Optional subjects in the *Matura* exam: Are candidates who select science subjects higher achievers?

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Abstract

External *Matura* examination at the end of Upper Secondary Education (USE), upgraded with Slovene school performance feedback system (SPFS) - the *Assessment of/for Learning Analytic (ALA) Tool*, gives new applicability to *Matura* results for evaluation of the school system. Each candidate attends five units: compulsory mother tongue, maths and foreign language as well as two optional subjects. ALA Tool makes it possible to analyse students' selection of different optional subjects and compare grades in one subject with overall achievement. Some research questions can be posed. Are candidates who selected science optional subjects higher achievers in the USE prior to the *Matura*? Are they higher overall achievers in the five subject *Matura* exam? The comparison between grades distribution of candidates who selected science optional subjects and those who selected social sciences subjects will be presented. Trend analysis of overall achievement of candidates with science optional subjects and those with social sciences optional subjects, from years 2002 up to 2008, will be carried out. Mann-Whitney-Wilcoxon (MWW) U-test and the area above/below the Ordinal Domninance (OD) Graphs will be used as a measure of the difference (discrimination) between two distributions.

Keywords: optional science subjects, ALA tool, educational effectiveness, higher achievers, index ρ, Ordinal Dominance (OD) Graph

Introduction

'*Top-quality education and training is vital if Europe is to develop as a knowledge society and compete effectively in the globalising world economy*,' said Ján Figel', European Commissioner for Education, Training, Culture and Youth (European Commission, 2008). The European Union (EU) set itself the overall ambition of achieving 5 benchmarks by 2010: on literacy, reduction of early school-leaving, upper secondary attainment, maths, science and technology graduates and participation in adult learning. The EU countries in 2003 agreed to establish a series of reference levels, one of them was the need for more scientific specialists in order to become dynamic and competitive knowledge-based economy. Therefore, the total number of graduates in mathematics, science and technology in the EU should increase at least for 15 % by the year 2010 (Council of the European Union, 2003).
For the OECD countries the share of graduations by field of education at tertiary level has changed slightly to the benefit of health and welfare and of social sciences, business, law and services. Rates in science related fields (engineering, manufacturing and construction, life sciences, physical sciences and agriculture, mathematics and computing) have decreased. (Education at a Glance, 2008: 81)

Percentage of the population aged 20-24 having completed at least upper-secondary education in Slovenia in 2007 was 91.5% - Slovenia was at the 3rd place among EU Member State, high above EU (27) average -78.1% (Commission of the European Communities, 2008: 35). The upper secondary graduates - entry rates to tertiary education in Slovenia is very high - 89 %, higher than in OECD countries - 72 % and higher than in EU (19) countries - 68 % (Education at a Glance, 2008: 68). Also the number of tertiary students has increased in Slovenia from 2000 to 2006 by 36.9% or 5.4% per year; in the EU (27) the growth per year was 2.8%. (Commission of the European Communities, 2008: 73).

Compared to other EU member states, young people in Slovenia after finishing upper secondary education more frequently decide to continue their studies at the tertiary level. In the academic year 2003/04 in the EU on average a third of 20-year-olds was included in tertiary education while in our country the share was close to a half (47%). In transition following upper secondary education, the majority of new entrants choose to follow tertiary programmes in the field of social sciences, business and law. In Slovenia in the academic year 2006/07 these programs were attended by 41% of all students (Mednarodni dan študentov, 2007). The fewest students decided to study science, mathematics and computing; in 2006/07 these programs were attended by only 6 % of all students.

Access to university studies in Slovenia goes through successfully completing upper secondary program with *Matura* as final examinations. Slovene *Matura* is an exam consisting of five subjects, three are compulsory, i.e. the mother tongue (for the majority of candidates this is Slovene), Maths and a foreign language, and two are optional, i.e. a candidate can select two from a given list of subjects. In spite of increasing number and proportion of *Matura* graduates the proportion of candidates who took natural sciences optional *Matura* subject is decreasing from year to year (Zupanc, Vrtačnik, Zorec, 2006). There were 3,278 more candidates who select social sciences subjects in 2006 compared with 2002, i.e. 32.7% increase. Moreover in the same period the selection of natural science subject decreased in absolute number from 4,399 to 4,343 (Zorec, 2006: 16). The legitimate question arises: is there a significant difference between groups of students who select certain optional subjects (research question No. 1) and research question No. 2: How overall achievements of candidates with different optional subjects differs in years. This is important for subject experts as well as for selection procedures for enrolment in tertiary education (Zupanc, Urank, Bren, 2007: 288-289).

Slovenia, being the first in this part of Europe to introduce external assessment, has been gathering data on students' achievements at the end of Upper Secondary Education (USE) – in *Matura* – for 15 years. Data on students' achievement at the end of schooling and for *Matura* have been systematically gathered for the last seven years: 7 x 2 = 14 exam sessions, 80,000 candidates, or 64,000 of those who sat for all five subjects of *Matura* for the first time. Data are gathered for 64,000 x 5 = 320,000 *Matura* exams. *General* and *Vocational Matura* data include the achievement of the entire yearly cohort, i.e. 150,000 secondary school students in the last seven years, from 2002 until 2008. This represents more than 150,000 of young Slovenian citizens who sat for both types of *Matura* exam for the first time; this is 7.5% of the entire Slovene population.

The National Examinations Centre in Slovenia started pursuing activities not only to give back to schools their students' results but also to develop an information tool and analyses (School performance feedback system - SPFS), so that schools could carry out self-evaluation and improve their work (Zupanc, Urank, & Bren, 2009). With the support of the Slovene Ministry of Education and Sport and the European Social Fund we developed the Assessment of/for Learning Analytic Tool (ALA Tool).The entire feedback is based on the data at the national level and could be adjusted to individual schools or even different classes within a

school. The basic data in the database are acquired from school (i.e. teachers') assessment and from external examinations held for all students who completed USE.
Analyses of students' achievement are feasible at the national, school as well as classroom levels for several consecutive years, from 2002 until 2008.

Methodology

Teacher grades, *Matura* grades, overall achievement results and other similar educational scales have only ordinal justification - not interval (Bren, Zupanc, Blejec, 2008; Zupanc, 2005). In school systems with numerical grades means are often calculated, however with ordinal scales ranking and calculating medians will have to suit us (Nunnally & Bernstein, 1994).
One of the best known non-parametric significance tests is the Mann-Whitney U test also called the Mann-Whitney-Wilcoxon (MWW). U test remains the logical choice when the data are not interval but ordinal. It is often recommended for situations where the distributions of the two samples are very different. In the case of small samples, the distribution is tabulated, but for samples above 20 there is a good approximation using the normal distribution. In educational grade distributions proportion of ties is quite large; thus the correction for ties must be applied (Bren & Zupanc, 2008; Siegel & Castellan, 1988). If the ranking of two groups are different, the MWW test will give us the answer. If the ranking of two groups differs, the next question is how much?
With MWW-U test index ρ – linearly related to U is calculated (Herrnstein, Loveland, Cable, 1976: 288; Birnbaum, 1956:13) dividing U by product of the given group sizes, N_A and N_B

$$\rho_A = U_A / (N_A N_B) \quad \text{and} \quad \rho_{\boldsymbol{B}} = U_{\boldsymbol{B}} / (N_A N_B) \quad \text{and} \quad \rho_A + \rho_{\boldsymbol{B}} = 1.$$

ρ is a non-parametric measure of the overlap between two distributions; if $\rho = 0.5$ it represents complete overlap, if it's value is 0 or 1 this means complete separation – complete dominance of one distribution over the other. Bamber (1975: 401) stated that index ρ. represents the area above or below the ordinal dominance graph (Darlington, 1973; Darlington, 1975). The area above the ordinal dominance graph (ODG – see Figure 1, 2 and 3) equals the probability that a randomly chosen candidate from group B exceeds a randomly chosen candidate from group A plus one half the probability that they will have the same rank

$$\rho_B = P(B > A) + \tfrac{1}{2} P(B = A). \qquad (1)$$

Index ρ - the area above and below ODG will be used to define an *ordinal dissimilarity* between two distributions.

Cliff (1993) suggested an ordinal statistic d

$$d = P(A > B) - P(B > A)$$

that represents *ordinal* i.e. antisymmetric dissimilarity (values between -1 and 1) of two ordinal distributions as an area difference in the ODG. We have

$$d = 2\,\rho - 1 \qquad \text{or} \qquad d = 2\,U / (N_A N_B) - 1.$$

We define

$d_A = \rho_A - \rho_B$ and $d_B = \rho_B - \rho_A$ thus $d_A = - d_B$

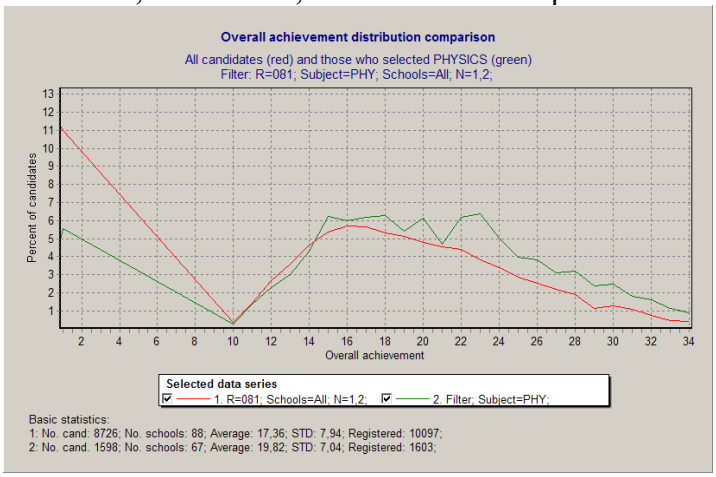
and we call d_A (d_B) *ordinal dissimilarity* between two distributions. If d_A has negative value distribution *A* lag behind distribution *B.* The group *A* is inferior in ranks with regard to group *B*. If d_A is positive, distribution *A* dominates B. Both extreme values d_A = 1 or d_A = - 1 represent complete separations, while $d_A = d_B = 0$ represent complete overlap.

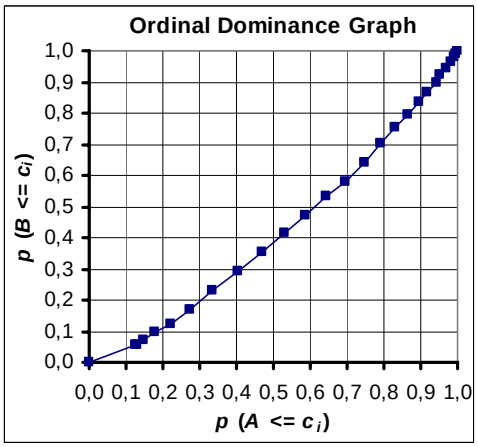
Overall achievement distribution differences

Two years ago we discussed (Zupanc, Urank, Bren, 2007: 290), that in Slovenian *Matura* the highest achievement in the three compulsory subjects have the subgroups of students who selected Chemistry, than Physics and Biology as optional subject. Students with optional subjects: Psychology, Geography, History and Sociology have lower achievement in the three compulsory subjects. In the three compulsory subjects achievement there is a gap between the subgroup of 'Natural Sciences' and in the subgroup of 'Social Sciences'.

We can as well apply candidates' overall achievement to compare groups of students who selected a certain optional subject. In the *Matura*, each candidate gets a grade for each of the five subjects, from 1 (Insufficient, i.e. Fail) to 5 (Excellent) at Foundation tier, and from 1 to 8 at Higher tier. Candidates pass *Matura*, if they get at least grade 2 (Sufficient) in all subjects (there is an exception, i.e. a Near Pass grade). Therefore the lowest overall successful achievement is 10 points, while the overall achievement of the best candidates, i.e. those taking three subjects at Higher tier (3 x 8 = 24) and two at Foundation tier (2 x 5 = 10), is 34 points. Unsuccessful candidates are represented with 1 point overall achievement.

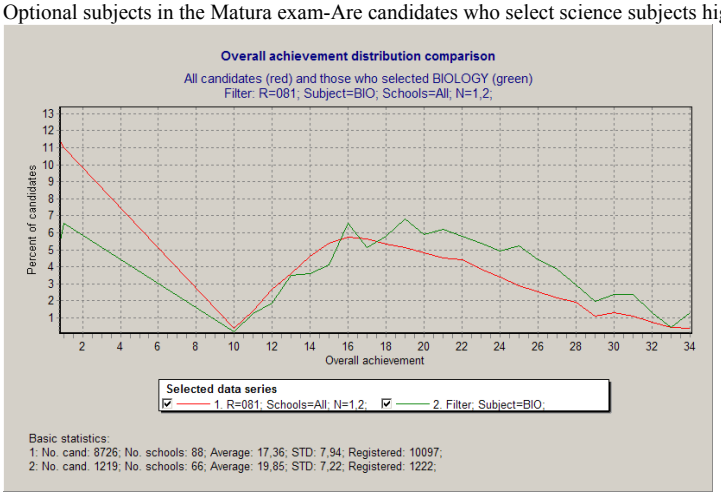
Analyses in the ALA Tool are user friendly: numerical data and charts can be exported for further processing. ALA Tool allows us to analyse the overall achievement for subgroups of candidates with different optional subjects. Overall achievement distributions for all Matura candidates (red) in year 2008 and for those who select science optional subjects (green): PHYSICS, BIOLOGY, CHEMISTRY are presented in Figures 1 to 3.

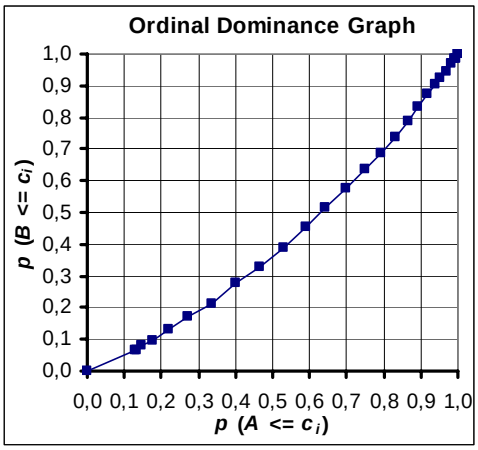




PHYSICS	N	U	z	p	ρ	d
A_{All}	8726	5766147	-11,03	0,0000000000000	0,414	-0,173
$B_{PHYSICS}$	1598	8178002	11,03	0,0000000000000	0,586	0,173

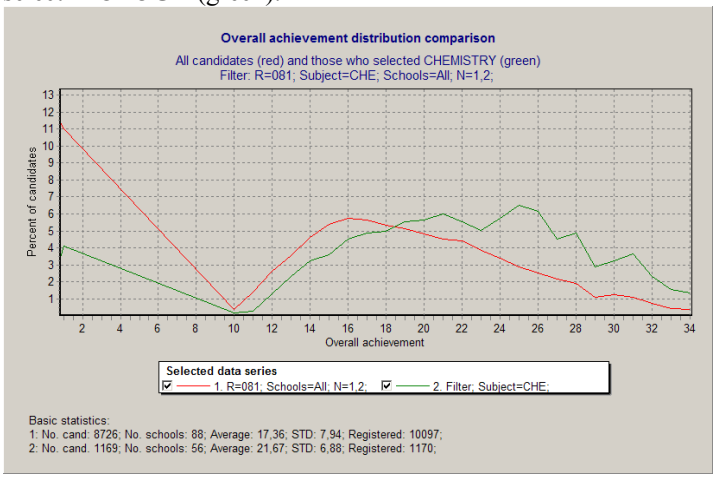
Figure 1: Overall achievement distribution comparison and statistics for ALL (red) candidates and those who select PHYSICS (green).

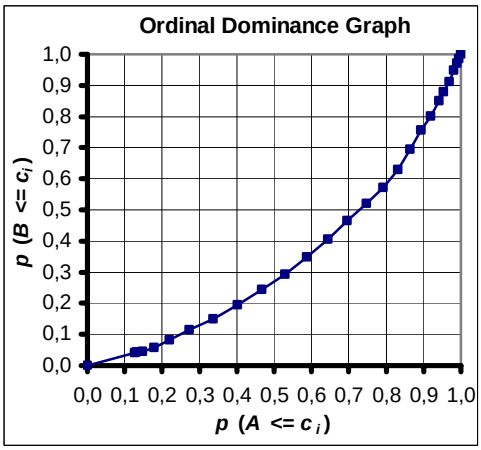




BIOLOGY	N	U	z	p	ρ	d
A_{All}	8726	4318016	-10,68	0,0000000000000	0,406	-0,188
$B_{BIOLOGY}$	1219	6318978	10,68	0,0000000000000	0,594	0,188

Figure 2: Overall achievement distribution comparison and statistics for ALL (red) candidates and those who select BIOLOGY (green).





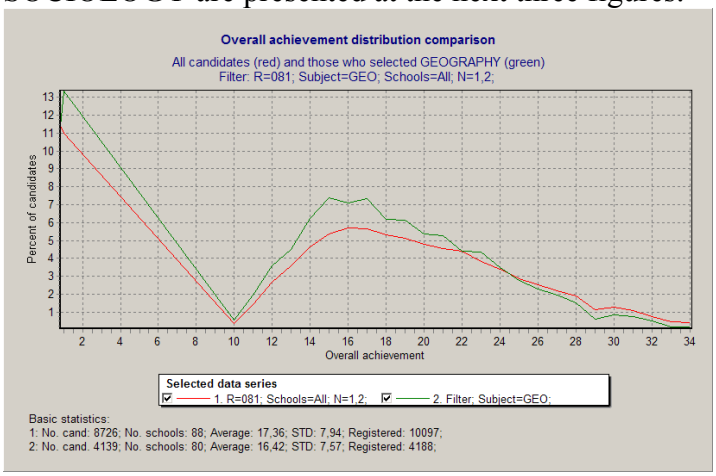
CHEMISTRY	N	U	z	p	ρ	d
A_{All}	8726	3414921	-18,41	0,0000000000000	0,335	-0,330
$B_{CHEMISTRY}$	1169	6785773	18,41	0,0000000000000	0,665	0,330

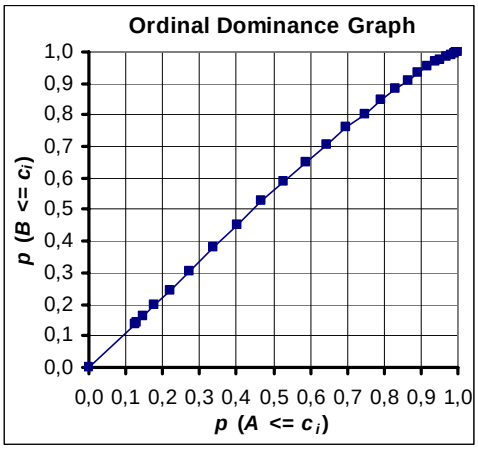
Figure 3: Overall achievement distribution comparison and statistics for ALL (red) candidates and those who select CHEMISTRY (green).

In all three cases the MWW statistics U are statistically significant ($p << 0,001$) and the values $\rho_{PHY} = 0,586$ and $d_{PHY} = 0,173$; $\rho_{BIO} = 0,594$ and $d_{BIO} = 0,188$; $\rho_{CHE} = 0,665$ in $d_{CHE} = 0,330$. The indexes ρ, area above the ODG equals the probability that a randomly chosen candidate with an optional subject (PHY, BIO, CHE) will have higher overall Matura achievement than a randomly chosen Matura candidate (A_{All}) plus one half the probability that they will have the same overall achievement (1). The probability for PHYSICS is $\rho_{PHY} = 0,586$, for BIOLOGY is $\rho_{BIO} = 0,594$ and for CHEMISTRY is $\rho_{CHE} = 0,665$. All the curves are convex and stay entirely below the diagonal. The proportion of group B exceeds that of group A_{All} at any point on the

scale. Candidates who select natural science subject – the group *B* completely dominates all Matura candidates – group A_{All}.

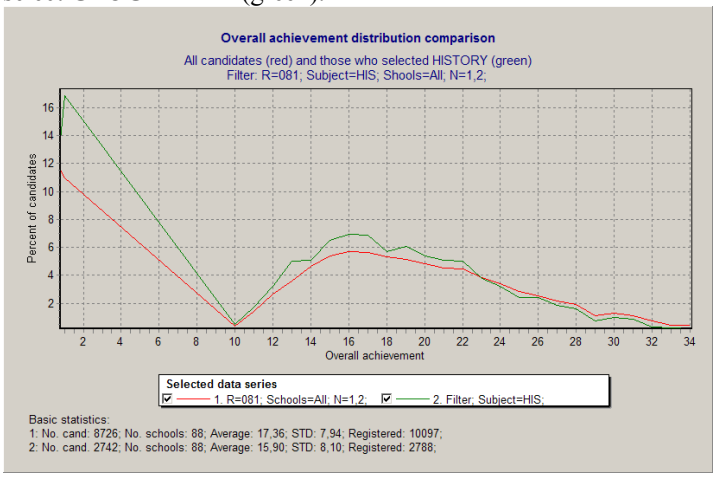
In Slovenia the majority of Matura candidates select social sciences optional subjects. More than two out of three took at least one social sciences subject: GEOGRAPHY, HISTORY or SOCIOLOGY. Almost 50% of them select GEOGRAPHY. Huge proportion of candidates with social sciences subjects means that overall achievement distributions of those candidates fit closely to the overall achievement distribution for all Matura candidates. Overall achievement distributions for all Matura candidates (red) in year 2008 and for those who select social sciences optional subjects (green): GEOGRAPHY, HISTORY and SOCIOLOGY are presented at the next three figures.

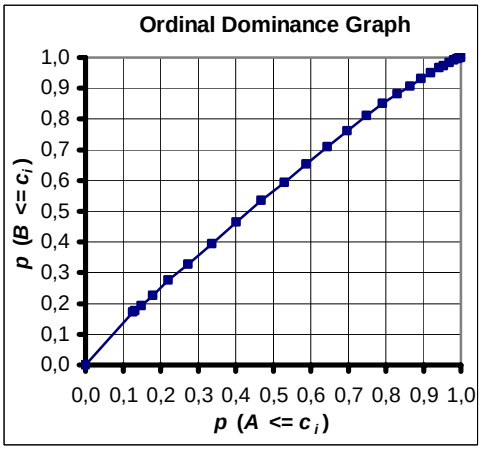




GEOGRAPHY	*N*	*U*	*z*	*p*	*ρ*	*d*
A_{All}	8726	19492071	7,30	0,0000000000003	0,540	0,079
$B_{GEOGRAPHY}$	4139	16624843	-7,30	0,0000000000003	0,460	-0,079

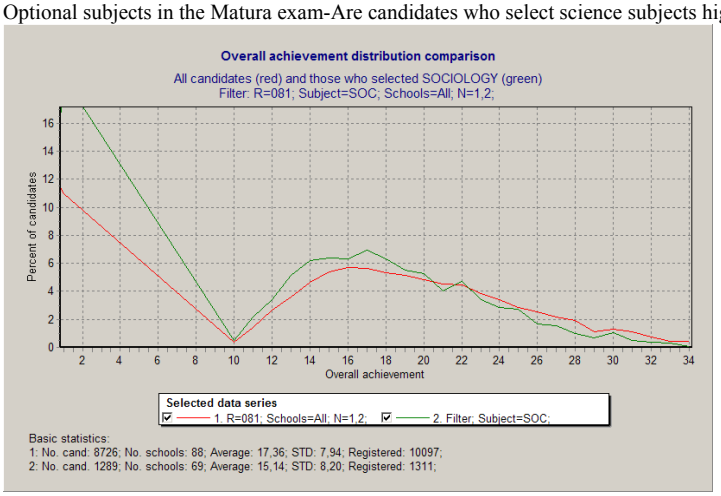
Figure 4: Overall achievement distribution comparison and statistics for ALL (red) candidates and those who select GEOGRAPHY (green).

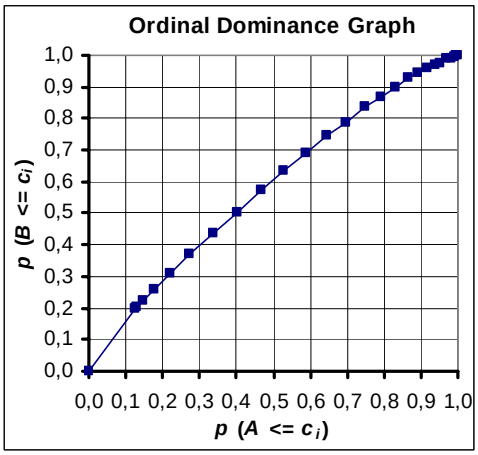




HISTORY	*N*	*U*	*z*	*p*	*ρ*	*d*
A_{All}	8726	13163579	7,96	0,0000000000000	0,550	0,100
$B_{HISTORY}$	2742	10763113	-7,96	0,0000000000000	0,450	-0,100

Figure 5: Overall achievement distribution comparison and statistics for ALL (red) candidates and those who select HISTORY (green).





SOCIOLOGY	*N*	*U*	*z*	*p*	*ρ*	*d*
A_{All}	8726	6498476	9,05	0,0000000000000	0,578	0,156
$B_{SOCIOLOGY}$	1289	4749338	-9,05	0,0000000000000	0,422	-0,156

Figure 6: Overall achievement distribution comparison and statistics for ALL (red) candidates and those who select SOCIOLOGY (green).

Two GEOGRAPY and HISTORY distributions fit closely to the overall achievement distribution for all Matura candidates (red line) because of the huge number (proportion) of candidates. In spite of that graphs show us that candidates who select social sciences subjects have lower overall achievements. In all three cases the MWW statistics *U* are statistically significant ($p << 0{,}001$). Ordinal dissimilarity between two distributions – *d* are negative and indexes ρ are less than 0.5: ρ_{GEO} = 0,460 and d_{GEO} = - 0,079; ρ_{HIS} = 0,450 and d_{HIS} = - 0,100; ρ_{SOC} = 0,422 in d_{SOC} = - 0,156. The probability for GEOGRAPHY is ρ_{GEO} = 0,460, for HISTORY is ρ_{HIS} = 0,450 and for SOCIOLOGY is ρ_{SOC} = 0,422. All the curves are concave and stay entirely above the diagonal. The proportion of group *B* lag behind that of group A_{All} at any point on the scale. Candidates who select social sciences subjects is completely inferior in ranks with regard to all Matura candidates.

Consecutively, there is complete dominance of overall achievement distribution for candidates who select natural science subjects over overall achievement distribution for candidates who select social sciences subjects.

Trends in overall achievement differences

There is a question if overall achievements of candidates with different optional *Matura* subjects are different during the years – second research question. The ALA Tool allows analyses from 2002 (Urank, Zupanc, 2007). For the last seven years the analysis of overall achievement in the final year – prior the *Matura* and overall *Matura* achievement were done for candidates who took different optional *Matura* subjects. Figure 7 shows the analysis of

average overall achievement for spring Matura sessions from 2002 to 2008. For each of six optional subjects the difference between the overall achievements of candidates and the average overall achievement of all *Matura* candidates in one session is shown.
The scale for overall achievements of successful candidates goes from 10 to 34 points. The average overall achievement in 2008 was 17.4 points. Candidates who selected CHEMISTRY optional subject in all seven consecutive years had above average overall achievement, in the last six years more than 4 points higher than overall average achievement for all candidates. Candidates who took BIOLOGY and PHYSICS had above average overall achievement as well. The difference is between +2 and +3 within seven consecutive years.
The overall achievements differences for candidates who select social sciences optional subject are negative. Candidates who selected GEOGRAPHY had below average overall achievement in all seven consecutive years; -1 point below the overall average achievement for all candidates. Candidates who took HISTORY had below average overall achievement as well. The difference is between -1 and -2 within seven consecutive years. For SOCIOLOGY the difference in the last three years was more than -2.

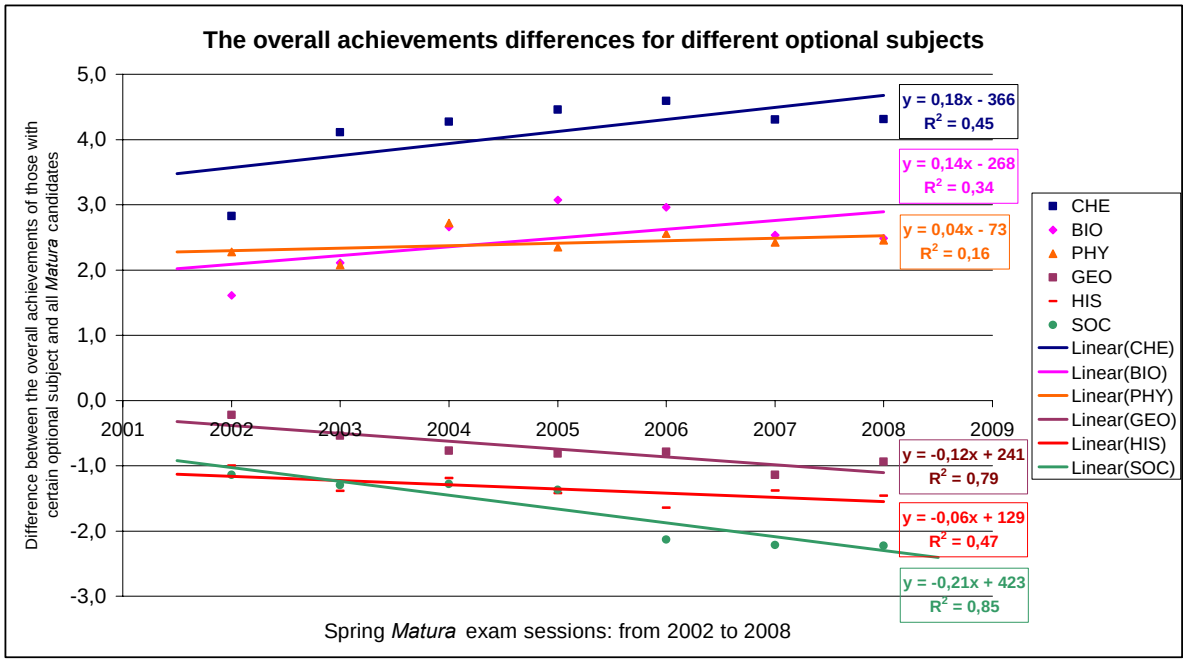


Figure 7: The overall achievements differences for candidates who select different optional subjects as to overall average achievement for all candidates from 2002 to 2008
There's a trend of increasing overall achievement of candidates who selected one of the three natural sciences subjects (PHY, BIO, CHE) in the last seven years. On the contrary in the last seven years there's a trend of decreasing overall achievement of candidates who selected one of the three social sciences subjects (GEO, HIS, SOC). Although all coefficients of regression lines are statistically not significant ($p < 0.05$), the gap between overall achievements of candidates who select natural sciences and social sciences subject is widening. From year to year on average "higher and higher achievers" select natural sciences optional subjects and "lower and lower achievers" select social sciences optional subjects.
To conclude, results are the same also with teachers grades in the final year of the USE. In the last seven years candidates who select natural science subjects were higher overall achievers in the final year – with teacher's grades. Candidates who select social sciences subjects had below average overall achievement also with teacher's grades.

Discussion

Natural Sciences optional subjects are less frequently selected, but they are selected by candidates with better achievement in the compulsory part in Slovenian *Matura*, while Social Sciences subjects are selected in greater numbers, but by candidates with significantly lower achievements. At the national level, these findings lead to a pattern: some optional subjects (Chemistry, Physics and Biology) are selected by candidates with better achievement in the compulsory common part, while Social Sciences subjects (Geography, History, Sociology) are selected en masse by candidates with significantly lower achievement in the compulsory common part. From year to year the gap between overall achievements of candidates with science subjects and overall achievements of candidates with social sciences subjects is widening. Though groups of subjects that candidates select present a kind of demarcation line between 'high', 'average' and 'low' achievers, at least on average (Zupanc, Urank, Bren, 2009). With our research we confirmed that in Slovenia USE we have less demanding - 'easy' and more demanding - 'tough' *Matura* subjects.

Such facts can be particularly relevant for the formulation of the national school policy in the light of national as well as European directives for increasing the interest of secondary-school students and students at universities to study natural sciences and engineering (Indicators on the quality of school education 2000). The findings are also important for the decisions that candidates make when entering university courses and that faculties make when admitting candidates who took different optional subjects in Matura (Zupanc, Urank, Bren, 2007: 292-293).

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