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An Analysis of Differentiated Levels of Knowledge of Junior High School Graduates in 2002-2013

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Abstract

The aim of the article is to apply selected methods of econometrics (dynamic and spatial) for analysis and assessment of knowledge and skills of junior high schools graduates in the years 2002-2013. In particular, the objective of the analyses was to answer the following questions:

- How did junior high school students cope with the tasks and issues contained in the exam in the part concerned with mathematics and natural sciences as well as in the humanities part in subsequent years?
- Are there any differences in the results obtained in the exams in the sub-periods of the twelve years under discussion?
- Are there any differences in the exam results in the individual sub-periods between voivodships and the parts of the exam?

In the analyses, data were used obtained from Student Achievement Analysis Team operating at the Institute for Educational Research[1] which made it possible not only to assess the dynamic changes in the graduates' exam scores but also to conduct their spatial analysis by voivodships. Linear trend was used for the dynamics analysis, whereas for the studies of spatial changes, the k-means classification method was employed.

The analysis showed certain regularities present in the scores achieved by the junior high school graduates:

- There was a systematic decline in the graduates' performance in mathematics and natural sciences in all voivodships in the period under study.
- The division of the years 2002-2013 into three periods – good, medium and poor results of junior high school graduates – had no clear impact on the diversification amongst voivodships.
- Students from the voivodships of south-eastern Poland achieved better exam scores in mathematics and natural sciences, and humanities.

The analysis has cognitive and applicative value. It can be used by local governments in their decision-making process relating to the improvement of the quality of educational services at the junior high school level.

[1] http://pwe.ibe.edu.pl/ [accessed on 20.09.2015]

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Introduction

16 years have passed since the launch of reforms in Poland pertaining to programs and methods of didactic and educational work. The reforms were concerned with the education structure transformation, with the aim to improve the quality of the education system and adjust it to the requirements of a modern economy. "The changes were to ensure that the population of learners would have access to a lifelong learning system. They were also to improve the links between higher education institutions, academic community and business, which, in turn, was to have a positive impact on the technology transfer process between science and practice, such as we witness in other countries" (Błaczkowska, 2015, p. 585; Goldberg et al., 2004).

The aim of this paper is to investigate whether, during the implementation of the reform and the functioning of a new component of compulsory education – junior high schools – graduates of those schools performed better year by year. Two main fields of knowledge were subject to evaluation: mathematics and natural sciences, and humanities. Moreover, the analyses were to find out whether the entire period under discussion, covering the years 2002-2013, was uniform in terms of graduates' performance, or whether it is possible to distinguish certain periods characterized by better or worse exam scores. In addition, it was examined whether there were any differences in the distinguished sub-periods as regards the graduates' knowledge, both due to the territory – in individual voivodships, and to the tested fields of knowledge.

Studies on pupils' progress are necessary for new education methods to be improved and implemented.

The results of the PISA[2] test show that Polish youth aged 15 have increasingly better achievements test by test (PISA assessment has been carried out every three years since 2000). Poland moved from being ranked 24, amongst all the countries participating in the test, in 2003 [3](total of 40 countries) to rank 14 in 2012[4] (total of 64 countries)[5].

15-year-olds from randomly selected schools participate in PISA sample tests, while the results and assessment of the level of knowledge of junior high school graduates cover 16-year-olds leaving those schools.

In the analysis, data from Student Achievement Analysis Team operating at the Institute for Educational Research was used, which allow for comparing the graduates' scores not only between schools or territorial units within a period of one year, but also between different years. The equalized

[2] PISA Programme for International Student Assessment. It coordinated by OECD (*Organization for Economic Co-operation and Development*) internationally with several dozens countries across the world participating in the programme, including Poland.

[3] In 2000 the measurement of the level of knowledge covered pupils who were educated in the old educational system, that is the graduates of 8-year primary schools, already attending the first classes of schools above the primary level.

[4] The PISA report from the test carried out in 2015 is not yet available.

[5] Programme for International Student Assessment; OECD PISA, TEST RESULTS 2012 IN POLAND; PISA 2012; http://www.ibe.edu.pl/images/prasa/PISA-2012-raport_krajowy.pdf [accessed on 21.09.2012]

exam scores, which were used, are uniform in terms of the test difficulty across different years. "If the difficulty of the tests in subsequent years was similar, then, on the basis of the test results, it would be possible to make conclusions as to how the level of pupils' skills changes over time. However, constructing tests having similar parameters is a very difficult task and it is not always successful. The comparability of results between various years can be achieved by controlling the difficulty of the test (procedure of equalizing scores), or assuming a constant level of skills in the population (normalization and standardization of distributions, e.g. mapped to the stanine scale). In the first case, we obtain an absolute comparability of scores and the possibility to draw conclusions as to the change of skills of the population. In the second case, we obtain relative comparability in relation to the mean score in a given year[6] Equalized test scores are interpreted as the mean score which would have been achieved by pupils taking the junior high school leaving exam in a given school, municipality, poviat or voivodship, had they taken the exam in 2012.

Research Methods

The analysis of the degree of differentiation of the scores was carried out in two dimensions: dynamic and spatial. The studies covered the years 2002-2013[7]. Mean equalized exam scores were generated for those years by voivodships in the field of mathematics and natural sciences, and humanities.

For the analysis of the dynamics of change observed in the exam scores the linear trend models were employed (Aczel, 2003, pp. 624-628) having the following form:

$\hat{y}_t = a_0 + a_1 t$,

where ai denotes the estimation of the structural parameters of the model, t is a time variable, and yt is the analysed phenomenon. For the evaluation of the correctness of the estimated trend models, their adjustment was tested by using the coefficient of determination R2 and a significance test was performed for directional parameters of the models by applying t-Student test (Lipiec-Zajchowska (ed.), 2003, pp. 8-9)

For the analysis of the spatial differentiation of the exam scores, a classification method – k-means method – was employed.

The classification methods – of clustering and partitioning, hierarchical and non-hierarchical ones – consist in isolating certain subsets, in a set of observations, which are characterized by distinctive properties. They are applied in the situation where the characteristics of these subsets are yet unknown, as they are in the process of being discovered. These methods have seen numerous theoretical and practical applications (in particular, Balicki, 2013; Jajuga, 1993; Gatnar, Walesiak (ed.), 2004; Grabiński et al., 1989; Nowak, 1990, Pociecha, 1996; Pociecha et al., 1988; Walesiak, 1996). One of the classification methods very frequently applied is the k-means method (centroids) (Stanimir (ed.), 2006), which was used in this paper. This method belongs to a group of methods optimizing the preliminary division of the set of objects which can be obtained using any classification method, established randomly or by the researcher's intuition. For each class arising from the preliminary division the centroids and distances of each object from these centroids are determined. The underlying idea is to find such a division of the set of n objects against K classes for which

[6] **http://pwe.ibe.edu.pl/** Czym są Porównywalne Wyniki Egzaminacyjne (PWE)? [accessed on 20.09.2015]

[7] Equalised data are published only until 2013.

the value of the function below is minimum:

$$\sum_{k=1}^{K}\sum_{i\in C_k}(d_{ik})^2,$$

where: dik – distance between the i-th object and the vector of the measures of location calculated on the basis of objects from the k-th class;

$i \in C_k$ - i-th object belongs to the k-th class.

The essence of the correct classification is to have classes comprising objects as similar to one another as possible, hence the distances of the objects from the class centroid and between objects belonging to one class should be as small as possible (Stanimir (ed.), 2006, pp. 111-113).

The Analysis of the Dynamics of Junior High School Exam Scores in 2002-2013

In the first stage of the analysis, linear trends models were determined for the mean equalized exam scores from the years 2002-2013. The models of trends were determined for each voivodship, separately for the results obtained in the mathematics and natural sciences part, and in the humanities part (Table 1).

Table 1. Trend models parameters for 2002-2013 by voivodships together with stochastic structure parameters

Voivodeship	Part							
	Mathematics and natural sciences				Humanities			
	a0	a1	ta1	R2	a0	a1	ta1	R2
Dolnośląskie	102,69	-0,437	-4,927	0,71	98,61	-0,090	-0,606	0,04
Kujawsko-pomorskie	101,66	-0,339	-4,248	0,64	96,20	0,124	1,042	0,10
Lubelskie	103,61	-0,455	-4,030	0,62	99,04	0,059	0,559	0,03
Lubuskie	99,61	-0,075	-1,206	0,13	96,92	0,137	1,180	0,12
Łódzkie	105,48	-0,592	-4,951	0,71	97,62	0,088	0,640	0,04
Małopolskie	104,76	-0,349	-2,630	0,41	100,41	0,054	0,411	0,02
Mazowieckie	106,45	-0,525	-5,245	0,73	100,65	0,028	0,267	0,01
Opolskie	101,47	-0,228	-2,669	0,42	96,78	0,129	0,907	0,08
Podkarpackie	103,58	-0,338	-2,262	0,34	98,33	0,213	2,053	0,30
Podlaskie	104,09	-0,402	-4,065	0,62	97,38	0,092	0,642	0,04
Pomorskie	103,57	-0,494	-5,725	0,77	96,89	-0,024	-0,163	0,00
Śląskie	102,57	-0,323	-3,868	0,60	100,15	-0,077	-0,595	0,03
Święto-krzyskie	106,10	-0,812	-5,293	0,74	97,59	0,048	0,356	0,01
Warmińsko-mazurskie	99,73	-0,159	-1,840	0,25	94,69	0,208	1,798	0,24
Wielko-polskie	101,95	-0,311	-4,997	0,71	98,32	-0,099	-0,740	0,05
Zachodnio-pomorskie	101,15	-0,326	-3,874	0,60	98,09	-0,084	-0,850	0,07

Source: Author's own study based on the data of Student Achievement Analysis Team operating at the Institute for Educational Research http://pwe.ibe.edu.pl/ [accessed on 20.09.2015]

It can be easily gleaned from the table that in all voivodships, in the years under discussion, there was a decline in the knowledge of mathematics and natural sciences, which is illustrated by the negative directional parameters of the estimated trend models. For all voivodships, with the exception of two – Lubuskie and Warmińsko-Mazurskie- the decline is statistically significant (Student test), at the significance level of $\alpha = 0,05$. The adjustment of models, measured by the determination coefficient R2 is also sound. Only in five voivodships (Lubuskie, Małopolskie, Opolskie, Podkarpackie and Warmińsko-Mazurskie) it is weak ($R2 < 0,5$).

The trajectory of changes in the exam scores in mathematics and natural sciences for six voivodships where the significance of the trend directional parameters was at the level of $\alpha = 0,001$ is shown in Figure 1.

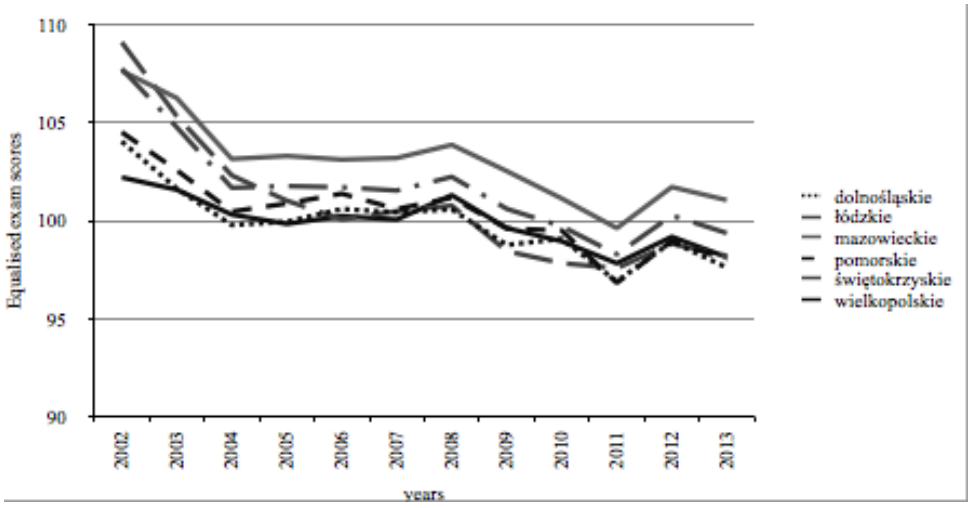
The change dynamics of the exam scores in mathematics and natural sciences in the voivodships where the significance of the trend directional parameters was at the level of $\alpha = 0,05$ is shown in Figure 2.

For two voivodships with insignificant trend directional parameters the trajectory of changes in the exam scores in mathematics and natural sciences is shown in Fig 3.

In both voivodships, the level of knowledge is very differentiated in the subsequent classes of junior high school graduates. However, the behavior of the trend empirical functions for the two voivodships is similar in the period under discussion. It is also worth noting that only in two years – 2002 and 2008 – the scores of pupils from these voivodships were only slightly above the 100 level, which corresponds to the mean score in 2012 for Poland (resulting from the procedure of equalizing the exam scores). In the remaining years, the graduates from these voivodships achieved worse scores than the mean score.

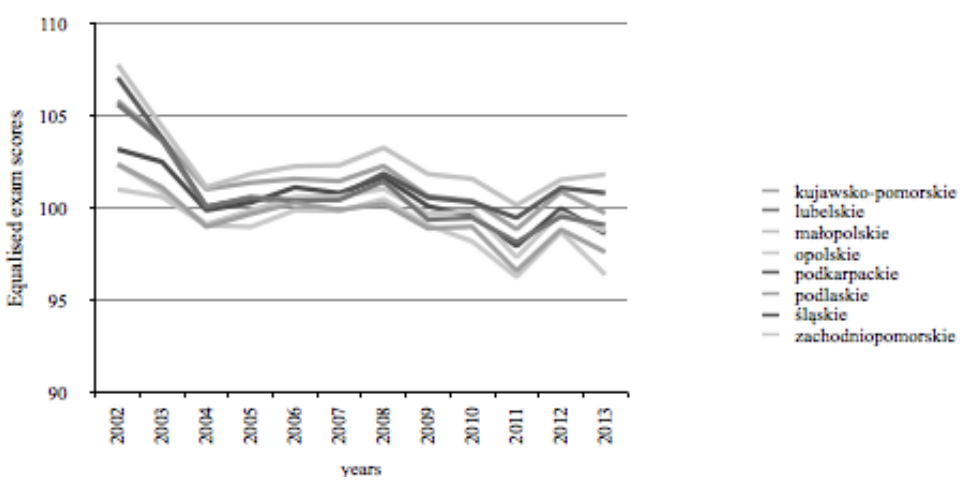
The scores achieved in the humanities exams differ clearly from those in mathematics and natural sciences. Only five voivodships saw a decline in the knowledge of humanities in

Fig. 1 The change dynamics of the exam scores in mathematics and natural sciences in six selected voivodships in 2002-2013.



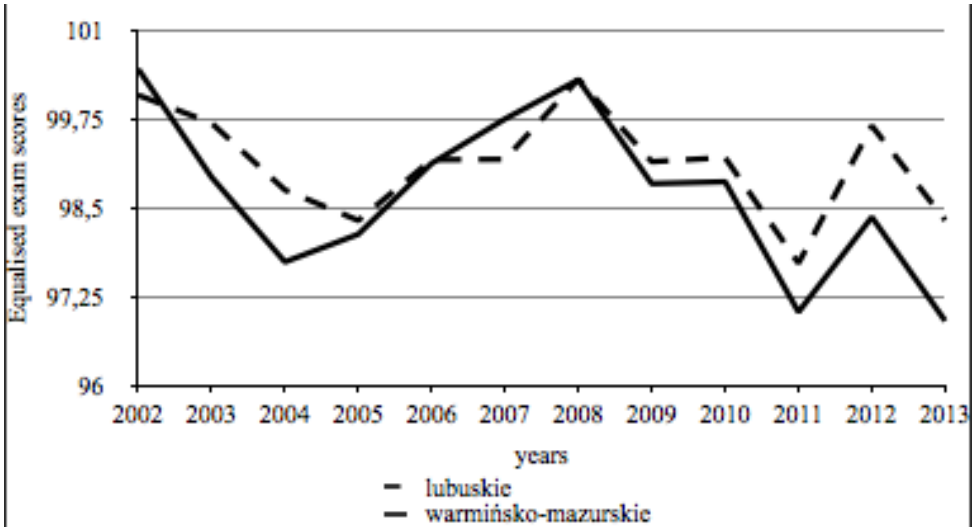
Source: Author's own study based on the data of Student Achievement Analysis Team operating at the Institute for Educational Research http://pwe.ibe.edu.pl/ [accessed on 20.09.2015]

Fig 2. The change dynamics of the exam scores in mathematics and natural sciences in the voivodships where the significance of the trend directional parameters was at the level of α = 0,05.



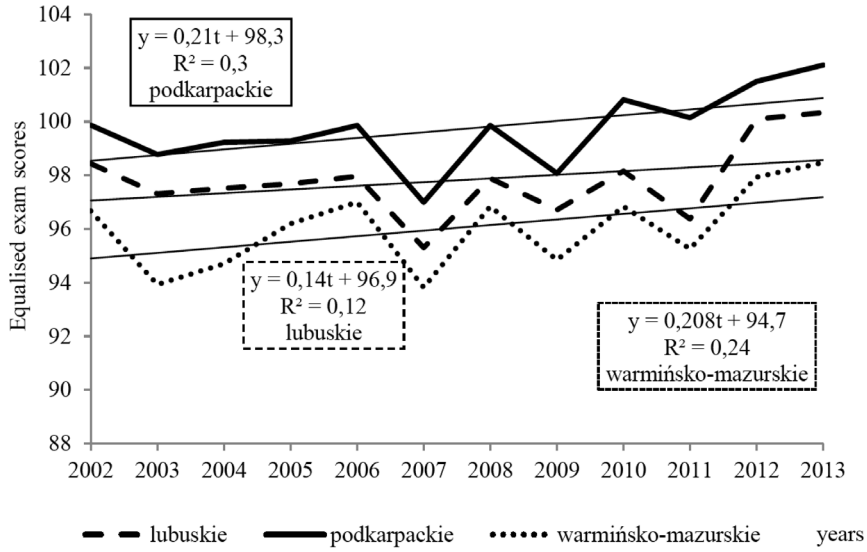
Source: Author's own study based on the data of Student Achievement Analysis Team operating at the Institute for Educational Research http://pwe.ibe.edu.pl/ [accessed on 20.09.2015]

Fig 3. The change dynamics of the exam scores in mathematics and natural sciences in Lubuskie and Warmińsko-Mazurskie voivodships in 2002-2013.



Source: Author's own study based on the data of Student Achievement Analysis Team operating at the Institute for Educational Research http://pwe.ibe.edu.pl/ [accessed on 20.09.2015]

Fig 4. The change dynamics of the exam scores in humanities in Lubuskie,Podkarpackie and Warmińsko-Mazurskie voivodships in 2002-2013.



Source: Author's own study based on the data of Student Achievement Analysis Team operating at the Institute for Educational Research http://pwe.ibe.edu.pl/ [accessed on 20.09.2015]

the years under study – Dolnośląskie, Pomorskie, Śląskie, Wielkopolskie and Zachodniopomorskie. For all the voivodships, directional parameters of trend models are statistically insignificant (for α =0,05). Only in Lubuskie, Podkarpackie and Warmińsko-Mazurskie voivodships could they be considered to be significant, with the significance levels being as follows: α = 0,3, α = 0,1, α = 0,2, respectively. The estimated parameters should therefore be regarded as insignificant statistically. Moreover, the adjustment of models measured by the determination coefficient R2 is also very weak.

The trajectory of changes in the junior high school humanities exam for the three "best" voivodships in this respect is presented in Fig. 4.

In the three voivodships demonstrated in Fig, 4 the change dynamics is the greatest amongst all other voivodships. Podkarpackie voivodship is characterized by the fastest increase in the graduates' performance, where, in addition, the exam scores slightly exceeded 100 points in the last years of the period under study. The second voivodship with the similar dynamics of changes is Warmińsko-Mazurskie, whose scores, however, were below the mean of 100 points during the entire period under study. Małopolskie and Mazowieckie are the voivodships with the exam scores being above 100 points almost throughout the entire period under discussion.

Classification of Voivodships in 2002-2013

The individual voivodships differ in terms of the change dynamics of the exam scores and the level of those scores. Assuming that the voivodships are objects and the scores in individual years represent variables, their

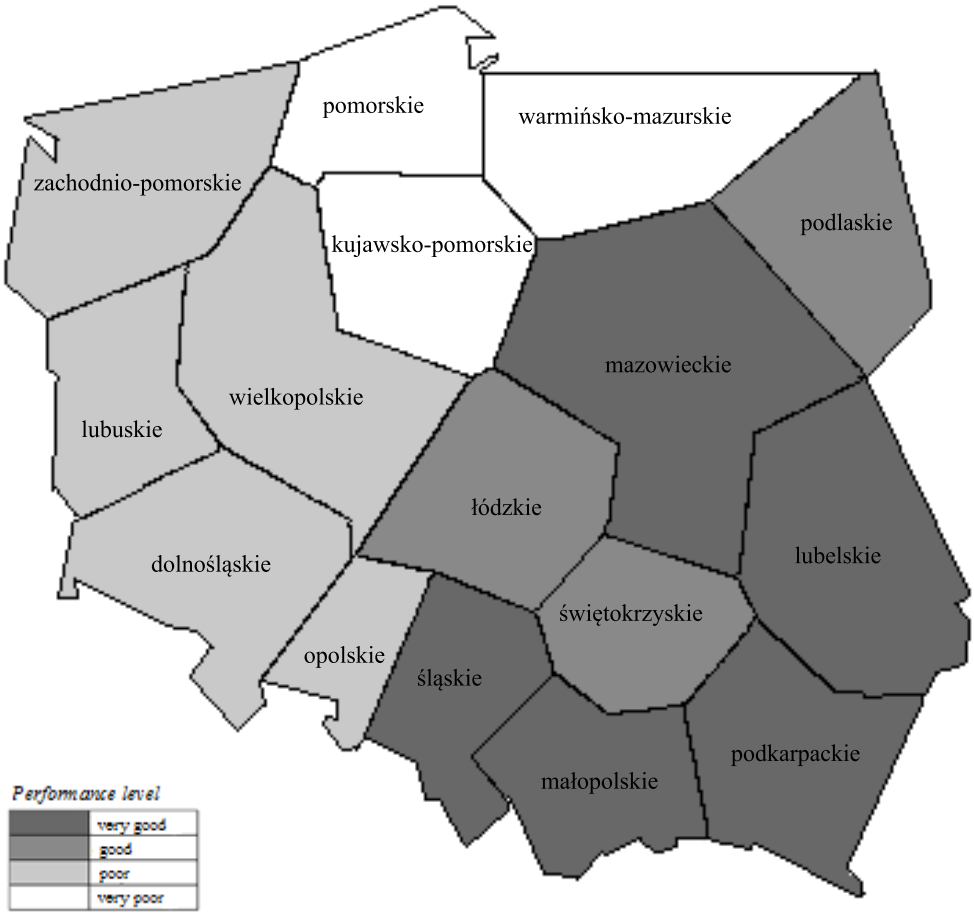


Fig. 5 The map representing the classification of voivodships by junior high school exam scores in humanities in 2002-2013

Source: Author's own study based on the data of Student Achievement Analysis Team operating at the Institute for Educational Research http://pwe.ibe.edu.pl/ [accessed on 20.09.2015]

classification was carried out using the k-means method. The division obtained comprised four classes with the following levels of knowledge: very good, good, average and poor. The division into classes was done separately for exams in mathematics and natural sciences, and in humanities. The scores which were achieved are shown in Figure 5 and 6.

The classification of voivodships according to the exam scores of junior high school graduates allowed for distinguishing regions whose level of knowledge was clearly similar.

In the area of humanities, the graduates in south-eastern regions performed better in the entire period under study than the graduates coming from the north-western voivodships.

The comparison of the mean scores for the generated classes of voivodships are presented in Table 2.

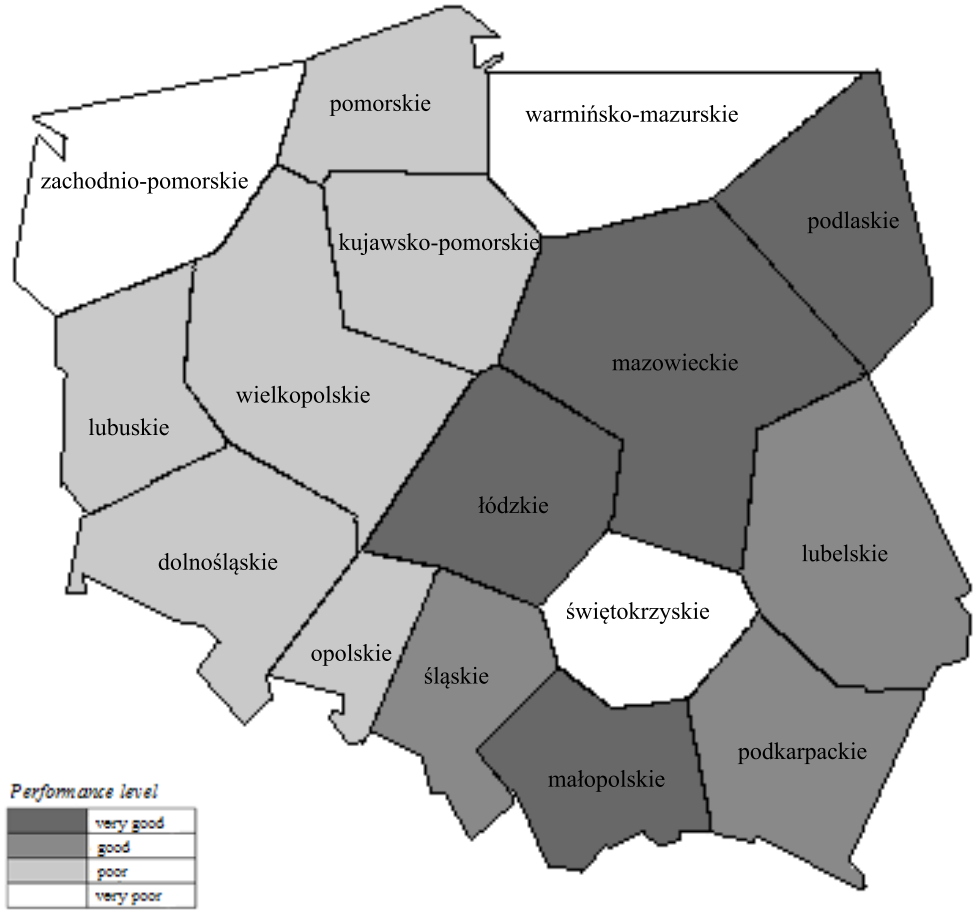


Fig. 6 The map representing the classification of voivodships by junior high school exam scores in mathematics and natural sciences in 2002-2013

Source: Author's own study based on the data of Student Achievement Analysis Team operating at the Institute for Educational Research http://pwe.ibe.edu.pl/ [accessed at 20.09.2015]

Table 2. The mean scores in humanities by the voivodship classes.

Class	Class number	Voivodships belonging to a particular class	Mean score for the class
Verygood	1	Lubelskie, Małopolskie, Mazowieckie, Podkarpackie, Śląskie	100,07
Good	2	Łódzkie, Podlaskie, Świętokrzyskie	98,03
Average	3	Dolnośląskie, Lubuskie, Opolskie, Wielkopolskie, Zachodniopomorskie	97,74
Poor	4	Kujawsko-Pomorskie, Pomorskie, Warmińsko-Mazurskie	96,59

Source: Author's own study based on the data of Student Achievement Analysis Team operating at the Institute for Educational Research http://pwe.ibe.edu.pl/ [accessed on 20.09.2015]

Table 3. The mean exam scores in mathematics and natural sciences by voivodship classes.

Class	Class number	Województwa należące do klasy	Mean score for the class
Very good	1	Łódzkie, Mazowieckie, Małopolskie, Podlaskie	102,16
Good	2	Lubelskie, Podkarpackie, Śląskie	100,83
Average	3	Dolnośląskie, Lubuskie, Opolskie, Wielkopolskie, Pomorskie, Kujawsko-Pomorskie	99,78
Poor	4	Świętokrzyskie, Warmińsko-Mazurskie, Zachodniopomorskie	99,52

Source: Author's own study based on the data of Student Achievement Analysis Team operating at the Institute for Educational Research http://pwe.ibe.edu.pl/ [accessed on 20.09.2015]

The classification of voivodships according to the exam scores in mathematics and natural sciences did not yield regions with such clearly similar scores. However, the graduates in south-eastern voivodships (with a very few exceptions) also perform better than their peers from north-western voivodships.

The comparison of the mean scores for the classes of voivodships is shown in Table 3.

The classification of voivodships according to the two distinguished fields of knowledge could be considered to be stable in that the voivodships belonging to, e.g. a class with very good results in humanities also belong to that class in mathematics and natural sciences. In order to evaluate this stability more objectively, let us employ Kendall's coefficient of concordance τ. Ranks were given to individual voivodships, taking into account their position in the classification (very good, good, average and poor class) and that in a specific class there are a few voivodships at the same position (tied ranks).

The Kendall's coefficient of concordance τ, which was determined and equal to 0,59, indicates an average stability of those classifications. The least stable were Podkarpackie and Świętokrzyskie voivodships.

The next step of the analysis is connected indirectly with the dynamics of changes in the exam scores in 2002-2013. In the entire period, certain sub-periods were observed which differed fairly considerably in the graduates' performance level at the exams. Hence, the years 2002-2013 were divided into three sub-periods[8]:

- good performance period,
- average performance period,
- poor performance period.

In each of the sub-periods thus obtained, the voivodships were divided into four classes (with the level of performance being very good, good, average and poor), separately for the knowledge of mathematics and natural sciences, and of humanities.

A somewhat different sub-periods were obtained in the field of mathematics and natural sciences than of humanities. The sub-periods determined for the scores in mathematics and natural sciences are characterized by greater uniformity, where the findings are as follows:

- good performance period – the years 2002-2003,

[8] For the division, the k-means method was used, however, in this case the individual years were the object of analysis, whereas voivodships represented variables, characterized by the level of exam scores.

- average performance period – the years 2004-2010 and 2012,
- poor performance period– the years 2011, 2013.

The classification with regard to the performance in humanities is not so cohesive in nature and encompasses the following years:

- years of good performance: 2002, 2012, 2013,
- years of average performance: 2003-2006, 2008, 2010,
- years of poor performance: 2007, 2009, 2011.

The results of the classification are demonstrated in Figures 5-10.

In the individual sub-periods a similar tendency is maintained – the junior high school graduates from south-eastern voivodships performed better than the graduates from north-western voivodships.

However, one can always point to the voivodships which in each of the sub-periods are the best in terms of the graduates' scores '– here we have Małopolskie and Mazowieckie voivodships. Also, Podkarpackie voivodship is at the top of the ranking, as it was placed in the good class only once.

The poorest results got Warmińsko-Pomorskie voivodship, which in all cases under discussion (sub-periods) was in the least strong class. Hardly better fared Zachodniopomorskie and Kujawsko-Pomorskie voivodships, which were four times classified in the class with poor performance and only two times in a better class.

Conclusion

The analysis showed certain regularities present in the scores achieved by junior high school graduates. The entire period under discussion saw a systematic decrease in the performance of junior high school graduates in mathematics and natural sciences in all voivodships. With respect to humanities, in five voivodships there is a slight decline while in the remaining voivodships we see a slight increase in the exam performance.

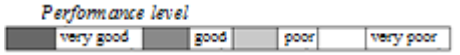
Both in mathematics and natural sciences, and in humanities, pupils from south-eastern Poland performed better in their school-leaving exams.

The division of the years 2002-2013 into three sub-periods – graduates' good, average and poor performance had no clear impact on the change with respect to the differentiated level of knowledge among the voivodships.

Two of the sixteen voivodships – Małopolskie and Mazowieckie – are distinguished by very good exam scores in each of the period under study.

At the other extreme was Warmińsko-Pomorskie voivodship, where the graduates performed the worst in each of the period under discussion.

The analysis that was carried out, in particular, the analysis of dynamics, is cause for thought. What is puzzling is the fact that the PISA tests previously cited indicate that the performance of Polish students have been increasingly better, whereas the studies concerned with the exam scores of the junior high school graduates show that their performance have been increasingly worse, especially in mathematics and natural sciences. Perhaps this discrepancy regarding the assessment of the junior high school pupils derives from the varied difficulty of the PISA test and the junior high school-leaving exams. Is there any possibility to equalize those scores so as to make them comparable? This question remains open, possibly providing the subject for further research.



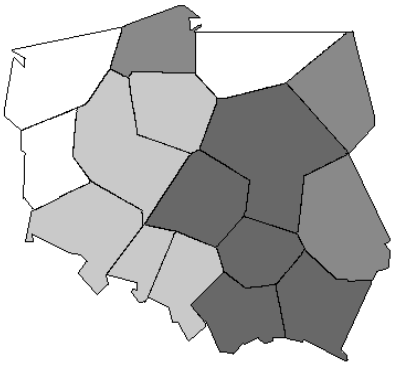


Fig. 5. Map with the voivodship classification according to the junior high school exam scores in mathematics and natural sciences in the good performance years of 2002-2003

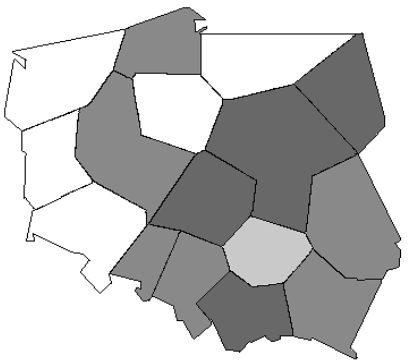


Fig. 6. Map with the voivodship classification according to the the junior high school exam scores in mathematics and natural sciences in the average performance years of 2004-2010 and 2012

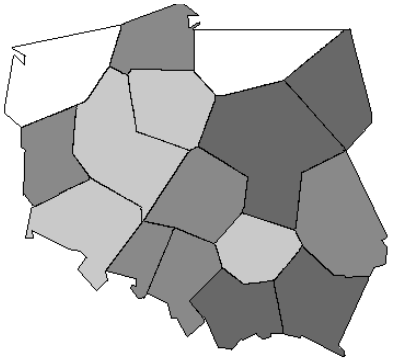


Fig. 7. Map with the voivodship classification according to the the junior high school exam scores in mathematics and natural sciences in the poor performance years of 2011, 2013

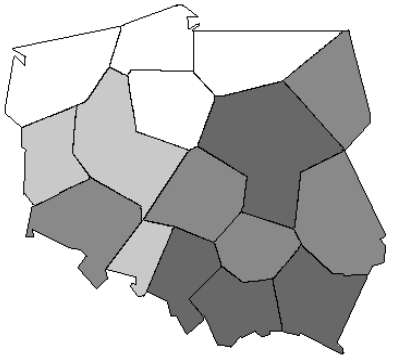


Fig. 8. Map with the voivodship classification according to the junior high school exam scores in humanities in the good performance years of 2002, 2012, 2013

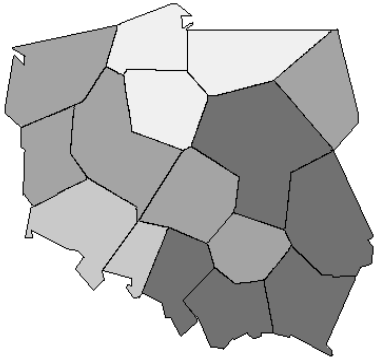


Fig. 9. Map with the voivodship classification according to the junior high school exam scores in humanities in the average performance years of 2003-2006, 2008, 2010

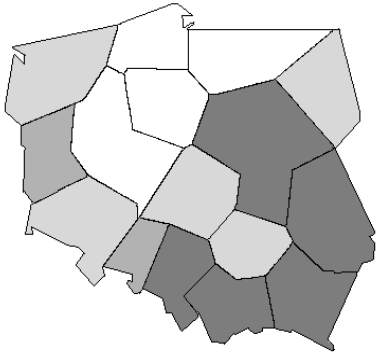


Fig. 10. Map with the voivodship classification according to the junior high school exam scores in humanities in the poor performance years of 2007, 2009, 2011

Source: Author's own study based on the data of Student Achievement Analysis Team operating at the Institute for Educational Research http://pwe.ibe.edu.pl/ [accessed on 20.09.2015]

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Analiza zróżnicowania wiedzy absolwentów gimnazjów w latach 2002-2013

Abstrakt

Celem pracy jest wykorzystanie wybranych metod ekonometrii (dynamicznej i przestrzennej) do analizy i oceny wiedzy i umiejętności absolwentów gimnazjów w latach 2002-2013. W szczególności celem przeprowadzonych analiz jest odpowiedź na pytania:

- Jak w kolejnych latach młodzież gimnazjalna radziła sobie z zadaniami i problemami w części matematyczno-przyrodniczej i części humanistycznej egzaminu?
- Czy występują różnice w wynikach egzaminów gimnazjalnych w dających się wskazać podokresach badanego dwunastolecia?
- Czy w poszczególnych podokresach występują różnice w wynikach egzaminów gimnazjalnych w poszczególnych województwach oraz w częściach egzaminu?

W przeprowadzonych analizach korzystano z danych pozyskanych ze strony Zespołu Analiz Osiągnięć Uczniów (ZAOU) działającego w Instytucie Badań Edukacyjnych[9], które pozwoliły zarówno na ocenę dynamicznych zmian w wynikach egzaminacyjnych absolwentów gimnazjów, jak i ich analizę przestrzenną według województw. Do analiz dynamiki wykorzystano trend liniowy, natomiast do badania przestrzennych zmian zastosowano metodę klasyfikacji k-średnich.

Analiza wskazała na pewne prawidłowości występujące w wynikach absolwentów gimnazjum:

- W całym badanym okresie występował systematyczny spadek w wynikach z egzaminu gimnazjalnego z części matematyczno-przyrodniczej we wszystkich województwach.
- Podział lat 2002-2013 na trzy okresy – dobrych, średnich i słabych wyników absolwentów gimnazjów nie wpłynął wyraźnie na zmianę zróżnicowania województw.
- Uczniowie z województw południowo-wschodniej Polski uzyskiwali lepsze wyniki egzaminacyjne zarówno dla części matematyczno-przyrodniczej jak i humanistycznej.

Przeprowadzona analiza ma walor poznawczy i aplikacyjny. Może być wykorzystana przez samorządy w procesie podejmowania decyzji, związanych z podnoszeniem jakości usług edukacyjnych na poziomie gimnazjalnym.

Słowa kluczowe: wyniki egzaminacyjne absolwentów gimnazjów, trend, klasyfikacja, metoda k-średnich

[9] http://pwe.ibe.edu.pl/ [dostęp 20.09.2015]