et al. (2022) have shown that active participation in competition (*the Chain Experiment*) increases scientific knowledge, soft skills, and motivated physics learning.

Gender equality "means that women, men, girls and boys must enjoy equal rights, resources, opportunities and protections" (https://www.unicef.org/lac/en/gender-equality), in education and beyond. Gender disparity or gender gaps in education means unequal access and opportunities for education between male and female students. "Gender bias and gender-based discrimination still permeate the entire education process in far too many settings, and education systems often perpetuate rather than challenge gender inequalities. This is embodied in the teaching and learning process, including differential engagement, expectations, and interactions by teachers with their male and female students, as well as gender stereotypes in textbooks and learning materials" (UNESCO, 2019, p. 6). To determine whether there is a gender disparity in learning achievements in physics during lower secondary school (the first three years of studying physics as a separate subject), the performance of male and female students across three levels of a national competition over three consecutive school years was analyzed. An ex-post facto study design was used – analysis of official competitors' achievements.

The study of gender differences in physics education falls into a broader theoretical framework encompassing sociocultural, motivational, and contextual factors.

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Literature Review

Non-(existing) Gender Gaps in Learning Physics

Gender differences in science education have long been a topic of interest and concern among educators and researchers worldwide (Acar et al., 2015; Buenestado-Fernández et al., 2024; Contini et al., 2017; Delaney & Devereux, 2019; Nissen & Shemwell, 2016; Reid & Skryabina, 2003). Understanding these differences is essential for promoting equality in science learning environments. Science, Technology, Engineering, and Mathematics, or STEM disciplines in general, and physics in particular, are attracting more male than female students, as shown by reports made by the Organization for Economic Cooperation and Development (OECD, 2023). An exception from the previous statement is Biology (Tsabari & Yarden, 2008). The study from Jones et al. (2000) has shown that data for students' self-reported learning interests indicate that males have shown significantly more interest in a range of science topics. Despite some exceptions to the general tendency for boys to favor physical sciences and girls to favor biological sciences, students' reported interests have largely reflected these gender-based patterns. These marked differences in the interests of sixth-grade boys towards physical sciences suggest that gender-related science interests may emerge early on.

The previous study has indicated that girls have considered physics difficult and that they have had poorer mastery of physical concepts than boys (Murphy & Whitelegg, 2006). The reasons behind this may have been found among the following: interests, motivation, course choices, career aspirations, relevance and curriculum interventions, teacher's effects, perceptions of difficulty, assessment processes, and techniques (Murphy & Whitelegg, 2006). Furthermore, empirical data have suggested a gender disparity in the cognitive level of achievement among boys and girls (Hofer & Stern, 2016; Marsh et al., 2019), so boys having better understood physical phenomena, while girls have mostly memorized knowledge, have had a poorer understanding of physical concepts, although they have had better grades in school (Jugović, 2017; Stadler et al., 2000). It has been noticed that at the beginning of learning physics at school, boys have connected physical concepts with phenomena in everyday life more than girls (Stadler et al., 2000). In their free time, boys have, more often than girls, acquired knowledge in physics and technology (Jugović, 2015). However, a comparison of possible causes of the difference in the achievements of boys and girls shows that neither of them alone can explain the observed gap (Madsen et al., 2013). Furthermore, Madsen et al. (2013) have claimed that the gender gap exists and that it is most likely due to a combination of many small factors.

Nevertheless, according to some studies, physics has been described as difficult to learn and understand (Lasry et al., 2009), and as a result, there has been a great responsibility on teachers to motivate and involve students in the learning process using interactive teaching methods and techniques (Crouch & Mazur, 2001; Docktor et al., 2015; Gavrin, 2010; Rosdianto & Murdani, 2017; Vlassi & Karaliota, 2013, etc).

Although interactive techniques (such as inquiry-based learning) have had a positive impact on reducing the gender gap in mastering physics (Lim & Kim, 2023) they have not been enough if they do not take "into account social-psychological and cognitive processes that lead to gender differences" (Miyake et al., 2010, p. 1237). Namely, social-psychological factors (such as values, attitudes, stereotypes, interests, motivation, self-confidence, self-efficacy, etc.) have often been crucial to one's success in learning (Jugović, 2015; Radulović et al., 2022). Therefore, some interventions like 'value affirmation' may have decreased the gender gap in mastering physics (Miyake et al., 2010). Blankenburg et al. (2016) have suggested that participating in science competitions can help students recognize their abilities and enhance their self-confidence. Therefore, it is crucial to encourage more female students to get involved in such competitions.

Although stereotypical, it has been usual to think that young people associate physics with the male way of life (Jugović, 2015). Namely, the future professions of most girls have not been based on a profound study of physical concepts. The results of Jugović (2017) have indicated that a possible reason for boys' higher interest in physics is the future professional orientation. In Serbia, there have been more male than female scientists in the research field, while the number of physics teachers in lower and upper secondary schools have been in favor of females (Stojanović et al., 2019; Brewe & Sawtelle, 2016). Many factors have influenced the choice of profession, and it has been impossible to determine it unambiguously, for example, by someone's better achievement. Research has shown that, among others, economic factors have strongly influenced the choice of future profession, so boys have been directed towards better-paid jobs than girls early in their schooling (Rapoport & Thibout, 2018). This has not been evidence of their scientific abilities, but can be perceived as an indicator of ambition, self-confidence, and/or lack of resources, etc.

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Among psychological factors, motivation and interest have been necessary for learning physics because solving physical problems slightly pushes the boundaries of understanding (Dias & Penido, 2021), which is important not only for the development of scientific literacy for both genders (OECD, 2009) but also for developing a view on real-life situation (Murphy & Whitelegg, 2006). Interest and motivation have been preconditions for learning, so a lack of these factors may have been taken as a learning disadvantage for girls (Radulović et al., 2022).

Social-psychological factors mentioned previously, such as stereotypes of women in science and associating physics with the male way of life, may have naturally decreased motivation and interest in learning physics among female students (Jugović, 2017; Miyake et al., 2010; de Barros Vidor et al.,2020). However, some studies (Byman et al., 2012) have shown that there has been no difference in motivation to learn physics between girls and boys. Many published studies (Cavallo et al., 2004; Lindstrom & Sharma, 2011; Marshman et al., 2018a; Nissen & Shemwell, 2016; Sawtelle et al., 2012) have described significantly lower female students' self-efficacy in physics compared to male ones, even in interactive engagement courses (Nissen & Shemwell, 2016), and even if female high school students had received prior physics instruction (Lindstrom & Sharma, 2011). Self-efficacy has been deeply rooted in self-confidence, and several studies have suggested lower self-confidence in girls regarding learning physics (Murphy & Whitelegg, 2006; Stadler et al., 2000). In the study conducted by Rachmatullah, Diana, and Ha (2018), three main differences were noted: female students viewed science as memorization, relied on surface-level motivation, and had their self-efficacy more influenced by higher levels of conceptual understanding and application than males.

Reid and Skryabina (2003) have researched the attitudes of boys and girls towards science in general and physics in particular. Before the end of lower secondary school, it turned out that both boys and girls had had very positive attitudes towards science and considered physics an important subject. However, at the end of the second year of high school, there had been a significant decrease in the positive attitudes of girls. The study of Tsabari and Yarden (2008) supports the findings, showing that while boys have developed an interest in physics with age, girls have not developed such an interest to the same degree, and the initial gap in interest is probably not based on school-related causes.

However, besides a large amount of research showing gender differences in mastering physics, there have been research-based opinions suggesting that a gender gap does not exist. Hyde and Linn (2006) identified no gender gap in primary and secondary education for complex problem-solving. Some research (Klainin et al., 2007; Mutjaba & Reiss, 2014) has investigated the performance of girls in physics and shown that, in practical and theoretical tests, girls have had the same or even better results than boys. Furthermore, Akpınar et al. (2009) pointed out that girls have been significantly more interested in science than boys and that there have been no significant differences between boys and girls in enjoying science and scientific experiments. Interestingly, the findings for Turkey for 8th graders or 14-year-olds show that girls outperformed boys in science (Acar et al., 2015), and the same situation has been observed in middle school for 10 to 14-year-old students (Bursal, 2013). The cited recent research has shown the absence of a gender gap, which could indicate that education systems have been more successful in reducing the gender gap than in the 1980s or 1990s (Murphy & Whitelegg, 2006). This has been supported by the systematic research of the OECD (2019), which has shown that the gender difference in scientific performance has been narrower than that observed in mathematics and reading. On average, in OECD countries in 2018, girls have been slightly better in science than boys. Moreover, in only six countries, the performance of boys in science has been significantly higher; the opposite has been noticed in 34 countries. In comparison with these results, in Serbia, the PISA 2018 tests have shown (Videnović & Čaprić, 2020) no statistically significant difference in scientific achievements between girls and boys.

The results of TIMSS 2019 (Mullis et al., 2020) have shown that girls have had higher average achievement than boys in 15 countries. In 18 countries, the results have been equal in science, while boys have had better average achievement in six countries. Comparing the results of Serbian students, participants in TIMSS 2019 (Đerić et al., 2020), it can be seen that girls have had statistically better achievement than boys.

Although it is difficult to compare some research results on this topic, considering different places (sociocultural factors affecting psychological – affective and cognitive – dimensions), time (rapid changes in education), and differences in education systems, research inconsistency has been noted in understanding (a) an (non)-existence of a gender gap in learning physics.

Regarding numeric and symbolic problems, the research conducted by Wilson et al. (2016) has indicated that questions requiring mathematical manipulations, such as performing algebra or interpreting equations, have generally had small or zero gaps between male and female performance. This suggests that both genders perform similarly on numeric and symbolic problems, with no significant gender bias having been observed in these types of questions (Wilson et al., 2016).

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The study has found that students generally found symbolic problems more challenging than numeric ones due to difficulties in interpreting and manipulating symbols and equations (Umrotul, 2022).

Physics Competitions

The study of competitions in physics and natural sciences has been a current topic of research (Bukleski, 2023; Campbell & Walberg, 2010; Dziob et al., 2022; Jordens & Mathelitsch, 2011; Petersen & Wulff, 2017; Tschisgale et al., 2024a; Tschisgale et al., 2024b). Despite the topicality and importance of both themes (physics competitions and a gender gap), there has been very little research merging these themes. Some researchers have already pointed out (Steegh et al., 2019) the lack of literature that deals with gender roles and competitions at the same time.

To the best of knowledge, only a few studies in the literature (De Araujo, 2021; Steegh et al., 2019; Wilson et al., 2016) have addressed gender differences in the physics competitions, which could help answering the research questions in this paper. The investigation of differences in gender performance in competitive selection tests in physics has shown that female students have acquired less content in physics, as well as procedural knowledge or the ability to apply that knowledge, meaning that they have not been as good as boys in different types of knowledge (Wilson et al., 2016). Also, De Araujo (2021) has reported that in the Netherlands, girls have had lower achievement than boys at the Junior and Upper secondary physics Olympiad. Steegh et al. (2019) have found that on an international level, there have been significant gender differences in favor of male students regarding participation and achievement in all Olympiads in physics. Gender stereotypes and their influence on self-concept and interest have been presented as causes of these determined differences (Steegh et al., 2019).

The study investigates gender differences in physics competition performance, focusing on whether these differences remain consistent across various competition levels and grades. It also examines the impact of numeric and symbolic physics problems on gender-based achievements.

Research Context

Societal and Cultural Context

Earlier in the paper, several contextual (societal and cultural) factors that may contribute to the gender gap in learning physics were discussed. Studies conducted in the country show the domination of patriarchy and collectivistic culture, which is especially characterized by clear roles and positions of both genders from their early childhood (Tomanović 2004; 2006). Since Tomanović's (2004; 2006) research, many things have changed in Serbian society, but some patriarchal characteristics are still present (Tomanović, 2019). However, in contemporary Serbian society, there is a mixture of traditional and modern value systems, meaning that contemporary society may be labelled as a transitional one (Tomanović, 2006). It has been proved that children adopt gender discourses in their early childhood (Tomanović, 2004), meaning that they may already be 'ready' or 'unready' to learn physics based on their gendered features when the time comes (in lower secondary school grades). That means that teachers of physics should be able not only to teach physics but also to deconstruct students' stereotypes. Stojanović et al. (2019) presented the data on a higher number of female physics teachers in Serbia. According to the attachment theory, based on the mother-child connections (Pianta et al., 2012), more female teachers in a patriarchal society may be a factor sustaining a gender gap. Findings from Buck et al. study (2008) do support that, in general, sex-stereotypical images of careers serve as a limiting factor in the career aspirations of women.

Educational System

Primary education in the Republic of Serbia is obligatory and lasts for eight years, in accordance with the National Curriculum (see for more details Eurydice Serbia, 2024). Physics is taught as a compulsory subject in the last three years of all lower secondary schools in Serbia. Students start to study physics as a separate subject in the sixth grade of lower secondary school (11 to 12 years old), continuing until the end of their primary school education.

Physics teaching is carried out through regular classes, but also in additional ones intended for: 1. particularly interested and motivated students, or 2. students who have difficulties in understanding physical concepts. In this research, the focus is on students who compete in physics. The main goal of the physics competition is to popularize science among the younger population and also to strengthen their professional orientation towards Science, Technology, Engineering, and Mathematics (STEM). On the other hand, teachers' great effort in preparing

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students for competitions develops their professional competencies. Competitors have the opportunity to apply acquired knowledge and compare and share it with peers.

Research Aim and Research Questions

The aim of this research was to investigate the potential existence of a gender gap in physics problem-solving among lower secondary school students participating in a national competition. Specifically, the study analyzes the performance of male and female students at different rounds of the competition to determine whether any achievement disparities exist between genders. The results of the research are presented.

The research questions in this study were:

1. Do male and female lower secondary school students differ more by gender in terms of overall performance in physics competitions than vice versa?
2. Are there significant differences between male and female students' achievement in physics, and are they stable, i.e., do they occur at every level of the competition? If any, do they occur at every considered grade?
3. How do different types of physics problems (numeric and symbolic problems) influence gender achievements?

Research Methodology

Design

The achievements of male and female students in physics tests, conducted through three rounds of national competitions, are analyzed in this paper. An ex post facto research design was used (Lammers & Badia, 2005) to explain the facts that *have already been done* during the competition (Fraenkel & Wallen, 2000). Three consecutive school years in which the competition was held were analyzed. Since the physics tests were designed for national competitions, the structure of the competition will first be described.

According to the competitions' agenda established by the Ministry of Education, Science and Technological Development of the Republic of Serbia (further only: Ministry), competitions always start during the second semester of the current school year, in February at the earliest. The competition calendar is published by the competent ministry in advance, after the beginning of the current school year and is also published on the website of the Serbian Physical Society www.dfs.rs. During the period set, competitors have to pass several rounds of competition: school, municipal, district, and state rounds. Every year, about 12,000 lower secondary school students participate in school competitions in physics. This number represents about 6% of lower secondary school students with a formal physics education. Students voluntarily participate at the school level competitions, and their teachers prepare school tests for that level. According to the results achieved at the school competition, schools delegate competitors for the next municipal round of competition. School competition data were not available, so they were excluded from any further analysis. Other demographic variables (socioeconomic status, region, school, etc.) were not examined in this research.

The exact dates of each level of competition are planned in advance so that they fit into the work calendar for the current school year, which is prescribed by the Ministry, and they differ slightly from year to year. About one month passes between each competition level (municipal-district-state) (Appendix 1 – The exact timetable for the three analyzed school years). The problems solved by students of the same grade were developed by the same authors, ensuring consistency across all levels of the competition within a single school year.

An expert team of eight professors and researchers from three universities in Serbia developed problems for each level of competition, and these problems were unique to all participants. The competition plan combined the contents of regular and additional classes within the school program and was known in advance.

For students of the sixth and seventh grades, the state level is the final level of competition, while for the eighth-grade students, there are two more levels - The Serbian Physical Olympiad (SPhO) and The Elective Competition for participation in the International Junior Science Olympiad (IJSO).

Besides, the replicability of the study – an analysis of student achievement in national physics tests – can be verified by analyzing student performance data. All tests, as well as their solutions, are available on the Serbian Physical Society Website via the following link http://www.dfs.rs/takmicenja/predhodne%20godine/pr.%20god..htm.

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Sample

The goal of the physics competition is to attract students who are interested in science, particularly physics. The examination of students' achievement across three years at three different levels provided a wealth of pertinent data regarding gender representation.

Therefore, to have a representative sample of students from all parts of the country, the one way to do this study was to follow all stages of physics competitions. The competitions included not just different parts of the country; they involved students from all regions, which is why the validity of the analysis is higher.

The data used in the study were collected at competitions in the school years 2015/2016, 2016/2017, and 2017/2018. A total of 3392 lower secondary school students in 2015/2016, 4404 in 2016/2017, and 5170 in 2017/2018 represent the initial sample in the investigation. These students participated in the municipal round of the national competition. The number of participants – *N* (*f* – female and *m* – male) for each particular competition level and for three observed years is presented in Table 1 (Research Results section).

Instrument and Procedures

The instrument for collecting data on the achievement of male and female students was a competition test. In each round of the competition, participants solved a test consisting of five problems (numeric and symbolic) formulated in accordance with the physics competition curriculum for lower secondary school within a specified time frame. The problems were newly developed specifically for this purpose. The maximum score for solving the test was 100, with a maximum score of 20 for an individual problem. Within those 20 points, the steps in the solution were also scored. When writing the official solution, each problem was sequenced in a key. The 20 points for every problem were divided into steps, enabling scoring of parts of the solved problem and providing greater test discrimination. It was known in advance from which areas problems could be assigned to a specific competition level.

Tests in the competitions in Serbia may include numeric and symbolic problems. A complete distinction between a symbolic and a numeric problem is often difficult. In this paper, problems formulated only by general symbols for physical quantities are marked as symbolic. In any other case, the problem is marked as numerical.

Validity

It is known from the literature (Fraenkel & Wallen, 2000) that the curriculum can be used as a criterion for test validity. It has been mentioned before that physics problems at all competition levels were covered by the content of the official national curriculum for physics for lower secondary school (Rulebooks on curricula for 8th, 7th, and 6th grade of lower secondary school, 2018; 2019) and the content of officially approved textbooks from the Ministry of Education of Serbia.

The table in Appendix 2 provides a comparative overview of the teaching areas in the competition plan, the official curriculum, and the textbooks. This analysis of the content of the teaching area in the official physics curricula and the competition plan shows that there are no differences in the teaching areas. The state level of the competition ends before the end of the current school year. Teaching areas not included in the competition plan are taught at the end of the school year and cannot be included due to the competition calendar (Appendix 1).

Reliability

Reliability is ensured by the method of applying three equivalent forms of instruments (retest), with different content. The procedure involved the assignment of the three forms of the instrument, with a short time interval between them (Fraenkel & Wallen, 2000). Methodologically, it is sufficient to ensure the application of two forms of the instrument (test twice), which means that three measurements with an equivalent form represent a sufficient condition for reliability.

Objectivity

At each level of the competition, students are assigned to classrooms in the schools where the competition is held. Then, they receive an envelope with a random code, and they have to mark all their worksheets with the code.

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The committee evaluates the works under the codes. As well as at the IJSO, students have the opportunity to appeal the assigned number of points and view their work. The results are published under the code, and only after moderation are the envelopes decrypted, so that the entire assessment process takes place under the code. The evaluation of key steps in solving problems is predefined to eliminate any possibility of a subjective approach (see: *Design*).

Ethics

Students who were competing were underage, and on their behalf, their parents signed a document confirming that competition results could be used and published on the official competition website. The analysis is based on the data presented on the official website of the Serbian Physical Society (http://www.dfs.rs/takmicenja).

Furthermore, the students' personal data will not be used in the paper, but only achievements related to the gender and age group will be included. The ethical approval to report this case was obtained from The Serbian Physical Society (approval number: 004-2024).

Data Analysis

The data were analyzed using descriptive statistics. *T* – tests were used to determine whether there were statistically significant differences between the means of independent groups (Fraenkel & Wallen, 2012) at the state competition round for 8th grade students. Hypothesis tests, probability calculations, and *F* and Shapiro–Wilk statistics, were carried out using the Origin Pro 2022 software package. Histograms were also drawn using the same software.

Comparisons between two groups were made using *t* – test with a confidence level of 95%, and a significance level $a = 0.05$. The hypothesis of the research was that there is no difference in the achievements of female and male participants. The effect size was calculated using a Cohen's *d*, (Cohen & Swerdlik, 2009) directly from the sample sizes, means, and standard deviations of the gender subgroups.

Research Results

Table 1 provides an overview of the results obtained by comparing students' achievement for the three rounds of the national physics competition in the school years 2015/2016, 2016/2017, and 2017/2018. Parameters describing participants' achievements are: *N* – the number of participants (*f* – female and *m* – male), *M* – the mean achievement, and *SD* – the standard deviation. The effect size calculation is shown in the columns denoted as S_{pooled} – standard deviation and *d* – Cohen's *d*.

Looking at a school year and comparing the performance of boys and girls, three tests were carried out as part of the curriculum, at the municipal, district, and state levels. The highest performing students from the initial group of participants at the municipal level were then tested at the district level, and the best from the district were tested at the state level.

Cohen's *d* is used as an indicator to assess the similarity hypothesis, suggesting that the achievements of boys and girls are more similar than different. The positive value of *d* in Table 1 indicates boys outperform girls, and the negative value indicates girls outperform boys in competition tests when comparing the average mean number of points on tests. According to Cohen & Swerdlik (2009), $d < 0.2$ indicates a small size effect between two groups, *d* - value between 0.2 and 0.5 indicates a moderate effect, and $d > 0.5$ indicates a sufficient effect.

With reference to the first research question (Do male and female lower secondary school students differ more by gender in terms of overall performance in physics competitions than vice versa?), it can be seen in Table 1 that the descriptive statistics on the performance of male and female students in physics competitions show that the mean performance of male students is higher at the municipal and district round. The difference in the mean score (*M*) ranges from 5.2 (Cohen's $d = 0.20$) to 10.5 (Cohen's $d = 0.37$) in favor of male participants at the municipal round. According to Cohen & Swerdlik (2009), this difference shows a small to moderate effect size.

Answering the second research question (Are there significant differences between male and female students' achievement in physics, and are they stable, i.e., do they occur at every level of the competition? If any, do they occur at every considered grade?) The current study has analyzed the stability of this gap and examined whether it persists at subsequent, higher levels of the competition.

Table 1 shows that male participants have a higher mean score in 85.2% of cases, female participants perform better in 11.1 % of cases and both groups have exactly the same mean score in 3.7 % of cases. The obtained

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results show that Cohen's *d* is less than 0.42, indicating a small to moderate effect (Cohen & Swerdlik, 2009) for all compared cases.

Table 1
Descriptive Statistic of Male and Female Students' Achievements in Physics Competitions.

Round	Year	Grade		*N*	M	SD	S_{pooled}	*d*
Municipal	2015/16.	6.	*m*	856	38.4	24.7	24.16	0.32
			f	842	30.6	23.6		
		7.	*m*	599	29.9	24.5	23.08	0.33
			f	484	22.2	21.2		
		8.	*m*	366	44.7	29.6	30.25	0.24
			f	245	37.4	31.2		
	2016/17.	6.	*m*	1069	41.9	27.9	26.44	0.26
			f	1015	34.9	24.8		
		7.	*m*	819	30.1	21.4	21.27	0.25
			f	666	24.7	21.1		
		8.	*m*	483	36.6	26.7	25.60	0.33
			f	352	28.2	24.0		
	2017/18.	6.	*m*	1279	36.7	23.2	21.78	0.29
			f	1165	30.4	20.1		
		7.	*m*	920	37.0	27.3	26.29	0.20
			f	811	31.8	25.1		
		8.	*m*	541	51.5	27.3	27.95	0.37
			f	460	41.0	28.7		
District	2015/16.	6.	*m*	618	46.6	21.9	22.35	0.16
			f	361	43.0	23.1		
		7.	*m*	370	41.3	29.9	28.86	0.26
			f	229	33.8	27.1		
		8.	*m*	347	46.0	24.5	24.5	0.18
			f	167	41.5	24.5		
	2016/17.	6.	*m*	602	44.1	26.9	26.34	0.15
			f	470	40.0	25.6		
		7.	*m*	411	49.5	30.4	30.79	0.17
			f	255	44.3	31.4		
		8.	*m*	292	55.0	54.5	52.58	0.11
			f	170	49.4	49.1		
	2017/18.	6.	*m*	581	40.6	23.0	22.71	0.23
			f	427	35.4	22.3		
		7.	*m*	428	37.6	24.2	24.08	0.02
			f	285	37.2	23.9		
		8.	*m*	341	47.9	22.9	23.55	0.18
			f	188	43.7	24.7		
State	2015/16.	6.	*m*	132	68.2	22.1	22.26	-0.15
			f	60	71.5	22.6		
		7.	*m*	119	39.4	23.6	22.75	0.05
			f	47	38.3	20.4		
		8.	*m*	115	47.9	21.4	21.14	-0.09
			f	37	49.9	20.3		
	2016/17.	6.	*m*	114	65.3	19.1	19.21	0.18
			f	70	61.9	19.4		
		7.	*m*	96	64.0	21.5	20.87	0.06
			f	59	62.8	19.8		
		8.	*m*	97	60.5	20.6	19.98	0.13
			f	46	57.9	18.6		
	2017/8.	6.	*m*	144	67.7	19.4	18.96	0
			f	68	67.7	18.0		
		7.	*m*	113	51.1	15.7	15.62	-0.14
			f	71	53.3	15.5		
		8.	*m*	97	46.0	21.2	20.28	0.42
			f	60	37.4	18.7		

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As the round of competition increases, the differences in the mean achievement decrease to values between 0.4 (Cohen's $d = 0.02$) and 7.5 (Cohen's $d = 0.26$) at the district round in favor of males. At the state round, the mean achievement gap continues to narrow in general to values between 0 (Cohen's $d = 0$) to 3.4 (Cohen's $d = 0.18$), with an exception for the eighth grade of the year 2017/18(Cohen's $d = 0.42$). In three cases out of nine at the state level, female participants had better mean achievement than male participants from 2.0 (Cohen's $d = -0.09$) to 3.3 (Cohen's $d = -0.15$) in favor of females. Additionally, there is one case in Table 1 with no difference due to the mean achievement.

In general, considering all competition levels, the effect size tended to decrease with the competition level from 0.20-0.37 for Municipal level to 0-0.18 for State level in favor of boys (with one exception of 0.42 for the eighth grade of the year 2017/18). A better result for female participants in the mean score (*M*) at the state level is observed once in all three grades.

Table 2 shows the percentage shares of female competitors through rounds of competition for the three considered years. It can be seen from the data in Table 2 that for every competition round, from a municipal to a state level, the percentage of female participants decreases. At the state level, the number of female competitors is significantly lower compared to male competitors. Additionally, Table 2 shows that the percentage of female participants generally decreases with the grade.

Table 2
Percentage Shares of Female Competitors

Grade		2015/16.	2016/17.	2017/18.		2015/16.	2016/17.	2017/18.		2015/16.	2016/17.	2017/18.
6th	Municipal	49.6	48.7	47.7	District	36.9	43.8	42.4	State	31.3	38.0	32.1
7th		44.7	44.8	46.9		38.2	38.3	40.0		28.3	38.0	38.6
8th		40.1	42.2	46.0		32.5	36.8	35.5		24.3	32.2	38.7

Table 3 provides an overview of the results obtained by comparing eighth grade male and female students' achievement for the state level in the school years 2015/2016, 2016/2017, and 2017/2018. A threshold of $p = .05$ was used for determining the level of the effect significance within all conducted tests.

Table 3 summarizes *t* - test, Shapirro - Wilk and F - statistics for eighth grade students at the state level. Parameters *t* - value, *p* - and column Remark describing the *t* - test statistics. In the Remark column, a statistically significant difference between male and female in the *t* - test statistics is labeled as SG, and cases where there is no significant difference are labeled as NS. The homogeneity of variance was tested using the F - test for two sample variances, which showed no significant difference in variances (Table 3, column Decision for F). The Shapiro - Wilk test shows that the distribution is normal. In addition, histograms showing the distribution of scores for female and male participants in the eighth grade over the three years considered are presented in Appendix 3.

In the samples of male and female students, individual score distributions were observed for all three years and for three different tests at the state level of competition. For all three tests, the largest number of students in each group, scored between 30 and 70 points (out of 100) at the state level (see Appendix 3) 2-13% of students scored more than 80 points, while 0-15% of students scored less than 20 points when the distribution of boys and girls is considered separately. These results indicate that the difficulty level of the test was appropriate for the group of students who were tested.

Table 3 shows that the *t* - test reveals a significant difference ($t = 2.556$, $p = .006$) only for the 2017/18 school year at the state level. When comparing these three years and the state level, no difference was found between male and female participants in the average score in the competition for two years, 2015/16 ($t = 0.494$, $p = .690$) and 2016/17 ($t = 0.727$, $p = .230$).

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Table 3
T - test, Shapirro - Wilk and F - statistics for Eighth Grade Students at the State Level

				t - test statistics			Shapirro - Wilk statistics			*F* statistics		
Year	Grade	N		t	p	Remark	W	p_w	Decision	F	p	Decision for F
2015/16.	8.	m	115	0.494	.690	NS	0.989	.464	Normally	1.114	.728	Not different
		f	37				0.980	.717	Normally			
2016/17.	8.	m	97	0.727	.230	NS	0.985	.344	Normally	1.230	.444	Not different
		f	46				0.958	.093	Normally			
2017/18.	8.	m	97	2.556	.006	SG	0.978	.096	Normally	1.281	.305	Not different
		f	60				0.990	.917	Normally			

Numeric and Symbolic Problems

The third question in this research is how different types of physics problems (numeric and symbolic problems) influence gender achievements. In the three analyzed school years, the total number of problems was 135, 13 of which were symbolic (9.6%). Table 4 shows the mean score per problem for the mentioned 13 symbolic problems of male (*m*) and female (*f*) competitors. In some tests, several symbolic tasks appeared in one test (Table 4).

Table 4
Male and Female' Mean Score per Problem for all Observed Symbolic Problems

School year	Grade	Municipal round	District round	State round
2015/16.	6th	/	/	/
	7th	/	/	*m* 4.8 *f* 5.7 *m* 7.1 *f* 7.9 *m* 10.1 *f* 8.4
	8th	*m* 10.2 *f* 8.9	*m* 4.0 *f* 3.4 *m* 7.9 *f* 7.4	*m* 2.2 *f* 2.0 *m* 9.2 *f* 9.3
2016/17.	6th	/	/	/
	7th	*m* 2.0 *f* 2.0	/	/
	8th	/	*m* 11.7 *f* 10.7	/
2017/18.	6th	*m* 7.1 *f* 5.9	/	/
	7th	/	/	*m* 3.1 *f* 3.3
	8th	/	*m* 1.4 *f* 1.3	/

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Figure 1 shows examples of numeric and symbolic problems in a competition test. This example of problems for numeric and symbolic types is from the test for the 2016/2017 school year for the 7th grade, municipal level. Problem 1 is an example of a numeric problem, and Problem 2 of a symbolic problem. Considering the five tasks in the test, both male and female participants scored lowest on the symbolic task shown in Figure 1, and highest on the numerical task also shown in Figure 1. Both groups of participants scored the lowest on symbolic task 2 (Figure 1), with the mean score for males and females being 2 out of 20 (Figure 1, Table 4). Both groups of participants also achieved the highest average scores when solving numerical task 1 (Figure 1): 12.5 out of 20 points for males and 9.8 out of 20 points for females.

Out of a total of nine different tests, the symbolic task was the one in which both female and male participants achieved the lowest average score in six cases. The average score in mentioned six cases for each group is highlighted in Table 4. This indicates that there is no gender difference, as tasks containing only symbols and no numerical values of physical quantities are equally challenging for both genders to solve.

Figure 1
Examples of Numeric and Symbolic Problems

Problem 1: A moving car at a constant speed of $v_1 = 36$ km/h at the particular moment starts to move at constant acceleration and within $t_1 = 2.5$ s reaches the speed v_2, if valid $v_1 : v_2 = 2 : 3$. Find the car path during its constant acceleration motion.

Problem 2: The object is ejected from the surface of the ground vertically upward with certain initial speed. The time elapsed since the moment of ejection until the moment when it is at the height h above the ground is t_1 ($h \neq h_{max}$). From that moment to the its fall to the ground elapsed time t_2, where $t_2 > t_1$. Determine: a) the maximal height (h_{max}) that the object reach during the motion; b) height h; c) object speed at height of $h/2$. $t_1$and t_2 considered as known values.

Discussion

The aim of this research was to analyze the achievements of male and female students as competitors in physics national competitions in Serbia, and it has been challenging in many ways. It was necessary to analyze a substantial amount of data collected so that they could be presented concisely. Several studies in the literature (De Araujo, 2021; Steegh et al., 2019; Wilson et al., 2016) were found on physics competitions and gender roles, so the conclusions could only be compared with those of qualitative research papers. Moreover, it is a common recent practice to compare educational results within the region (Japelj Pavešić et al., 2022), but authors did not find any national or regional research on the same or similar topic, except those dealing with the scientific skills of students (PISA and TIMSS), with no particular focus on physics.

The first question of this study aimed to determine whether a gender gap exists in achievements in physics competitions. It is evident from Tables 1 and 2 that this gap is detected at the municipal and district competition levels. This conclusion supports evidence from the previous research (De Araujo, 2021; Steegh et al.,2019). On the other hand, results from the state competition level are in accordance with other studies (Klainin et al., 2007; Mutjaba & Reiss, 2014).

Students from Serbia aged thirteen and fifteen participated in two large international projects, TIMSS 2019 and PISA 2018, respectively. As regards physics, the results presented in this paper, which are related to the municipal and district round of competition, are not in line with the results of these international studies. The findings that there is a significant gap in female and male participants' achievements at municipal and district competition levels are somewhat surprising given the fact that projects TIMSS 2019 and PISA 2018 indicate that there is no such difference in scientific achievement (Đerić et al., 2020; Videnović & Čaprić, 2020). Results of TIMSS 2019 even showed (Đerić et al., 2020) that female students had better average achievements than male students in physics. A potential explanation for this difference may be the fact that the research in this paper is focused only on physics problems, while PISA and TIMMS focused on students' scientific skills. However, according to Petersen and Wulff

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(2017), one of the goals of physics competitions has been to help students enhance their skills. According to this, if the competition meets this objective, it is also a test of skills.

Regarding the second research question, based on the obtained result (Table 1), it could be concluded that, as the round of competition increases, the difference in mean achievement between male and female students generally decreases. It is interesting to notice that the difference decreases, but the score does not decrease. This finding is in accordance with a study performed in Ireland by Delaney and Devereux (2019), which confirmed that gender disparity was smaller among high-achieving students.

As the competition progressed to higher rounds, the complexity of the problems also increased with each subsequent level. This may explain the difference in the obtained results between the municipal (or district) and state levels, which is also consistent with the previous study (Hide & Linn, 2006) that found no gender gap in solving complex problems.

It is generally expected that as problems become more complex, scores tend to decrease, and differences between scores also decrease until they become insignificant in the sample mean achievements. However, Table 1 shows that the sample mean achievements are higher at the higher round of competition, despite the increased complexity of the tasks. It is noticeable in Table 2 that the percentage shares of female competitors decrease at each subsequent round of competition. For the analyzed period of three school years, the observed decrease is found to be in intervals (49.6–31.3) %, (46.9–28.3) %, and (46.0–24.3) % for the sixth, seventh, and eighth grades, respectively. Despite the reduced number of female participants at each subsequent round of competition, the gap in male and female achievements has also been reduced. These results are in agreement with the findings from the competition system at the Netherlands Physics Olympiad (De Araujo, 2021), which is conducted in three rounds. In that study, the author showed that there was also a reduced number of female participants at each subsequent competition round (De Araujo, 2021). Blankenburg et al. (2016) showed that students who have taken part in a competition before are likely to participate again. This highlights the potential of competitions as ongoing strategies to engage and support students.

When considering research question 2, it is necessary to investigate whether the observed gap in the achievements of males and females could have been influenced, as it was shown that this gap decreased with the competition level. The ways of preparing the competitors and teaching physics in schools, which are mostly traditional in Serbia, may affect the achievements.

It was shown that teaching with certain interactive strategies reduced the gender gap (Gok, 2014; Lorenzo et al., 2006). Training competitors for higher rounds of competition was conducted in smaller groups and with a different approach. Tschisgale et al. (2024b) discussed a more individualized support for science competition participants and suggested the need for making teacher support more individual and flexible. Working in small groups provided opportunities for more individual work and better teacher support and insight into the needs of students. Given that the gender gap decreases with higher competition levels, this result may indicate that a more individual approach suits girls better (de Barros Vidor et al.,2020). Also, teaching becomes more interactive, and thus the communication between teachers and students, as well as among students themselves, increases. An interactive teaching technique could partly explain the reduction in the achievement gap between male and female competitors (Table 1). The results presented in this paper, as well as the results of other authors (Crouch & Mazur, 2001; Docktor et al., 2015; Gavrin, 2010; Lorenzo et al., 2006; Rosdianto & Murdani, 2017; Vlassi & Karaliota, 2013), indicate the need for interactive teaching even in regular education. Drawing from the findings of the presented investigation, this could lead to a narrowing of the gender gap and also to a reduction in underachievement among both male and female students in general.

Based on the previous results, a general conclusion that can be applied to all students could be made. Namely, the sample in this research was the population of competitors who were part of the regular primary education system in the Republic of Serbia (about 6% of all lower secondary school students attended the school physics competition every school year). Numerous authors found a difference between male and female students' achievements in education systems in their countries, such as Italy (Contini et al., 2017), Israel (Zohar & Sela, 2003), and Canada (Kitchenhaman, 2002). This means that there is a significant gap in males' and females' understanding and application of physical concepts independent of the education system. Potential explanations for female underachievement in physics may include fear of failure, lack of self-confidence, self-efficacy, and fear of confirming the stereotype that males have to be better in physics (Kost-Smith et al., 2010; Marshman et al., 2018 b; Radulović et al., 2022). Additionally, the relationship between gender and self-efficacy for Serbian secondary school students was reported (Radulović et al. 2022), suggesting that there was a deep belief among girls that physics is not for

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them. Radulović et al. (2022) identified differences between male and female students' motivation to learn physics. However, further research is needed to obtain and study the reasons behind gender differences deeply.

Numeric and Symbolic Problems

Formulas in physics usually represent dependencies involving real, measurable quantities expressed by different symbols. Most traditional materials for teaching and learning physics promote the manipulation of equations (Docktor et al., 2015). Namely, physics textbooks contain equations that represent the functional dependence between the corresponding physical quantities, with the recipe and instructions on when to apply them. Functional dependence has many powerful and interesting applications, and equations are not just calculation tools (Redish, 2022). Symbolic solutions are a technique that helps to find a general solution and identify key variables. This technique is important for natural science because it allows for discussions about the solution in terms of what would happen if one of the variables is negligible compared to the others and how certain dependence would look if some quantity is potentially neglected, etc. The failure to solve symbolic problems can also be attributed to misunderstanding the meaning of what the formulas in physics represent.

In line with research question 3, an obvious finding to emerge from the analysis of the symbolic problem over the three considered years (Table 3) is that both groups of competitors showed noticeably lower achievements in solving this type of problem than numerical problems. The same result is obvious for all competitors – regardless of gender, they had lower achievements (mostly scoring less than half of the maximum points predicted for the problem) in solving symbolic than numeric types of problems at all competition levels. This is in accordance with previous research that has shown that students achieve better results in solving numeric than symbolic problems (Torigoe & Gladding, 2011; Umrotul et al., 2022; Wilson et al., 2016).

At first glance, it might seem that the main challenge lies in solving complex equations, but previous research (Torigoe & Gladding, 2011; Umrotul et al., 2022) revealed that most errors stemmed not from mistakes in manipulating symbolic equations but from confusion over the symbolic meanings themselves. Another reason for the worse results that students achieve when solving symbolic problems can be the failure to identify the known and unknown variables in a given physics problem (Torigoe & Gladding, 2007). In the case of a numerical problem, some values for certain physical quantities are provided in the problem statement, making it clearer what the unknown quantity is that needs to be calculated.

Limitations

It is important to stress that there are some limitations in this research. The first refers to the fact that the participants in this research are students interested in physics in one specific science competition, not the entire student population. This is because students voluntarily participate in competitions. Obviously, in the first round of competition (school competition), the entire student population can participate, but only those students interested in physics do.

The evaluation committee, which consists of teachers from one municipality and district, is in charge of regularity and assessment of given physics problems at the municipal and district level, which might be one more limitation. Because the persons who evaluate students' papers are not the same, this might cause some differences, although not high due to the Rulebook (2006).

Conclusions and Implications

Despite all limitations, this study is important; first, the obtained results provide reliable Serbian evidence for international studies on gender differences. Second, the results of this study suggest that boys and girls are more similar than different in problem solving in physics competition.

This study has shown that:

- there is no statistically significant gender gap at the state round of competition;
- at each subsequent round of competition, the percentage share of female competitors decreases;
- both male and female competitors had a better achievement in solving numeric problems.

In general, as the level of competition increases, the achievement gap between male and female competitors narrows. Despite the identified gender gap, there were also significant similarities between male and female students in understanding and solving the problems from competition tests. In a general sense, the question that

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is much debated was whether the gender difference in students' science achievement really exists. It is expected that this empirical research will contribute to a deeper understanding of this issue. Future research on this topic in the same context should be directed towards the identification of the causes of the observed differences between male and female competitors.

This study may help to improve the conditions under which science competitions foster females. The intention and direction of future research is to look at students' attitudes towards physics and gather information about the motivation for participating in competitions and the connection with achievement, if any. An analysis of individual problems over three years, during which several competition cycles are held, can suggest whether there are possible concepts through the problems that may be close to students and what type of problems authors for future competitions should pay attention to when developing the test.

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Declaration of Interest

The authors declare no competing interest.

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Appendix 1

The Exact Timetable for the Three Analyzed School Years

School year	Municipal	District	State
2015/16.	13.03.2016.	10.04.2016.	07.05.2016.
2016/17.	19.02.2017.	11.03.2017.	09.04.2017.
2017/18.	18.02.2018.	10.03.2018.	28.04.2018.

Appendix 2

Comparative Overview of the Teaching Areas in the Competition Plan and the Official Curriculum in Physics for Lower Secondary School in Republic of Serbia

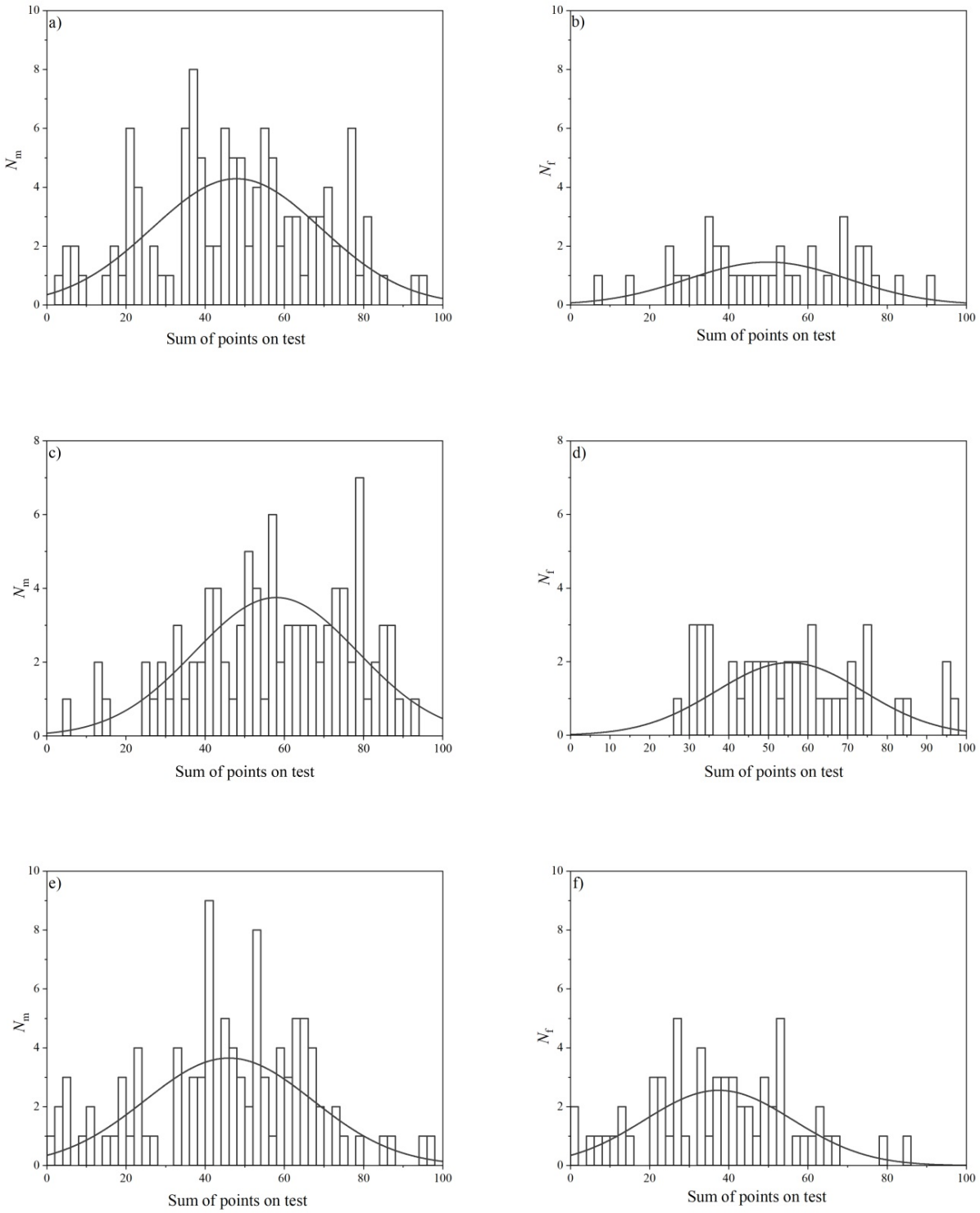
Grade	Curricula	Competition
VI	Introduction to physics Motion Force Measurement Mass and density Pressure	Motion Force Measurement Mass and density
VII	Force and motion Motion under the force of gravity. Frictional force Balance of the body-equilibrium Mechanical work and energy. Power Thermal phenomena and heat transfer	Newton's laws of motion Motion under gravity. Friction Balance Mechanical work and energy. Power
VIII	Oscillatory and wave motion Optics Electric field Electric current Magnetic field Elements of atomic and nuclear physics Physics and the modern world	Oscillatory motion and waves Optics Electric field Electric current Magnetic field

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Appendix 3

Distribution of the Sum of Points for 2015/16. 2016/17. and 2017/18. School Year for Eighth Grade: Male Participants (a, c, d) and Female Participants (b, e, f)



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