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GROUPING AREAS OF STUDENTS' COMPETENCES AND KNOWLEDGE ON THE BASIS OF GYMNASIUM EXAMINATION RESULTS

Summary: The paper considers the results of gymnasium exams in six areas: reading and the interpretation of texts; the creation of own text; application of terms, concepts and procedures; finding and using information; identifying and describing facts, relationships and dependences; the application of integrated knowledge and skills to solve problems. The students' scores were evaluated with regard to gender, region of residence and location of schools. Chosen multivariate statistical method, i.e. agglomerative hierarchical clustering, allowed to classify the competences areas and to identify areas specific for particular demographic groups.

Keywords: evaluation of competences and knowledge, examination results, agglomerative hierarchical clustering.

1. Introduction

Gymnasium exam was introduced in Poland during the education reform which started in 1999. The tests were conducted for the first time three years after establishing gymnasiums in the educational system. This external exam is carried out among third grade students. The aim of the examination is to evaluate students' knowledge and competences in the following areas:
    A.   The humanities part:
– reading and the interpretation of texts [HUM1];
– creation of own text [HUM2].
   B.   The science part:
– application of terms, concepts and procedures [SCIENCE1];
– finding and using information [SCIENCE2];
– identifying and describing facts, relationships and dependences [SCIENCE3];
– application of integrated knowledge and skills to solve problems [SCIENCE4].
    The aim of the presented paper is to identify techniques of multivariate statistics which can help to determine the most characteristic areas of knowledge. The analyses were conducted using data provided by the Regional Examination Board describing results obtained by all students from dolnośląskie (Lower Silesia) and opolskie voivodeships. The comparison of results from different territorial areas seems to be

a very interesting task. Therefore it was decided to carry out analyses taking into account not only the exam results but also the students' gender and the schools' location (urban, urban-rural and rural communities as well as big cities, i.e.: Wrocław, Opole, Jelenia Góra, Legnica).

Central Examination Board assesses skills and knowledge and compares the results achieved in different schools and time periods. This evaluation is possible after transforming raw test scores into the stanine scale (nine-point standard scale). Initially every student can gain 100 points in six areas of knowledge altogether: both areas of the humanities, i.e. HUM1 and HUM2 – 25 pts., SCIENCE1 – 15 pts., SCIENCE2 – 12 pts., SCIENCE3 – 15 pts., SCIENCE4 – 8 pts.

The stanine scale is a standardized one, also known as the standard nine. Its levels are determined according to the normal distribution of raw results given in non-decreasing order. The results are assigned to nine intervals containing 4%, 7%, 12%, 17%, 20%, 17%, 12%, 7%, 4% of the results. Each interval has the width of 0.5 standard deviation excluding the first and last, which are the tails of the distribution. The intervals from 1 to 9 are labeled as follows: 1 – the lowest, 2 – very low, 3 – low, 4 – below average, 5 – average, 6 – above average, 7 – high, 8 – very high, 9 – the highest. As the gymnasium results are integers it may be impossible to define the stanines exactly as the theoretical division suggests and therefore the appropriate percentages are fixed every year. The scheme adequate for the whole country in the year 2010 is presented in Figure 1.
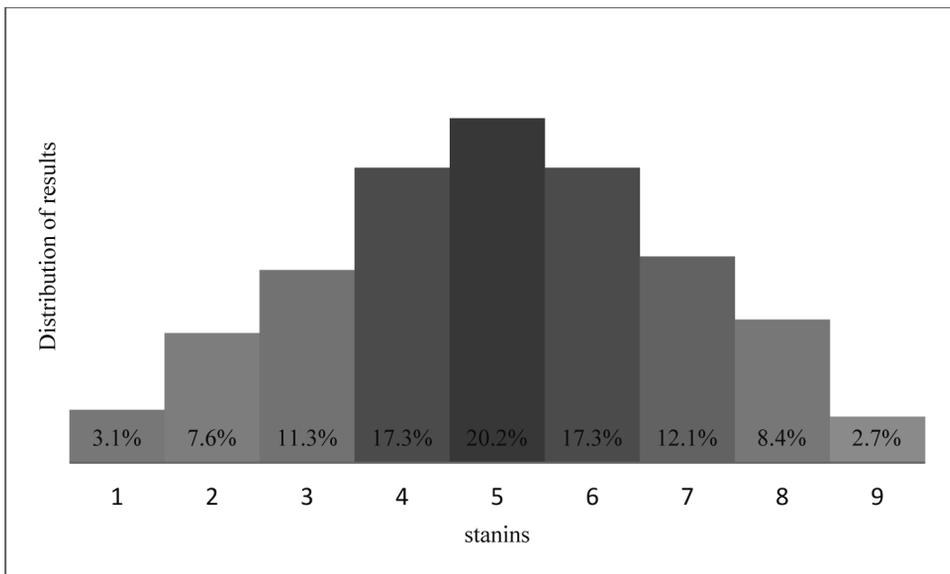
Figure 1. Distribution of results on the stanine scale in 2010

Source: own elaboration on the basis of [*Osiągnięcia uczniów… 2010*].

Figure 2 presents differences in the number of points forming successive stanine thresholds in both considered voivodeships: dolnośląskie and opolskie. Figure 2.A concerns the humanities part and Figure 2.B applies to the science part of the exam.
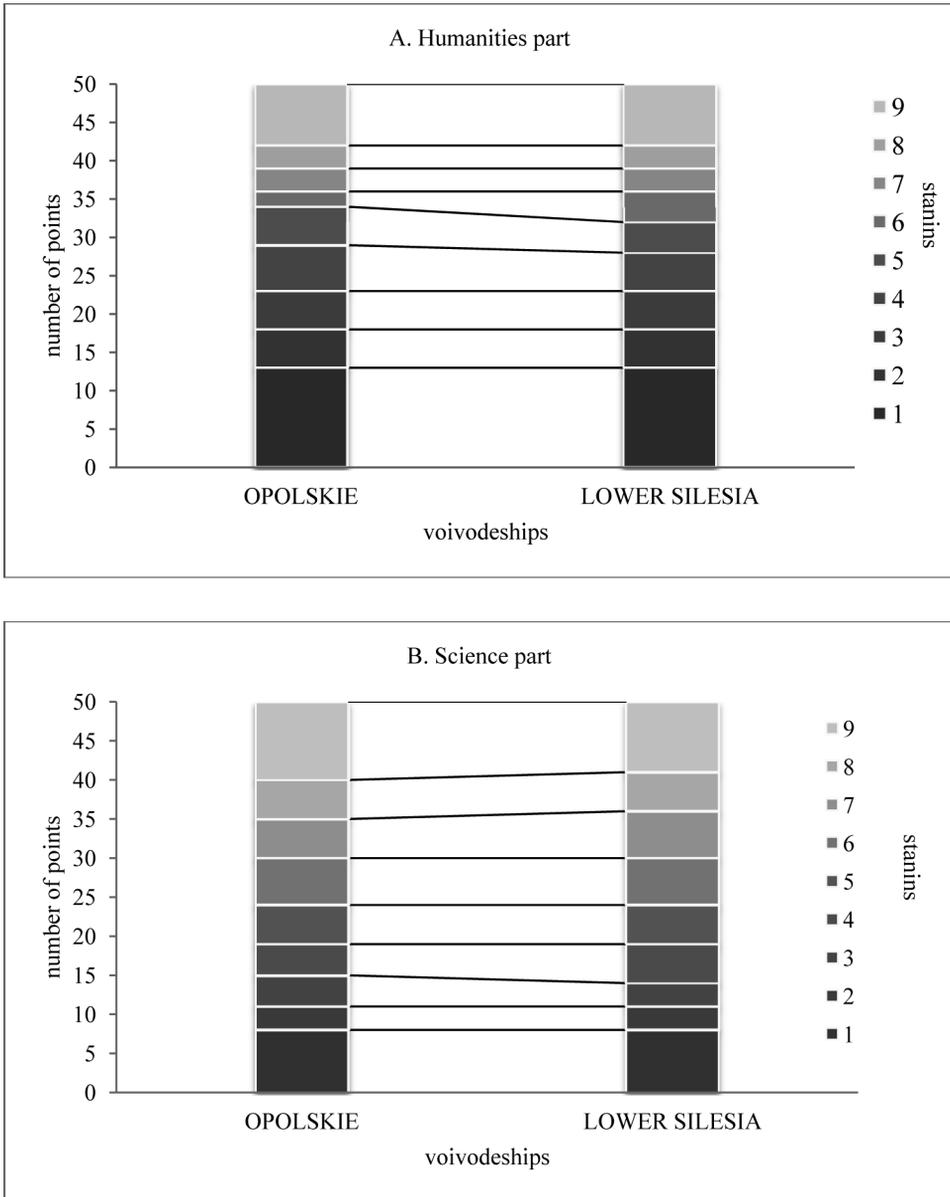
Figure 2. Examination points in the humanities (A) and science (B) by stanines

Source: own elaboration.

The division of the examination points from the humanities part into stanines (Figure 2.A) indicates that there are no differences between two regarded voivodeships within three lowest stanines, as well as within three highest ones. The results described as below average (stanine 4) in the opolskie region are represented by a larger point interval (24–29 pts.) than in Lower Silesia (24-28 pts.). Students from opolskie region had to gain at least 30 points to be assessed as average (students from Lower Silesia needed one point less). Stanine 5 in the opolskie region included points from 30 to 34, and in Lower Silesia from 29 to 32. The voivodeship performance of students in opolskie region was rated as above average (stanine 6) starting from 2 points more than in Lower Silesia (35 pts. and 33 pts. respectively).

No differences were observed in the science part in the numbers of points defining stanines 1, 2, 5, 6 in both voivodeships. Students from opolskie had to obtain one point more than the students from Lower Silesia to be classified to the group *below average* and not to the group *low*. The situation is different when regarding the intervals forming stanine 7 and 8. Then the students from Lower Silesian schools had to achieve one point more than the students from opolskie to have been classified as persons with a *very high* not *high* results (the same rule applies when comparing *very high* and *the highest* intervals).

In the humanities part of the exam students from opolskie had to get more points than students from Lower Silesia to be assessed as average, but in science part more strict criteria for high evaluation of the exam were determined for students from Lower Silesia.

In order to classify the competences areas and to identify areas specific for particular demographic groups Ward's **agglomerative hierarchical clustering algo**rithm was applied. This chosen method of multivariate statistical analysis is well known and described in the literature [*Analiza danych…*, 2006; *Metody statystycznej analizy…,* 2004; Backhaus, Erichson, Plinke, Weiber 2003], so the algorithm will not be discussed in this paper.

2. Classification of results in the six competences areas

2.1. Classification of results by voivodeships

The first presented analysis concerns the classification of competences areas in two regarded voivodeships. This clustering was performed to verify whether the achievements of students in two regions vary considerably and whether they result in different classifications of knowledge areas. Dendrograms illustrating the outcome of the proceedings are given in Figure 3.

The classification plots are very similar for two considered voivodeships. The competence area *application of terms, concepts and procedures* [SCIENCE1] and the area *identifying and describing the facts, relationships and dependencies* [SCIENCE3] constitute one cluster in both regions. The second cluster, but much more
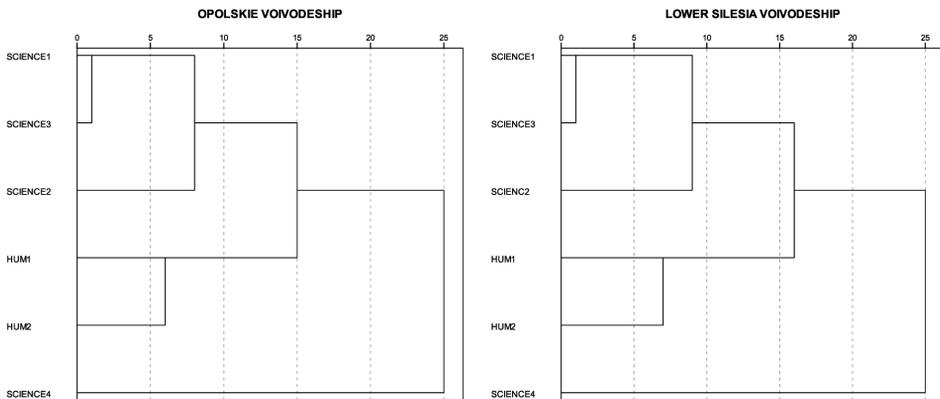
Figure 3. Classifications of competences areas results in voivodeships

Source: own computations based on data from Regional Examination Board, using IBM SPSS Statistics19.

diverse, is formed by the results obtained in the areas of humanities [HUM1, HUM2]. In the next step the results from [SCIENCE1, SCIENCE3] are linked with the competence described as *finding and using information* [SCIENCE2]. The area *application of integrated knowledge and skills to solve problems* [SCIENCE4] produces a completely separate cluster.

The acquired classifications can lead to some very disappointing conclusions. Students from both regions are not able to use their knowledge and skills in situations when active and creative approach is indispensable. The question is whether such a pattern is characteristic for both boys and girls, and whether the results vary if the location of schools is taken into consideration. The answers to these questions are included in the next sections of the paper.

2.2. Classification of girls' results by voivodeships

Next analysis was carried out to classify the competences areas according to the results obtained by girls in both voivodeships.

The classification of girls' results achieved in the six examination areas taking into account the division by voivodeships reveals that the agglomeration steps resemble the pattern described in point 2.1. The only difference is that the linkage of clusters [SCIENCE1, SCIENCE3, SCIENCE2] and [HUM1, HUM2] occurs earlier in Lower Silesia than in the opolskie region. Thus, the differences between these two clusters are less noteworthy in Lower Silesia than in opolskie voivodeship. It is a contradictory conclusion to the one which can be drawn from the dendrogram presented in Figure 3, so a more comprehensive analysis within the voivodeships seems to be essential.
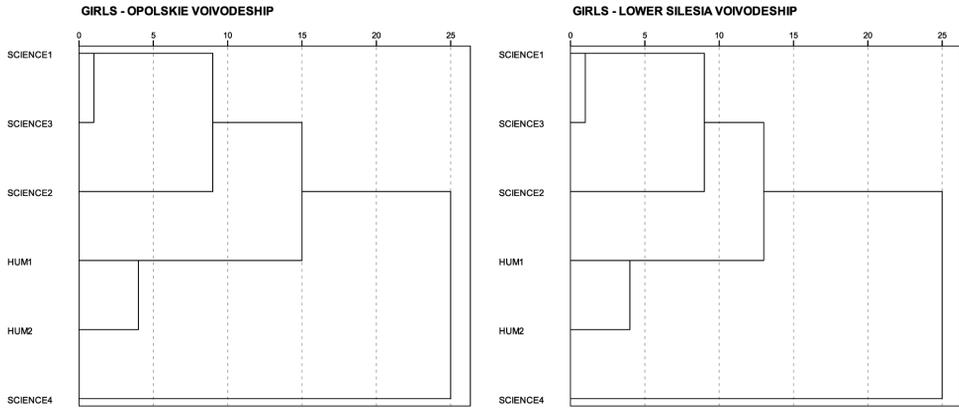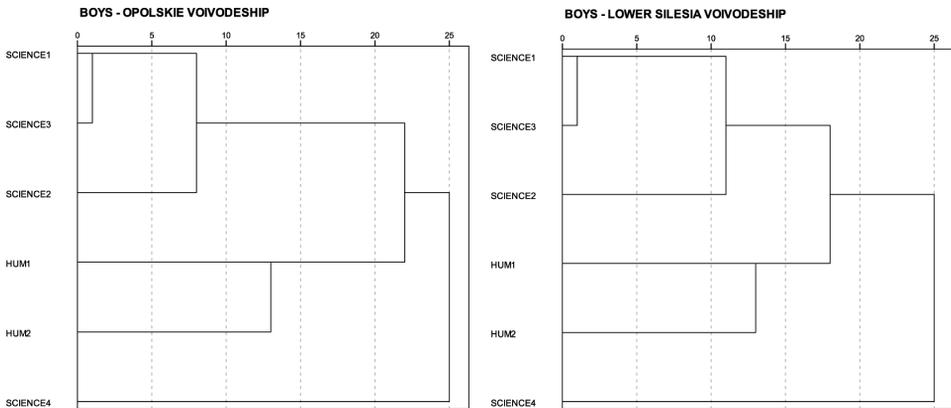
Figure 4. Classifications of competences areas results of girls in voivodeships

Source: own computations based on data from Regional Examination Board, using IBM SPSS Statistics19.

2.3. Classification of boys' results by voivodeships

As girls' results led to a slightly different classification of examination areas than the results of all students in the regions surveyed, a similar analysis was carried out for the boys' achievements. The agglomeration plots are presented in Figure 5.

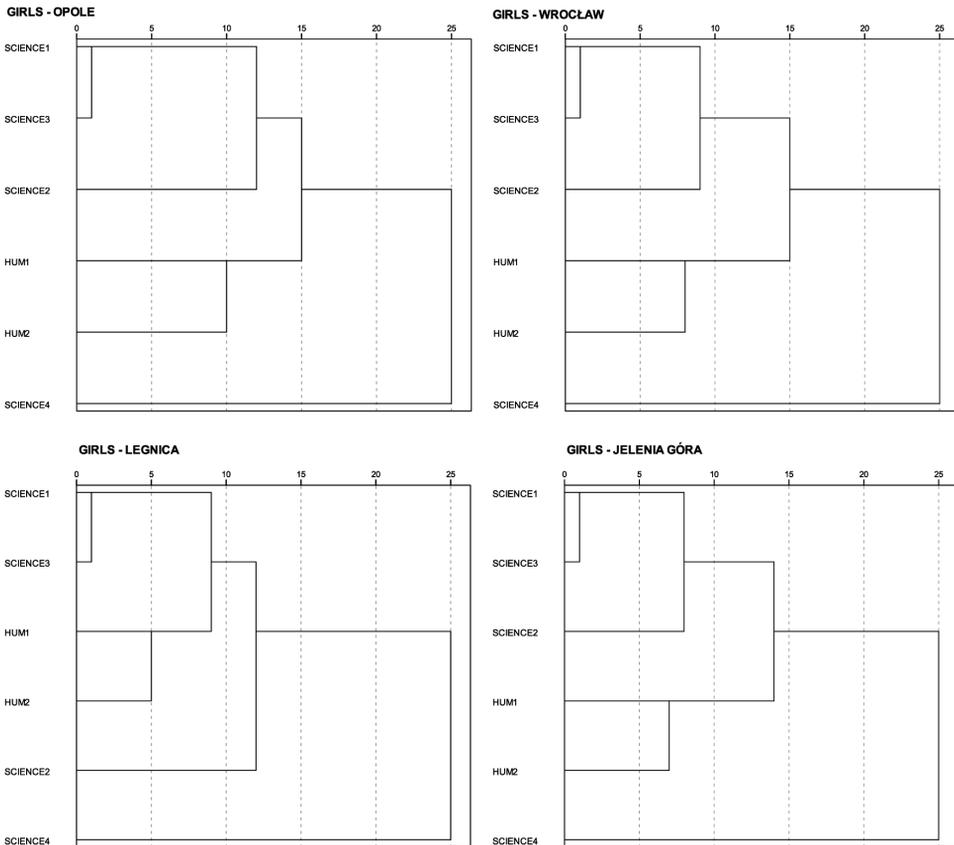**Figure 5.** Classifications of competences areas results of boys in voivodeships

Source: own computations based on data from Regional Examination Board, using IBM SPSS Statistics19.

The first cluster contains, as in previous analyses, two areas of science part [SCIENCE1, SCIENCE3] regardless of the place of residence, but the next linkage

is made differently since the derived cluster is connected with another area of the same examination part [SCIENCE2]. The clusters are more dissimilar in Lower Silesia than in opolskie region (longer linkage distances). The competences areas of the humanities part [HUM1, HUM2] create separate clusters in both dendrograms. As the linkage distances are much longer than those presented in Figure 3 and Figure 4 these clusters seem to be more internally diverse. The fourth examination area of science [SCIENCE4] forms again a cluster completely distinct from the others.

2.4. Classification of results achieved by girls from big cities

The agglomeration plots presented in Figure 6 for Opole, Wrocław and Jelenia Góra do not differ significantly from the dendrograms presented in Figure 4. Again two areas of science part [SCIENCE1, SCIENCE3] create the most homogeneous cluster

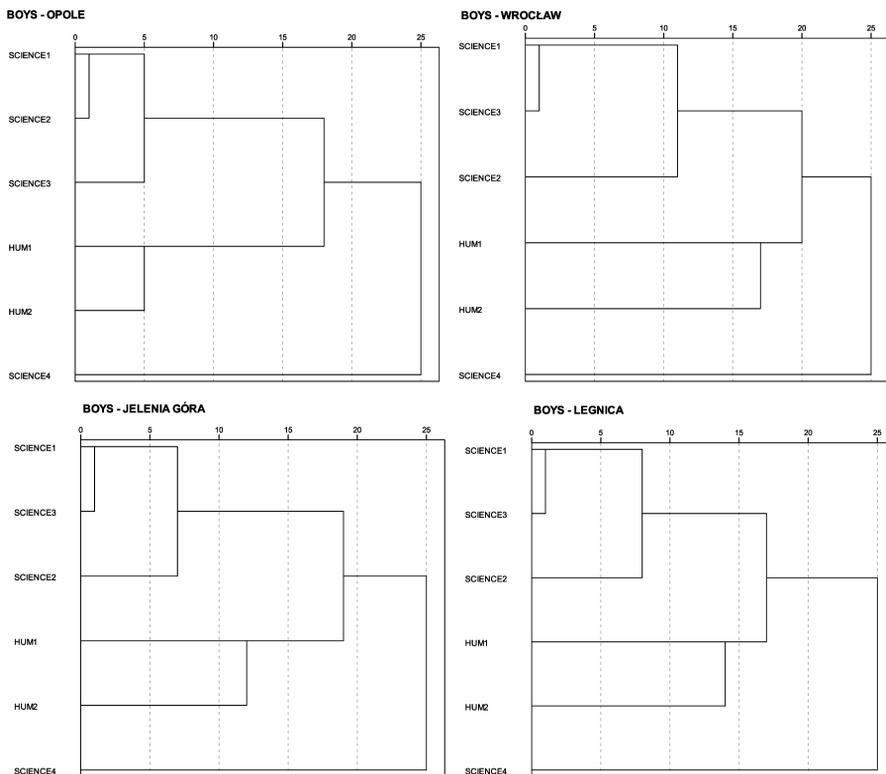**Figure 6.** Classifications of competences results areas of girls from big cities

Source: own computations based on data from Regional Examination Board, using IBM SPSS Statistics19.

and then the linkage with [SCIENCE2] occurs. In the next step a cluster [HUM1, HUM2] is extracted. The skills relating to *the application of integrated knowledge and skills to solve problems* [SCIENCE4] form a separate cluster as before.

Only the classification of the competences areas for the girls from Legnica varies from all presented above. The first cluster is created by combining skills concerning *the application of terms, concepts and procedures* [SCIENCE1] with *identifying and describing the facts, relationships and dependencies* [SCIENCE3]. The second cluster is formed from two examination areas of the humanities part [HUM1, HUM2]. These two clusters are matched together and then the area *finding and using information* [SCIENCE3] is joined. The area [SCIENCE4] gives a separate cluster again.

2.5. Classification of results achieved by boys from big cities

The next analysis is devoted to the division of the examination areas taking into consideration the results obtained by boys from big cities.

Figure 7. Classifications of competences areas results of boys from big cities

Source: own computations based on data from Regional Examination Board, using IBM SPSS Statistics19.

The classifications concerning boys from Wrocław, Jelenia Góra and Legnica (Figure 7) are in accordance with the ones discussed above. The first linkage is made for areas [SCIENCE1] and [SCIENCE3]. The next step of the algorithm gives a group consisting three science areas [SCIENCE1, SCIENCE3, SCIENCE2]. This cluster is the most consistent for objects representing Jelenia Góra. The subsequent group is arranged by connecting both areas of the humanities part [HUM1, HUM2]. However, it is worth mentioning that this cluster does not include the competences areas very much similar to each other due to the performance of students (it is the most evident in Wrocław). Finally a one unit cluster is formed by [SCIENCE4].

A bit different situation occurs in Opole. The first linkage, as in all previous instances, relates to science areas but in this case [SCIENCE1] and [SCIENCE2] are combined at first. Then another science area is attached [SCIENCE3]. A cluster containing both humanities areas [HUM1, HUM2] is generated on the same level of similarity. The three clusters formed at this stage should be considered as consistent. Next linkages give clusters internally diverse.

2.6. Other classifications of examination results

The aim of the subsequent analyses is to verify if different clusters are recognized when other territorial divisions are taken into consideration.

The clustering of six competences areas relating to girls from various community types indicates the same solutions as given in Figure 4 and therefore is not illustrated once again. Moreover, the results of boys from urban-rural communities produce a classification similar to the one presented in Figure 5.
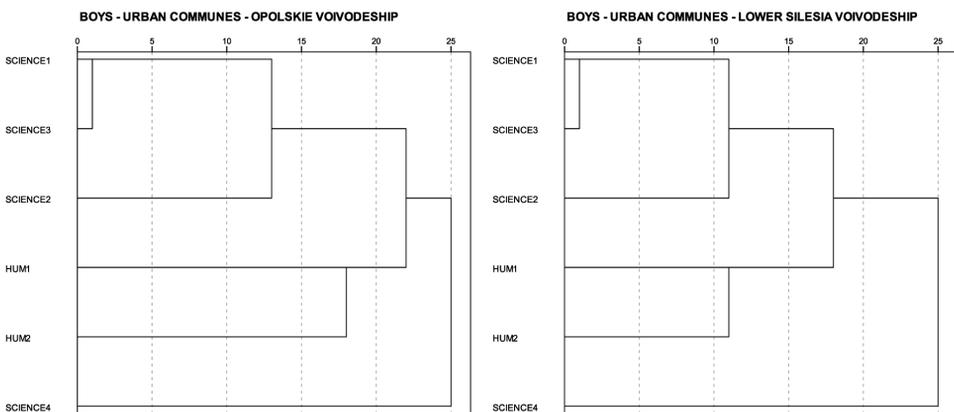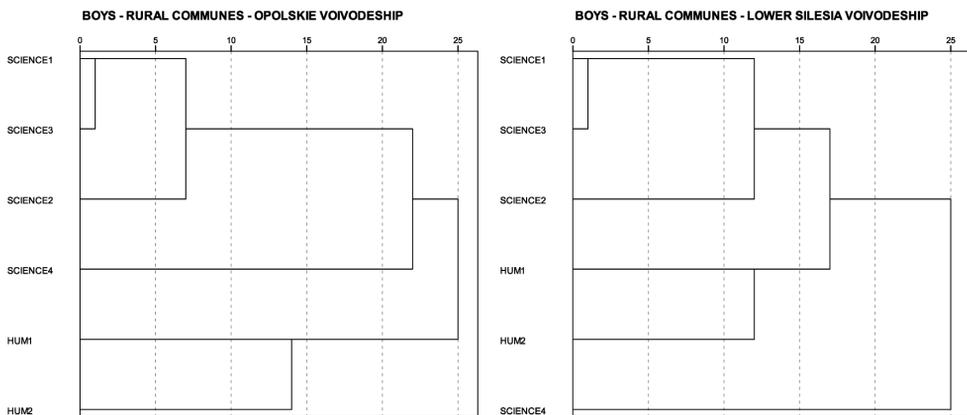

Figure 8. Classifications of competences areas results of boys from urban communities

Source: own computations based on data from Regional Examination Board, using IBM SPSS Statistics19.

Specific classifications were derived on the basis of the scores achieved by boys from urban (Figure 8) and rural (Figure 9) communities belonging to the discussed voivodeships.

The results attained by boys from urban communities (Figure 8) allow to find a cluster comprising two areas [SCIENCE1, SCIENCE3] at the beginning of the procedure. Another area of the science part [SCIENCE2] is incorporated in the next step. The cluster corresponding to Lower Silesia at this level of agglomeration is more cohesive than the one corresponding to opolskie voivodeship. The subsequent linkage concerns the two humanities areas. However, it should be emphasized that the big distance at which the objects are joined together suggests that boys from the opolskie region have rather divergent accomplishments in *reading and the interpretation of texts* [HUM1] and *the creation of own text* [HUM2]. More comprehensive skills such as *the application of integrated knowledge and skills to solve problems* [SCIENCE4] constitute a separate cluster in both voivodeships.

Figure 9. Classifications of competences areas results of boys from rural communities

Source: own computations based on data from Regional Examination Board, using IBM SPSS Statistics19.

The results of boys from rural communities situated in Lower Silesia and opolskie regions differ due to the classifications of the examination areas (Figure 9). The first cluster is formulated by connecting two areas [SCIENCE1, SCIENCE3], the same outcome as from other analyses. In the next step this group is enlarged by one competences area [SCIENCE 2] (similarly for both regions). The linkage distance adequate for opolskie voivodeship is much smaller than the one corresponding to Lower Silesia. Thus, the cluster [SCIENCE1, SCIENCE3, SCIENCE2] representing the rural communities in opolskie region contains relatively homogeneous elements in comparison with the cluster created for Lower Silesia region. The subsequent le-

vel of agglomeration generates the cluster combining two humanities areas [HUM1, HUM2], but large linkage distances indicate heterogeneity of the derived groups.

3. Conclusions

The application of Ward's agglomerative hierarchical clustering algorithm to the analysis of the results obtained by gymnasium students reveals the following regularities:

– regardless of the scrutiny level (results division by gender and school location), two competences areas of science [SCIENCE1] and [SCIENCE3] always constitute one, the most homogeneous cluster; in case of boys from Opole this cluster can be enlarged by one more area [SCIENCE2] (Figure7);

– regardless of the scrutiny level the area concerning *the application of integrated knowledge and skills to solve problems* [SCIENCE4] forms a separate cluster;

– the humanities areas are always classified together; this cluster is in certain cases very cohesive (the results of girls from both voivodeships – Figure 4, the results of girls from Legnica – Figure 6, the results of boys from Opole – Figure 7), and in other cases it is impossible to discover a high similarity in this group;

– classifications obtained by taking into consideration the community types do not differ significantly between voivodeships.

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**KLASYFIKACJA OBSZARÓW WIEDZY
I KOMPETENCJI UCZNIÓW NA PODSTAWIE WYNIKÓW
EGZAMINU GIMNAZJALNEGO**

Streszczenie: W artykule przeanalizowano wyniki egzaminu gimnazjalnego uczniów w sześciu obszarach: czytanie i interpretacja tekstu; tworzenie własnego tekstu; umiejętne stosowanie terminów, pojęć i procedur z zakresu przedmiotów matematyczno-przyrodniczych niezbędnych w praktyce życiowej i dalszym kształceniu; wyszukiwanie i stosowanie infor-

macji; wskazywanie i opisywanie faktów, związków i zależności, szczególnie przyczynowo-
-skutkowych, funkcjonalnych, przestrzennych i czasowych; stosowanie zintegrowanej wiedzy
i umiejętności do rozwiązywania problemów. Wyniki uczniów oceniano z uwzględnieniem
podziału na płeć, województwo i typ gminy, w której znajduje się szkoła. Wybrana me-
toda wielowymiarowej analizy statystycznej, tj. klasyfikacja hierarchiczna metodą Warda,
umożliwiła pogrupowanie obszarów w sposób najbardziej charakterystyczny dla wskazanych
grup demograficznych.

Słowa kluczowe: ocena wiedzy i umiejętności, wyniki egzaminu gimnazjalnego, klasyfikacja
hierarchiczna.