Pass rates in mathematical courses: relationship with the state matura exams scores and high school grades

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Abstract. In this paper authors investigate relationship between scores in state Matura exams in mathematics, Croatian language, high school grades and success in some mathematical courses in the undergraduate study of Information and Business Systems at the University of Zagreb, Faculty of Organization and Informatics. Mathematical courses are often courses with the lowest pass rates and the lowest average grade. Therefore, identification of required knowledge for successful passage of mathematical courses influences success rate for the whole study. Methods used in the paper are primary statistical and data mining methods: descriptive statistics, logistic regression and others. Computation is done in the R programming language.

Keywords: study success rate, math-courses success rate, state Matura exam results, data mining methods, R programming

1. Introduction

State Matura is a set of exams that students of gymnasium are obliged to take in order to finish their secondary education in Croatia. Student of vocational and art schools are also eligible for state Matura exams, provided that they completed a 4-year program and that their secondary education ends with the production of final assignment. There are mandatory and elective state Matura exams, they are equal for all the candidates and all candidates take them in the same time. State Matura exams in Croatian language, math and foreign language can be taken in two levels: higher (A) and basic (B), while all other state Matura exams are taken on one level. There are only few relevant researches about State matriculation implementation in Croatia and academic success of students who are obligated to State matriculation exams. Statistically significant difference in the exam pass rate between the generations enrolled in 2009 and in 2010 is confirmed in [4].

Each higher institution decides on their own requirements for enrolment to its study programs, and on the breakdown of points. The requirements for the undergraduate study program *Information and Business systems* at the Faculty of Organization and Informatics are presented in Table 1:

Table 1. Requirements for enrolment to the study program.

Element of scoring	**Percent in grading**	**Maximum of points**
Average of all grades	35%	350
Math A level	35%	350
Croatian language B level	20%	125 (200)*
Informatics	10%	100
Overall	100%	925 (1000)

*The exam result on the higher level (A) is multiplied by a coefficient of 1.6.

Students of the undergraduate study program *Information and Business systems* attend 2 math courses at the first year: *Mathematics 1* (in the first semester) and *Mathematics 2* (in the second semester). In *Mathematics 1* they were taught elements of mathematical logics, sets, functions and relations, and elements of linear algebra (matrices, determinants and systems of linear equations). In *Mathematics 2* they learned about functions, sequences, limits and elements of calculus of real functions of one variable (derivatives, integrals and their applications).

2. Data and methodology

We have data with observations for three year enrolment in study program Information and Business systems (2012, 2013, 2014) with total 830 students. Total 103 students of those students have incomplete documentation due to a variety of reasons, e.g. they enrolled the study based only on high school grades, they came to study from some other program, just enrolled those courses, etc. Those students are not included in analysis, so we have 263 students enrolled in year 2012, 179 in year 2013 and 275 in year 2014, so in total 717. Variables measured by the observation (student) are points achieved based on high school grades, percent of solved state Matura exams, which student took and passed, in Croatian (A or B level), Mathematics (A or B level) and Informatics.

Computation is done in R Studio, a user interface for R programming language, which is primarily used for statistical analysis. More about R studio and R is available on `www.rstudio.com`, and `www.r-project.org`.

2.1. Distribution of sample by subject and level of state Matura exam

Table 2 presents number of students by subject and level of state Matura exam taken.

Table 2. Number of students by subject and level of Matura exam.

State Matura Exam Level					
Mathematics	A (higher)				
Croatian	A (higher)	A (higher)	B (lower)	B (lower)	
Informatics	Yes	No	Yes	No	Total
Ac. year 2012	73	48	111	31	263
Ac. year 2013	64	3	112	0	179
Ac. year 2014	72	49	128	26	275
Total	209	100	351	57	

2.2. Achieved points for enrolment to the study program

Students achieve points based on requirements for enrolment presented in Table 1.

Table 3 presents elements of descriptive statistics of points achieved by elements of scoring for whole sample.

Table 3. Requirements for enrolment to the study program.

Elements of scoring	**Minimum**	**1st Quartile**	**Median**	**Mean**	**3rd Quartile**	**Maximum**
High school grades	172.2	239.4	264.6	266.8	293.3	348.6
Matura exam Croatian language	43.8	77.3	92.2	102.8	128.8	182.5
Matura exam Mathematics	52.5	110.8	148.8	154.2	192.5	338.3
Matura exam Informatics	15.0	37.5	47.5	49.2	62.5	95.0

Table 4 presents some elements of the descriptive statistics of points achieved by elements of scoring for two academic years: 2012/2013 and 2014/2015. Data indicates positive trend in number of points that enrolled students achieved during enrolment process. Students enrolled in 2014/2015 had better high school grades and Matura exam results than students enrolled in academic year 2012/2013.

Table 4. Some descriptive statistics for number of points by element of scoring samples by year of enrolment.

Academic Year	**2012/2013**				**2014/2015**			
Elements of scoring	**1st Q.**	**Median**	**Mean**	**3rd Q.**	**1st Q.**	**Median**	**Mean**	**3rd Q.**
High school grades	231.3	258.3	261.1	290.1	241.5	266.0	266.8	291.2
Matura exam Croatian lang.	78.1	94.5	104.8	129.4	78.1	93.0	105.1	133.8
Matura exam Mathematics	87.5	110.8	120.7	145.8	140.0	163.3	174.4	204.2
Matura exam Informatics	32.5	42.5	43.8	52.5	42.5	52.5	54.1	67.5

2.3. Correlation among points achieved in elements of scoring

Table 5 presents Pearson s correlation coefficients among points achieved by each of scoring element in the enrolment process. It indicates high correlation among points in mathematics and informatics. Points achieved by high school grades are medium to low correlated to points achieved by results of Matura exams. The lowest correlation in observed by points achieved by Matura exam in Croatian and Informatics.

Table 5. Correlation among achieved points in elements of scoring.

Elements of scoring	High school grades	Matura Mathematics	Matura Croatian	Matura Informatics
High school grades	1	0.295	0.286	0.278
Matura Mathematics	0.295	1	0.189	0.762
Matura Croatian	0.286	0.189	1	0.145
Matura Informatics	0.278	0.762	0.145	1

3. Analysis of success in Mathematics 1

Figure 1 presents observations (students) who succeeded to pass Mathematics 1 exam (black colour), and those who didn t (grey colour) by points achieved by Matura exam in Mathematics, points achieved in Matura exam of Croatian and year of enrolment.

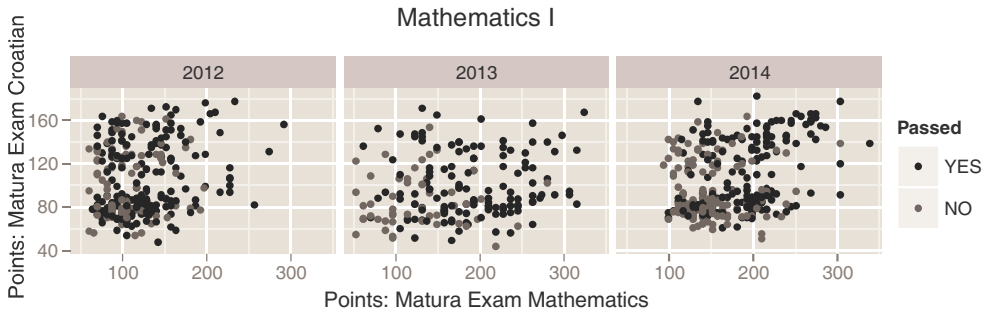

Figure 1. Success in Mathematics I based on points in Matura exam in Mathematics and Croatian by years.

Further on, we checked if there is statistically significant difference of means in achieved points between groups of students that passed Mathematics 1 (group A) and the group of students that did not pass (B group).

- State Matura Exam in Mathematics:

  Welch Two Sample t-test, gave t value of 8.80, on df $= 670.6$, which gives p-value smaller than $2.23e$-16. 95 percent confidence interval of the means difference is $[26.5, 41.7]$.

Difference between achieved points based on results of Matura exam in Mathematics of two groups of students: students that passed MAT1 and students that did not passed MAT1 is statistically significant.

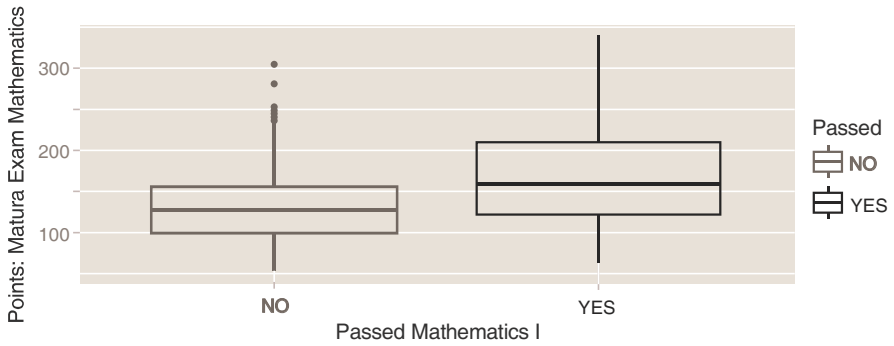

Figure 2. Boxplot of points (based on median) for two group of students: students that passed MAT1 and students that did not passed MAT1.

- State Matura Exams in Croatian:

  Welch Two Sample t-test, gave t value of 5.03, on df $= 613.9$, which gives p-value of $6.368e$-07. 95 percent confidence interval of the means difference is $[6.9, 15.9]$.

Difference between achieved points based on results of Matura exam in Croatian of two groups of students: students that passed MAT1 and students that did not passed MAT1 is statistically significant.

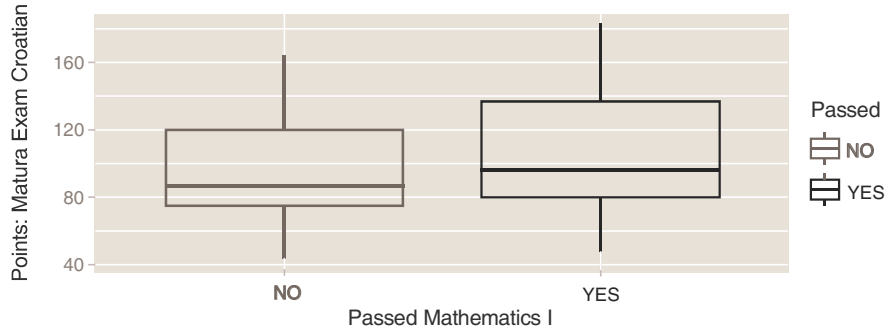

Figure 3. Boxplot of points (based on median) for two groups of students: students that passed MAT1 and students that did not passed MAT1.

- State Matura Exams in Informatics:

  Welch Two Sample t-test, gave t value of -0.5337, on df $= 360.261$, which gives p-value of 0.5938. 95 percent confidence interval of the means difference is $[-5.6, 3.2]$.

- High School Grades

  Welch Two Sample t-test, gave t value of 10.04, on df $= 587.667$, which gives p-value smaller than $2.2e$-16. 95 percent confidence interval of the means difference is $[22.0, 32.7]$.

Number of days from day of enrolment to pass the exam (days)

Table 6. Number of days from enrolment to pass of exam Mathematics 1.

Min	1st Quartile	Median	Mean	3rd Quartile	Maximum
111	189	192	234.4	194	922

More than 75% of students pass exam in Mathematics 1 in one year from enrolment.

3.1. Success prediction

Forthcoming analysis of success is done using logistic model. This model is used for assessment of probability for binary variable -success (passed exam in Mathematics 1). In other words, knowing the student results on Matura state exam and his/her high school grades, using the model, we can estimate probability that the student will pass exam in Math 1.

$$\ln\left(\frac{Probability\ of\ \ success(MAT1)}{1-Probability\ of\ \ success(MAT1)}\right) = \beta_0+\beta_1 PointsMAT+\beta_2 PointsCRO+\beta_3 PointsSCHOOL$$

Results:

Table 7. Results of logistic model for success in Mathematics 1 prediction.

exp(Estimate)	Values	Confidence interval (95%)		Pr(>|t|)
		lower limit	upper limit	
e^{β_0}	0.0023	0.0006	0.0091	$<$ 2e-16 ***
e^{β_1}	1.0010	1.0064	1.0135	2.52e-08 ***
e^{β_2}	1.0065	1.0007	1.0123	0.0269 *
e^{β_3}	1.0172	1.0123	1.0223	9.98e-12 ***

Table 7 presents that for every additional point in high school grades, with fixed values of other independent variables and coefficients, increase in odds ratio (i.e. p(success)/(1-p(success)) is about 1.7%. Second most influencing independent variable is number of points achieved based on State Matura in Mathematics.

Based on our model, odds ratio of the average student (the student which achieved median points, see Table 3) is 1.19 and corresponding probability that it will pass Mathematics 1 is 54.3%.

4. Analysis of success in Mathematics 2

Figure 4 presents observations (students) who succeeded to pass Mathematics 2 exam (black colour), and those who didn t (grey colour) by points achieved by Matura exam in Mathematics, points achieved in Matura exam of Croatian and year of enrolment.

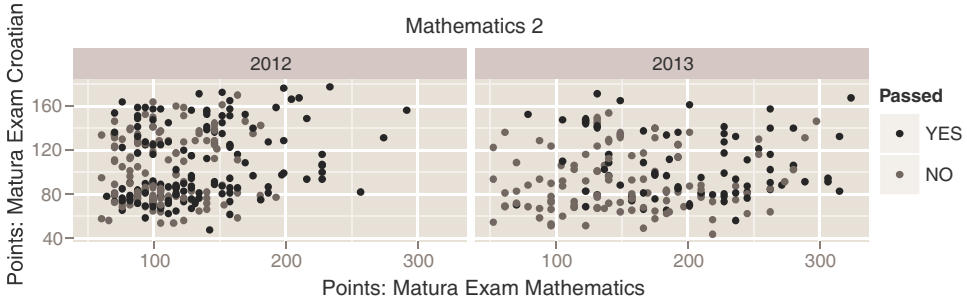

Figure 4. Success in Mathematics 2 based on points in Matura exam in Mathematics and Croatian by years.

We investigated if there is a statistically significant difference of means between those who passed Mathematics 2 and others in number of points obtained based on:

- State Matura Exams in Mathematics:

  Welch Two Sample t-test, gave t value of 5.467, on df $= 410.13$, which gives p-value $7.97e$-08. 95 percent confidence interval of the means difference is $[18.7, 39.7]$.

- State Matura Exams in Croatian:

  Welch Two Sample t-test, gave t value of 3.57, on df $= 427.694$, which gives p-value of 0.000396. 95 percent confidence interval of the means difference is $[4.6, 16.0]$.

- State Matura Exams in Informatics:

  Welch Two Sample t-test, gave t value of -0.3902, on df $= 357.135$, which gives p-value of 0.6966. 95 percent confidence interval of the means difference is $[-5.8, 3.89]$.

- High School Grades

  Welch Two Sample t-test, gave t value of 7.78, on df $= 428.734$, which gives p-value of $5.502e$-14. 95 percent confidence interval of the means difference is $[22.7, 34.7]$.

Time from day of enrolment to pass the exam (days)

Table 8. Number of days from enrolment to pass of exam Mathematics 2.

Min	1st Quartile	Median	Mean	3rd Quartile	Maximum
272	339	341	487.7	703	944

4.1. Success prediction

Similar to the success prediction for Mathematics 1, analysis of success is done using logistic model. The goal is to assess the probability for binary variable success (passed exam in Mathematics 2) knowing values of independent variables: points achieved based on State Matura in Mathematics, Croatian Language and High school grades.

$$\ln\left(\frac{Probability\ of\ success(MAT2)}{1-Probability\ of\ success(MAT2)}\right) = \beta_0 + \beta_1 PointsMAT + \beta_2 PointsCRO + \beta_3 PointsSCHOOL$$

Results:

Table 9. Results of logistic model for success in Mathematics 2 prediction.

exp(Estimate)	**Values**	**Confidence interval (95%)**		**Pr(>|t|)**
		lower limit	**upper limit**	
e^{β_0}	0.0027	0.0006	0.0131	$1.85e$-13 ***
e^{β_1}	1.0063	1.0025	1.0102	0.00129 **
e^{β_2}	1.0071	1.0003	1.0140	0.04001 *
e^{β_3}	1.0160	1.0102	1.0218	$5.46e$-08 ***

Table 9 presents that for every additional point in high school grades, with fixed values of other independent variables and coefficients, increase in odds ratio (i.e. p(success)/(1-p(success)) is about 1.6%. Number of points achieved based

on State Matura in Mathematics and Croatian are similarly influencing independent variables (influence of Croatian is more uncertain).

Based on the model, odds ratio of the average student (the student which achieved median points, see Table 3) is 0.88 and corresponding probability that it will pass Mathematics 2 is 46.9%.

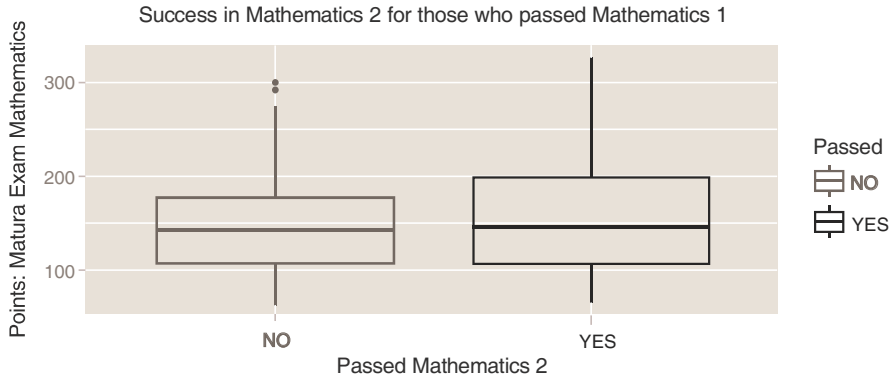

Figure 5. Points on Mathematics Matura Exam as predictor for success for Mathematics 2 for those who passed Mathematics 1.

Figure 5 presents that there is not big difference in points from Math Matura exam between students who passed and those who did not pass Mathematics 2, considering only students that passed Mathematics 1.

Concluding remarks

From presented analysis we conclude there is a positive correlation between the results of state Matura exam in Mathematics and pass rates in Mathematics 1 and 2. This result was expected. We also expected and confirmed in our analysis that results of Croatian language state Matura exam are the least important for passing Mathematics 1 and 2.

Significant impact of general high school GPA (grade point average) on pass rates in Mathematics 1 and 2 was somewhat unexpected. Better motivation and preparation associated with high GPA are possible explanation for better general success at university level, and specifically in mathematical courses.

No significant difference in state Matura exam impact on Mathematics 1 and Mathematics 2 success rate was observed. This contradicts student s perception of Mathematics 2 being much harder than Mathematics 1. Student s perception is probably influenced by the fact that Mathematics 1 is a prerequisite for Mathematics 2.

Future generations of students will provide more data allowing us to conduct further analysis and to validate our current results.

Acknowledgement

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