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IDENTIFYING SELECTED SOURCES OF VARIATION IN THE RESULTS OF GYMNASIUM EXAMINATION USING ANOVA[1]

Abstract: One of the parts of the Polish external examination system in preliminary education is the Gymnasium Examination. It is the first examination taken by the students, having serious impact on their prospective educational path, and because of its importance, a comprehensive and extensive study of the examination results should be carried out, allowing for identification of the factors influencing students' scores. This paper attempts to investigate the sources of variations in results of the Gymnasium Examination conducted in 2010 in Lower Silesia and Opole voivodships, in particular focusing on the extent to what the differences in students' scores are associated with the location of the gymnasium, the sex of the student and the dyslexia diagnosis. The results could provide the basis for guidelines in creating equal opportunities policies in education.

Key words: ANOVA, factorial ANOVA, analysis of variance, examination results, gymnasiums.

1. Introduction

One of the main and generally recognized goals of the education system is to equip students with a solid foundation of knowledge and skills needed to compete successfully in the modern, ever-changing world. Moreover the education system should assure the equality of educational opportunity for all individuals, by identifying and removing barriers, and enable all students to realise their full potential. In order to measure the extent to which this goal is achieved, a comprehensive and independent system of evaluation of knowledge and skills is required. The external examination system, which is being introduced in Poland since 2002, was designed to act as such instrument, by allowing for the diagnosis of the educational achievements of students, evaluation of quality of schools' educational activities and comparability of

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certificates and diplomas.[2] The evaluation is supervised by the Central Examination Board, and conducted by eight Regional Examination Boards.

The external examination system is composed of four parts:

- the Competence Test in the sixth grade of primary schools;
- the Gymnasium Examination in the third grade of lower secondary schools (the gymnasiums);
- the Matriculation Examination (the Matura Examination) for graduates of secondary schools;
- the Vocational Examination for graduates of vocational and technical schools.

The Gymnasium Examination, which is the scope of this study, is therefore the second obligatory external examination taken by the student, but the first one with an impact on the student's prospective educational path.[3] Because of its importance, a comprehensive and extensive study of the examination results should be carried out, allowing for identification of the factors influencing students' scores.

This paper attempts to investigate the sources of variations in the Gymnasium Examination results, in particular focusing on the extent to which the differences in students' scores are associated with the location of the gymnasium, the sex of the student and dyslexia diagnosis. The results could provide the basis for guidelines in creating equal opportunities policies in education.

2. The data

The data set used in this research was provided by Regional Examination Board based in Wrocław. It contains the examination results from the year 2010 of 40,919 students from gymnasiums located in the Lower Silesia and Opole voivodships. The data only comprises the students which took the standard examination test (i.e. the students without disabilities and students with diagnosed dyslexia). For the students with various physical and mental disabilities special examination tests are prepared, and therefore the results would not be comparable. The complete list and description of variables used in the research, with the basic descriptive statistics where appropriate, is given in Table 1.

The total score of the Gymnasium Examination is the sum of points from two distinct subject areas:[4]

– Humanities (including such subjects as Polish language, History, Civic Education, Art, Music and related fields);
– Exact and Natural Sciences (including Maths, Biology, Geography, Chemistry, Physics, Astronomy and related fields).

[2] More information on the external examination system may be found on the website www.cke.edu.pl.

[3] The Competence Test results provide only informative functions, whereas the Gymnasium Examination results are the basis for secondary schools recruitment process.

[4] The foreign language examination was additionally introduced in 2009, however, the results of the foreign language part are not the subject of this research.

Table 1. Variables description

Variable (a)	Description (values) (b)	Scale type (c)	Mean (d)	Standard deviation (e)	Structure* (f)
TS	The total number of points scored by the student in the Gymnasium Examination (min. 0; max. 100)	ratio	53.57	16.88	
HS	The number of points scored by the student in the Humanities Examination (min. 0; max. 50)	ratio	30.215	8.554	
SS	Number of points scored by the student in the Exact and Natural Sciences Examination (min. 0; max. 50)	ratio	23.353	9.576	
CTYPE	The type of the commune where the gymnasium is located (Urban, Rural, Urban-rural)	nominal (categorical)			19.29% 35.55% 45.17%
BCITY	The size of the city/village where the gymnasium is located (Big city**, Others)	nominal (dichotomic)			23.31% 76.69%
WRO	The location of the gymnasium (Wrocław; Others)	nominal (dichotomic)			12.71% 87.29%
VOI	The Voivodship where the gymnasium is located (Lower Silesia, Opole)	nominal (dichotomic)			73.73% 26.27%
SEX	The sex of the student (Female, Male)	nominal (dichotomic)			50.03% 49.97%
DYS	The dyslexia diagnosis (Dyslexia, No dyslexia)	nominal (dichotomic)			8.25% 91.75%

* For categorical and dichotomic variables the percentage for each category is reported in order of their appearance in column (b).

** The cities with more than 80 thousand inhabitants, which include Wrocław, Opole, Jelenia Góra, Legnica and Wałbrzych.

Source: own description and elaboration.

The maximum score in each part of the examination is 50 points. The Humanities Examination is divided into two areas, each granted 25 points (1. reading and interpreting cultural content, 2. writing own text), whereas The Sciences Examination is divided into four areas (1. the abilities to use terms and notions in the area of exact and natural sciences, essential in life and further education, 2. searching and using information, 3. indicating and describing facts, connections and relationships, in particular cause-effect, functional, spatial and temporal, 4. using integrated knowledge and skills for problem solving), granted 15, 12, 15 and 8 points respectively. The thorough and complex description of respective areas, including the content analysis of each exercise may be found in [*Wyniki egzaminu*... 2010].

3. ANOVA and factorial ANOVA

ANOVA (one-way analysis of variance) allows to compare means of the dependent variable Y (measured on interval or ratio scale) across s groups ($s > 1$) [Walesiak, Gatnar 2009; Warner 2008]. The groups are identified by a variable A assessed on nominal scale (dichotomic or categorical), called factor. The s categories of the factor variable are referred to as the levels of the factor. Formally, in ANOVA a following null hypothesis, stating the equality of all groups' means, is verified:

$$H_0: \mu_1 = \mu_2 = ... = \mu_s = \mu,$$

against the alternative, stating that at least in one pair of groups' means inequality is present:

$$H_0: \mu_k \neq \mu_j,$$

where $j = 1, ..., s$; $k \neq j$.

The essence of ANOVA is to describe each observation of the dependent variable $y_{k,i}$ (where $j = 1, ..., s$; $i = 1, ..., n$; n_k – number of observations in group k) as the sum of three elements: the population mean (μ), the effect of the k-level of the factor A (α_k), and the random component ($\varepsilon_{k,i}$):

$$Y_{k,i} = \mu + \alpha_k + \varepsilon_{k,i}, \quad \varepsilon_{k,i} \sim NID(0, \sigma^2). \tag{1}$$

In reference to model (1) the null hypothesis may be rewritten as:

$$H_0: \alpha_k = 0.$$

For the model (1) the decomposition of total variation (*TSS*) into between-group variation (*ESS*) and within-group variation (*RSS*) is conducted:

$$\sum_{k=1}^{s}\sum_{i=1}^{n_k}(y_{k,i} - \overline{y})^2 = \sum_{k=1}^{s} n_k(\overline{y}_k - \overline{y})^2 + \sum_{k=1}^{s}\sum_{i=1}^{n_k}(y_{k,i} - \overline{y}_k)^2, \tag{2}$$

where $\overline{y}_k$ – k-group mean. The bigger the *ESS* in comparison to the *TSS*, the more probable the rejection of the null hypothesis. More formally, under the null hypothesis the F-statistics of the form:

$$F = \frac{ESS}{TSS} \cdot \frac{n - s}{s - 1} \tag{3}$$

follows the Fisher-Snedecor distribution with $s - 1$ and $n - s$ degrees of freedom.

Factorial ANOVA is the generalization of one-way ANOVA, which allows to introduce two or more factors, denoted A, B, C, ... Moreover, if interactions between the factors exist, their influence on the dependent variable may by modelled as well. The model for Factorial ANOVA, analogically to model (1), is given by:

$$\begin{aligned} Y_{k_A,k_B,k_C,...,i} = \mu + \alpha_{k_A} + \beta_{k_B} + \gamma_{k_C} + ... + \alpha\beta_{k_Ak_B} + \alpha\gamma_{k_Ak_C} + \beta\gamma_{k_Bk_C} + ... \\ + \alpha\beta\gamma_{k_Ak_Bk_C} + ... + \varepsilon_{k_Ak_Bk_C,...,i}. \end{aligned} \tag{4}$$

The significance of the effect of each factor (and interaction between factors) may be tested, using the following set of hypotheses:

$$H_{0,A}: \alpha_{k_A} = 0,\ k_A = 1, ..., s_A;\ H_{0,B}: \beta_{k_B} = 0,\ k_B = 1, ..., s_B; ...;$$

$$H_{0,AB}: \alpha\beta_{k_A k_B} = 0,\ k_A = 1, ..., s_A,\ k_B = 1, ..., s_B; ...;$$

$$H_{0,ABC}: \alpha\beta\gamma_{k_A k_B k_C} = 0,\ k_A = 1, ..., s_A,\ k_B = 1, ..., s_B, k_C = 1, ..., s_C; ...;$$

and for each hypothesis *F*-statistics parallel to formula (3) is calculated, with the distinction that *ESS* in each case is calculated for a given factor or interaction (for the exact formulas see e.g. [Walesiak, Gatnar 2009]).

The assumptions for the ANOVA are as follows:

1) the dependent variable should be normally distributed;

2) the variances of dependent variable should be equal across the levels of factors;

3) the factor variables should be independent of each other (in factorial ANOVA).

4. The ANOVA analysis of the total score of the Gymnasium Examination

The following part of this paper contains the results of ANOVA and factorial ANOVA application, in order to verify the hypotheses that three factors: location, sex and dyslexia have an influence on the gymnasium students' scores. As can be seen in Table 1, the location factor is captured in four different ways, resulting in the occurrence of four variables. Two of those variables (namely *CTYPE* and *VOI*) were directly present in the dataset and are the natural consequence of administrative division in Poland, whereas the remaining two (*WRO* and *BCITY*) were constructed on the basis of the dataset, and are the image of two research hypotheses: 1. the scores of the students from Wrocław, which is undoubtedly the biggest city in both voivodships with a substantially larger number of educational institutions, are significantly different (higher) from the scores of other students; 2. the scores of the students from big cities are significantly different (higher) from the scores of the students from smaller cities and villages. Figure 1 presents the box plots for dependent variable *TS* for different levels of all factors. For the first factor – the type of the commune – the within-group means were equal 51.88, 55.80 and 51.65 accordingly, suggesting a significant difference between urban and rural areas as well as between urban and urban-rural, and much smaller difference between rural and urban-rural areas. The next two graphs seem to support the raised research hypotheses. Especially in the case of the distinction of the city Wrocław, where the means are equal 61.12 for the capital city of Lower Silesia and 52.47 for other cities and villages. The students from big cities scored on average 58.32, while the students from smaller cities and villages 52.12. The last location factor – variable *VOI* – differentiates the

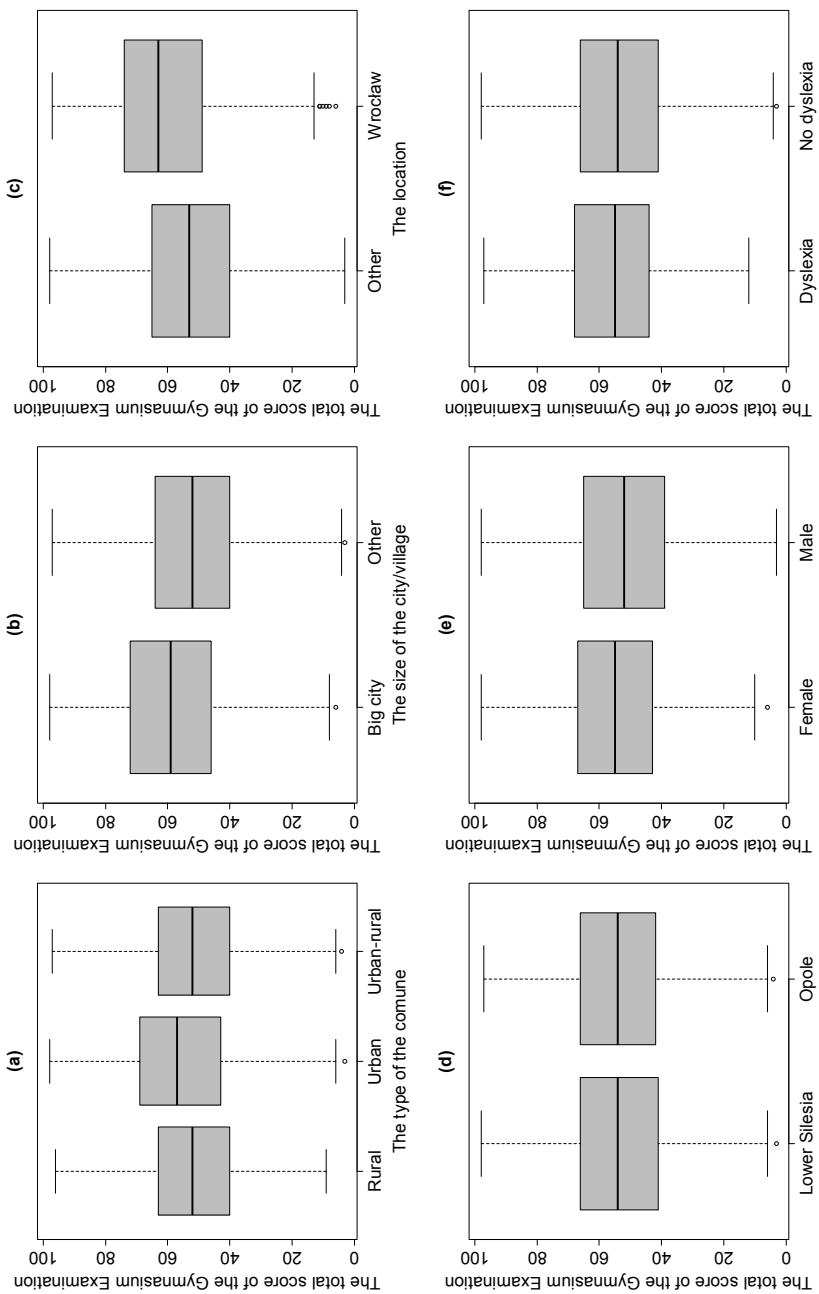

Figure 1. The relationship between the total score of the Gymnasium Examination (*TS*) and the factors: (a) the type of the commune (*CTYPE*), (b) the size of the city/village (*BCITY*), (c) the location (*WRO*), (d) the Voivodeship (*VOI*), (e) the sex of the student (*SEX*), (f) the dyslexia diagnosis (*DYS*)

Source: own elaboration.

students' results to a very small degree. The students from Lower Silesian gymnasiums were granted on average 53.55 points, and students from Opole voivodship 53.62. In turn, the variable *SEX* appears to have a significant influence on the students' scores. The girls on average scored around 3 points more than the boys (the means were 55.08 and 52.05 accordingly). The last variable analysis yields somewhat confusing results, indicating that the students with diagnosed dyslexia actually did better during the Gymnasium Examination – their average score was 55.41 versus 53.40 for other students.

ANOVA allows to evaluate whether the obtained differences within a group means are statistically significant or not. The same could be obtained by pairwise comparisons of means using *t*-tests, however in the case of more than two levels of the factor (e.g. variable *CTYPE*) such a procedure may lead to a large risk of the type I error. Moreover apart from the individual influence of each factor, an additional joint influence of the combination of the factors (the interaction) may be modelled using factorial ANOVA. In view of those facts, ANOVA was chosen as the tool of this research, and the results for the dependent variable *TS* are presented in Table 2. The analysis was preceded by a thorough examination of the assumptions' violations. All conducted statistical tests for normality (χ^2 test, Lilliefors test, Jarque-Bera test) quite strongly rejected the null hypothesis of normality of the dependent variable. However since the sample size is very large, and ANOVA is quite robust to violation of normality assumption (see e.g. [Warner 2008, p. 510]) no measures were undertaken. The second assumption – the homogeneity of variances for different

Table 2. ANOVA and Tukey-Kramer test results (dependent variable *TS*)

Analysis No.	Factor	Degrees of freedom	*F*-statistic	*F*-test p-value	Tukey-Kramer test p-value
1	*CTYPE*	2	295.01	2,2e-16 ***	(urban, rural): 2,2e-05*** (urban, urban-rural): 2,2e-05*** (rural, urban-rural): 0,649
	Residuals	40,916			
2	*BCITY*	1	925.82	2.2e-16***	9e-06***
	Residuals	40,917			
3	*WRO*	1	1,229.9	2.2e-16***	9e-06***
	Residuals	40,917			
4	*VOI*	1	0.1442	0.7041	-
	Residuals	40,917			
5	*SEX*	1	332.10	2.2e-16***	9e-06***
	Residuals	40,917			
6	*DYS*	1	46.839	7.815e-12***	1.1e-05***
	Residuals	40,917			

*** the significance level 0.001.

Source: own elaboration.

levels – was not valid for factors *CTYPE*, *BCITY*, *VOI*, *SEX* and *DYS* (the Levene's test on 0.01 significance level was used). Only for the factor *WRO* the null hypothesis of homoscedasticity was not rejected with *p*-value 0.053. In the case of the variables, for which heteroscedasticity was detected, the heteroscedasticity-corrected covariance matrices proposed by White [White 1980] were calculated to provide necessary amendment. All the calculations in Tables 2, 4, 5 and 6 were executed in **R** environment using package `car` written by Fox [2011].

In the case of all conducted analyses the null hypothesis, stating the equality of all groups' means was strongly rejected, except for the factor *VOI*, where the hypothesis could not be rejected, with substantially high *p*-value 0.7041. Thus the factor *VOI* was not taken into account in the following steps of the research. In order to identify which differences in means are significant (in the case of variable *CTYPE*) and due to the unequal number of observations in groups (especially in the case of variables *BCITY*, *WRO* and *DYS*), additional analysis (called post-hoc) with the application of Karmer's modification (see [Kramer 1956]) of Tukey's HSD[5] test was carried out. The test confirmed all previous results, reporting statistically significant differences in within group means for factors *CTYPE* (but only in pairs (urban, rural) and (urban, urban-rural)), *BCITY*, *WRO*, *SEX* and *DYS*.

The next section presents the results of factorial ANOVA of *TS* by *WRO* (factor *A*) and *SEX* (factor *B*). Parallel analyses with the use of *BCITY* and *CTYPE* location factors were conducted as well, however, the results will be omitted due to the limited size of this paper. The choice of factors is justified by following:

1) the variable *WRO* was chosen as the best (in view of *F*-test results) representation of the location factor (all the location variables are correlated, and their joint presence would violate the assumptions);

2) the variable *DYS* was omitted due to its smallest significance (the statistical significance was excellent due to large number of degrees of freedom but the difference in means was only 2 points), multicollinearity (Farrar-Glauber test [Farrar, Glauber 1967] was used,[6] resulting in p-value close to 0) and ambiguous interpretation (it is not clear why students with dyslexia obtained better results; if the finding is really true it could be the result of dissimilarities in grading (the dyslexia students are allowed to be mistaken 5 times without any consequences), the additional time for completion of the exercises or additional classes taken by those students, either way more research into the subject is needed);

3) the set of variables (*WRO*, *SEX*) was tested for multicollinearity, and the null hypothesis of no multicollinearity was not rejected with *p*-value 0,281.

The uneven number of observations in groups is not very problematic as long as the groups are balanced, i.e. the proportion of numbers of cases A_1/A_2 is the same for

[5] For the description of Tukey HSD test and statistical tables see e.g. [Rószkiewicz 2002].

[6] The function written by the author in **R** environment may be downloaded from the internet site http://www.ekonometria.ue.wroc.pl/modules.php?op=modload&name=Downloads&file=index&req=viewdownload&cid=17.

B_1 and B_2 (and vice versa). The analysis of groups' balance (presented in Table 3) proves that the groups are very close to being balanced. Even though the representation of students from gymnasiums located in Wrocław is lower than the representation of other students, there is no risk that the students from Wrocław are more likely to be male (or female) than the students from other cities or villages. Likewise, the boys are as likely to attend the gymnasium in Wrocław as girls are.

Table 3. Number of observations in groups in factorial ANOVA of *TS* by *WRO* and *SEX*

	Wrocław (A_1)	Others (A_2)	Sum
Male (B_1)	2,572	17,874	20,446
Female (B_2)	2,631	17,842	20,473
Sum	5,203	35,716	40,919

Source: own elaboration.

Figure 2 presents the box plot for variable *TS* for different levels of all the factors. The means in subsequent groups were: 54.06, 50.88, 62.03 and 60.19. Figure 3 presents the means within groups in the way allowing for identification of interactions. Since the lines are slightly non-parallel, there is a possibility of joint influence of combination of factors *WRO*SEX*. The results of factorial analysis of variance of variable *TS* by factors *WRO* and *SEX* are presented in Table 4. As before the correction for heteroscedasticity was imposed and the post-hoc Tukey-Kramer test was conducted.

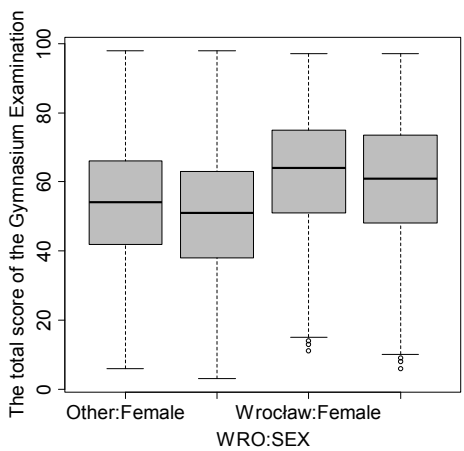

Figure 2. The total score of the Gymnasium Examination (*TS*) for the girls and the boys for gymnasiums located in Wrocław and other gymnasiums

Source: own elaboration.

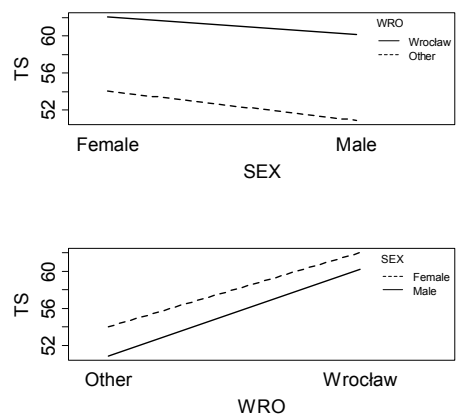

Figure 3. The interaction analysis between *WRO* and *SEX* for *TS* variable

Source: own elaboration.

The results prove that both factors, the location of the gymnasium (more precisely: whether the gymnasium is located in Wroclaw or not) and the sex of the student, significantly influence the total score of the student in Gymnasium Examination. The differences are quite substantial, especially in respect to the location factor. The boys from gymnasiums located in Wrocław on average obtained over 9 points more than other boys; for the girls the difference was smaller – about 8 points. The sex factor is less important and account for about 2 points difference between the girls and the boys in Wrocław, and about 3 points in other cities and villages.

Table 4. Factorial ANOVA of *TS* by *WRO* and *SEX* results

Factor	Degrees of freedom	*F*-statistic	*F*-test *p*-value
WRO	1	1,234.954	2e-16***
SEX	1	336.925	2e-16***
WRO·SEX	1	7.404	0.00651**
Residuals	40,915		

** the significance level 0.01; *** the significance level 0.001.

Source: own elaboration.

Moreover the influence of the sex of the students on the score is significantly different in Wrocław in comparison to other cities or villages (although the significance of the interaction is smaller than the significance of individual factors). The female students from Wrocław tend to obtain on average about 1.3 points more than would be expected just from the additive combination of the individual factors of sex and location.

5. The ANOVA analysis of the scores of the Humanities Examination and the Sciences Examination

An analogical analysis was conducted for separate parts of examination – the Humanities Examination and the Sciences Examination.

The presentation will be limited only to the results of factorial ANOVAs with specifications as presented in case of total scores, for the sake of conciseness of this paper. The findings for the Humanities Examination results (presented in Figures 4, 5 and in Table 5) are similar to previous results, however in this case the location factor seems to have slightly less effect on the scores then the sex factor (in terms of *F*-statistics). In Figure 4 it can be clearly seen that regardless of the location, the girls on average tend to obtain better results in the Humanities Examination than the boys (the respective group means were 31.45, 28.05, 34.65 and 32.20).

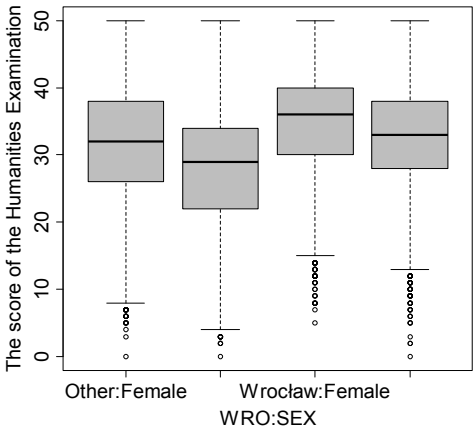

Figure 4. The score of the Humanities Examination (*HS*) for the girls and the boys for gymnasiums located in Wrocław and other gymnasiums

Source: own elaboration.

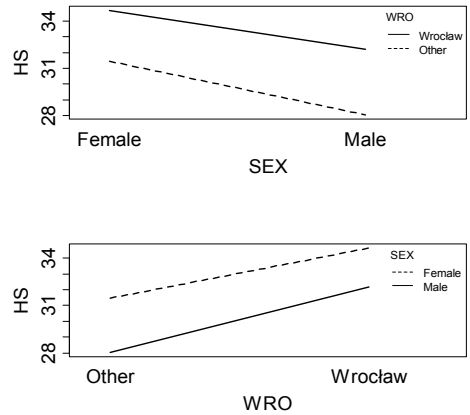

Figure 5. The interaction analysis between *WRO* and *SEX* for *HS* variable

Source: own elaboration.

Table 5. Factorial ANOVA of *HS* by *WRO* and *SEX* results

Factor	Degrees of freedom	*F*-statistic	*F*-test *p*-value
WRO	1	949.536	2.2e-16***
SEX	1	1,584.57	2.2e-16***
*WRO*SEX*	1	16.01	6e-05***
Residuals	40,915		

*** the significance level 0.001.

Source: own elaboration.

The students from gymnasiums located in Wrocław obtained on average higher scores – about 3 points more for girls, and about 4 points for boys. All the differences were statistically significant, both in ANOVA *F*-test and in Tukey-Kramer test. A significant influence of combination of factors *WRO* and *SEX*, of the similar nature as in the case of total scores, was also reported. In the case of the Humanities Examination the interaction influence could account for about 1 point in the students results.

The results of factorial ANOVA for the Sciences Examination are presented in Figures 6, 7 and in Table 6. The plots and calculations imply that the dominant factor influencing the students results in the exact and natural sciences field is location. Both male and female students from Wrocław obtained about 5 points more in comparison to the students from other cities and villages. In contrast to previous

analyses, the boys tend to do better in the Sciences Examination than the girls, but the difference (although statistically significant) is very small – less than one point (the respective within group means were 22.61, 22.83, 27.39 and 27.99). The presence of joint influence of factors *WRO* and *SEX* was not supported by the data from the Science Examination (the hypothesis could not be rejected with *p*-value 0.1956).

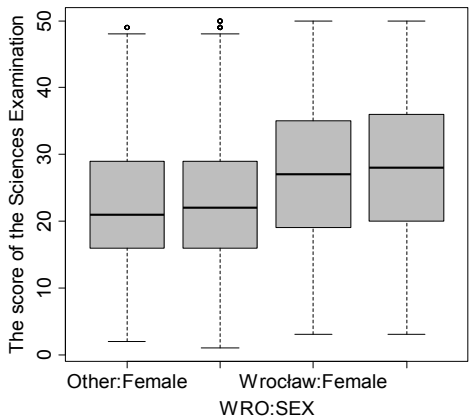

Figure 6. The score of the Sciences Examination (*SS*) for girls and boys for schools located in Wrocław and other schools

Source: own elaboration.

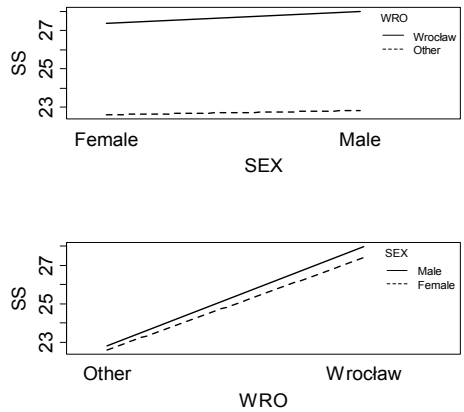

Figure 7. The interaction analysis between *WRO* and *SEX* for *SS* variable

Source: own elaboration.

Table 6. Factorial ANOVA of *SS* by *WRO* and *SEX* results

Factor	Degrees of freedom	*F*-statistic	*F*-test *p*-value
WRO	1	1,106.008	2.2e-16***
SEX	1	8.078	0.0045**
WRO·SEX	1	1.675	0.1956
Residuals	40,915		

** the significance level 0.01; *** the significance level 0.001.

Source: own elaboration.

6. Conclusions

The aim of the conducted research was to investigate whether there were significant differences in the results of the Gymnasium Examination in 2010 in the Lower Silesia and Opole voivodships, in respect to three characteristics: the location of the gymnasium, the sex of the student and the dyslexia diagnosis. For this purpose the methods of ANOVA and factorial ANOVA with the correction for heteroscedasticity were used.

The results of the study provide some evidence that the factors under examination influence the students' scores of the Gymnasium Examination in the following way:

- both the total scores and the partial scores (i.e. separate scores for the Humanities and the Sciences Examinations) are significantly higher for students:
  - from Wrocław in comparison to students from other cities and villages,
  - from big cites (i.e. Wrocław, Opole, Jelenia Góra, Legnica and Wałbrzych) in comparison to other cities and villages,
  - from urban regions in comparison to rural and urban-rural regions (however no significant differences between rural and urban-rural regions were reported);
- the differences in scores of students from different voivodships (Lower Silesia and Opole) are statistically insignificant;
- the total scores of the Gymnasium Examination are significantly higher for the female students in comparison to the male students (the difference is mainly due to the Humanities Examination, where the superiority of the girls is explicit; in the Sciences Examinations an opposite tendency is present though to a much smaller degree);
- the influence of the dyslexia diagnosis is ambiguous and unclear; a final conclusion in this matter requires additional research.

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IDENTYFIKACJA WYBRANYCH ŹRÓDEŁ ZMIENNOŚCI W WYNIKACH EGZAMINÓW GIMNAZJALNYCH Z WYKORZYSTANIEM ANALIZY WARIANCJI

Streszczenie: Egzamin gimnazjalny jest jedną z części wprowadzanego w Polsce od 2002 r. systemu oceny zewnętrznej. Jest to pierwszy dla każdego ucznia egzamin, którego rezultaty mają istotny wpływ na jego dalszą edukację. W związku z tym konieczne jest przeprowadzenie rozległych i różnorodnych badań wyników egzaminów gimnazjalnych, które to badania pozwolą na identyfikację czynników wpływających na wyniki uczniów. W artykule podjęto próbę identyfikacji źródeł zmienności w wynikach egzaminu gimnazjalnego przeprowadzonego w 2010 r. w województwach dolnośląskim i opolskim. W szczególności badaniu poddano wpływ na różnice w wynikach takich czynników, jak umiejscowienie szkoły, płeć ucznia oraz diagnoza dysleksji. Rezultaty badania mogą stanowić przydatną wskazówkę do tworzenia regionalnych strategii uwzględniających politykę równych szans w edukacji.

Słowa kluczowe: ANOVA, wieloczynnikowa ANOVA, analiza wariancji, wyniki egzaminów, gimnazja.