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MATHEMATICAL SUBJECTS AND THE ENTRANCE EXAM AS PREDICTORS OF THE ACADEMIC SUCCESS OF GEODESY STUDENTS

Abstract

All the neighboring countries are facing rapid depopulation, and thus decreasing number of high school graduates. On the other hand, it is needed to select the best quality candidates to enroll colleges/universities in order to be trained for future profession in shortest study time and solid passing rate. The most effective forecast for success in studying (graduation) is during candidate testing (entry exam) and during their first year of studies.

This paper shows analysis of factors that determine enrolment of candidates to geodesy study program; marks and passing mathematics (during the first year of study); status of enrolled students and completion of studies, as well as connection between the length of studying and academic results in the secondary school and results of entry exam and possibility of foreseeing successfulness of studying – graduation.

Keywords: Predicting of Academic success, entry exam, mathematical subjects, decision trees

МАТЕМАТИЧКИ ПРЕДМЕТИ И ПРИЈЕМНИ ИСПИТ КАО ПРЕДИКТОРИ АКАДЕМСКОГ УСПЈЕХА СТУДЕНАТА ГЕОДЕЗИЈЕ

Сажетак

Све земље ближег и ширег окружења суочавају се с брзим смањењем становништа, па и свршеним средњошколцима. С друге стране неопходно је спровести одабир што квалитенијих кандидата за упис на факултете / универзитете, како би били оспособљени за будуће занимање уз што краће вријеме студирања и солидну пролазност. Најефектније предвиђање за успјешност завршетка студија (дипломирање) је већ при тестирању (избору) кандидата при упису и током прве године студија.

У раду је приказана анализа фактора који одређују упис кандидата на студиј геодезије; оцјене и период полагања математичких предмета (које студенти слушају у првој години студија); статус уписаних студената и завршетак студија, као и повезаност дужине студирања и успјеха у средњој школи и резултата квалификационог испита и могућност предвиђања успјешности дипломирања.

Кључне ријечи: предвиђање академског успјеха, пријемни испит, математички предмети, стабла одлучивања

1. INTRODUCTION

In the course of the first year of study of the first cycle at study program Geodesy at Faculty of architecture, civil engineering and geodesy of the University of Banja Luka, the mathematical subjects are: Analytical geometry and linear algebra (AGLA), Differential and Integral calculus 1 (DIC 1) and Differential and Integral Calculus 2 (DIC 2). Majority of students enrolled to this study program come from gymnasium and secondary/vocational civil engineering school. The significance of entry (qualifying) exam for enrollment into the Faculty of architecture, civil engineering and geodesy (FACEG), as well as the correlation between the result on entry exam and success in mathematical subjects exam is analyzed in paper [1]-[3], while the impact of passing mathematical subjects in forecasting academic success of students is analyzed in papers [4]-[8].

The paper analyses: three factors that determine enrolment of students (secondary school success, entry exam results, total score); marks and period of taking math exams (the ones students have in the first year of study) during studying; status of enrolled students and completion of the first cycle, as well as correlation between the length of studying and success in secondary school and results of entry exam.

We used advanced techniques (decision trees) that enable students' graduation forecasting.

Looking into the passing of mathematical exams it appeared that for the successful completion of the first cycle of studies, a more important predictor was the period of passing (when was the exam taken and passed) rather than the mark obtained at the exam.

Taking and passing particular mathematical exams during the current year of studying shows that prediction of successful graduation is from 82,1% to 91,5%.

The improvement of prediction for successful graduation of geodesy students is achieved by generating rules form the data.

2. ORGANIZATION OF THE RESEARCH

Over the course of 12 years (since 2012 /the first generation/ till 2023) the Study program Geodesy (SP G) enrolled, or transferred from other faculties, 348 students.

The secondary school score and the entry exam are both valued with 50 points each, while for entry exam of mathematics, the minimum passing threshold is 15 points. At the start of academic 2023/24 year, there were 163 active students, while 122 students have completed (graduated) the first cycle of studies.

For the analysis and graphical presentation of data, application of adequate statistical tests (Anova, Independent t test and $\chi 2$ test) and classification trees, we used analytical-statistical tool IBM SPSS Statistics, version 27 [9],[10]. For the improvement of prediction of completion of the first cycle, we used classification trees that are most frequently used statistical techniques in the field of generating rules from the data [11],[12].

3. RESULTS OF RESEARCH

The secondary school success was in the range from 23,75 to 50, while the average score during the secondary education was 41,14.

The points that the candidates realized during the entry exam were in the range from 15 to 50, while the average score in the entry exam of enrolled students was 25,94.

Total scores were in the range from 42,25 to 99,02 and the average total score at entry exam was 67,08.

Figure 1 shows average success in secondary school, during the entry exam, and a total score of SP G students over the 12 years.

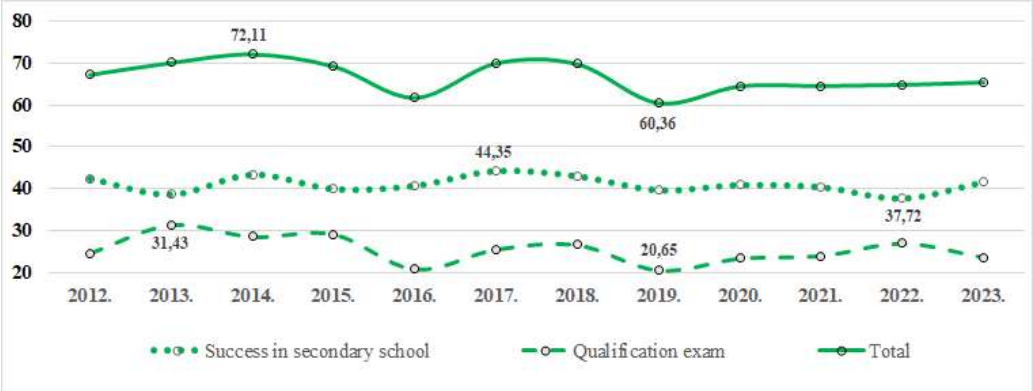

Figure 1. Average success in secondary school, during the entry exam, and a total score of SP G students over the 12 years

Applying the Anova test, we got statistically highly significant difference (p = 0,000) of achieved success during the secondary education of SP G students over the 12 years. Additional application of Multiple Comparisons Post Hoc test gave statistically highly significant difference (p = 0,0097; 0,0087) of achieve discusses during the secondary education of SP G students enrolled in 2013 and 2014, i.e. 2017 respectively, and statistically significant difference (p = 0,017; 0,011) of achieved secondary education success of SP G students enrolled in 2022 and 2014, i.e. 2017 respectively.

We also got statistically highly significant difference (p = 0,000) by applying Anova test on entry exam for SP G students over the course of 12 years. Additional application of Multiple Comparisons Post Hoc test gave statistically highly significant difference (p = 0,000 and 0,001) of achieved success on SP G entry exam of 2013 and 2016, i.e. 2019 respectively, and statistically significant difference (p = 0,043; 0,025; 0,013 and 0,030) of SP G students enrolled 2013 and 2023; 2014 and 2016; 2015 and 2016; 2016 and 2019 respectively.

Completed secondary schools were classified into three groups: Gymnasium, Vocational Civil Engineering secondary school (Civ. Eng. school) and other secondary schools.

Processing the candidates who enrolled SP G by applying Anova test we did not get statistically significant difference of achieved success in secondary education (p = 0,113) and during the entry exam (p = 0,152) of students were classified into three groups over the course of 12 years.

Status of students enrolled until academic year 2019/20 (they could have graduated) is shown in Table 1. 257 students were enrolled by 2019/20 (for three students transferred from other faculties second. school was not specified).

Table 1. Status students enrolled by 2019/20.

Students' status	Secondary schools (groups)			Total
	Gymnasium	Civ. Eng. school	Other secondary schools	
active	54	75	34	163
dropped out	14	27	13	54
no status	8	17	5	30
transfer – after 1st year	2	5	3	10
Total	78	124	55	257

Applying the $\chi 2$ test did not produce statistically significant difference ($\chi 2 = 2,763$, p = 0,838) of students' status in relation with completed secondary school.

Applying the Anova test, we got statistically highly significant difference (p= 0,000) of achieved success during the secondary education and during the entry exam of SP G students in relation to the status of studying. Additional application of Multiple Comparisons Post Hoc test gave statistically highly significant difference (p = 0,000) of achieved success during the secondary education of students who are active and who transferred after the first year, and statistically significant difference (p = 0,018) of student who are active and who dropped out, and (p = 0,041) students who dropped out and those who transferred after the first year.

We also got statistically highly significant difference (p = 0,006) during the entry exam of students who were active and who dropped out, i.e. who were active and without status (p = 0,002).
Passed mathematical subjects of students enrolled by 2019/20 are shown in Table 2.

Table 2. Achieved marks of mathematical subjects taken till 2019/20.

Subject	Mark					Total
	6	7	8	9	10	
AGLA	76	63	21	10	5	175
DIC 1	76	49	23	15	6	169
DIC 2	84	36	17	15	7	159

The time period of taking the passed mathematical exams for students enrolled by 2019/20 are shown in Table 3.

Table 3. Time of taking the Math exams in the period until 2019/20.

	Exam passed				Total
	In current year	In next year	After two or more years	Not passed	
AGLA	143 (73%)	28 (14,3%)	4 (2%)	21 (10,7%)	196
DIC 1	118 (61,5%)	35 (18,2%)	16 (8,3%)	23 (12%)	192
DIC 2	50 (29,2%)	53 (31%)	56 (32,7%)	12 (7%)	171

Graduated students enrolled until 2019/20 in relation to completed secondary school is shown in Table 4.

Table 4. Graduated students enrolled until 2019/20 and completed secondary school

Sec. school /groups/	Graduated		Total
	Yes	No	
Gymnasium	42	12	54
Civ. Eng. school	50	25	75
Other secondary schools	30	4	34
Total	122	41	163

Applying the $\chi 2$ test we got statistically significant difference ($\chi 2 = 6,149$, $p = 0,046$) of a number of students who did(not) graduate in relation to previously completed secondary school.
Table 5 shows lasting of studying (days) for students who completed the first cycle.

Table 5. Lasting of studying (days)

Study program	N	Min.	Max.	Median	Mean	Std. Dev.
Geodesy	122	1424	3797	1829,50	1983,97	483,491

We discovered statistically highly significant correlation between negative prefix of the length of studying and success in secondary school (r = - 0,381) and between the length of studying and entry exam (r = - 0,319), while there was statistically highly significant correlation between positive prefix of success in secondary schools and entry exam (r = 0,243).
By monitoring the correlation of passing two or all three mathematical subjects that students study during the first year, the results show that students successfully complete the studies if they pass at least two subjects during the current year, or at least one in the current year and the second, or the second and third, in the next year or the following year (Table 6).

Table 6. Correlation of passing of particular subjects and completion of the first cycle (graduation)

Subject(s)	During the current year	Graduated	During the next year	Graduated	After two years or later	Graduated
AGLA	123	101 (82,1%)	26	20 (76,9%)	2	1 (50%)
DIC1	105	93 (88,6%)	31	20 (64,5%)	13	9 (69,2%)
DIC2	47	43 (91,5%)	50	46 (92%)	49	33 (67,3%)
AGLA & DIC1	96	87 (90,6%)	40*	26 (65%)	13**	9 (69,2%)
AGLA & DIC2	47	43 (91,5%)	50*	46 (92%)	49**	33 (67,3%)
DIC1 & DIC2	47	43 (91,5%)	50*	46 (92%)	49**	33 (67,3%)
AGLA, DIC1 & DIC2	47	43 (91,5%)	50*	46 (92%)	49**	33 (67,3%)

* at least one of subjects passed in the following year
** at least one of subjects passed after two years

Additional correlation of monitored variables is possible to find using advanced techniques. As an example we give the application of the decision tree (Figure 2).

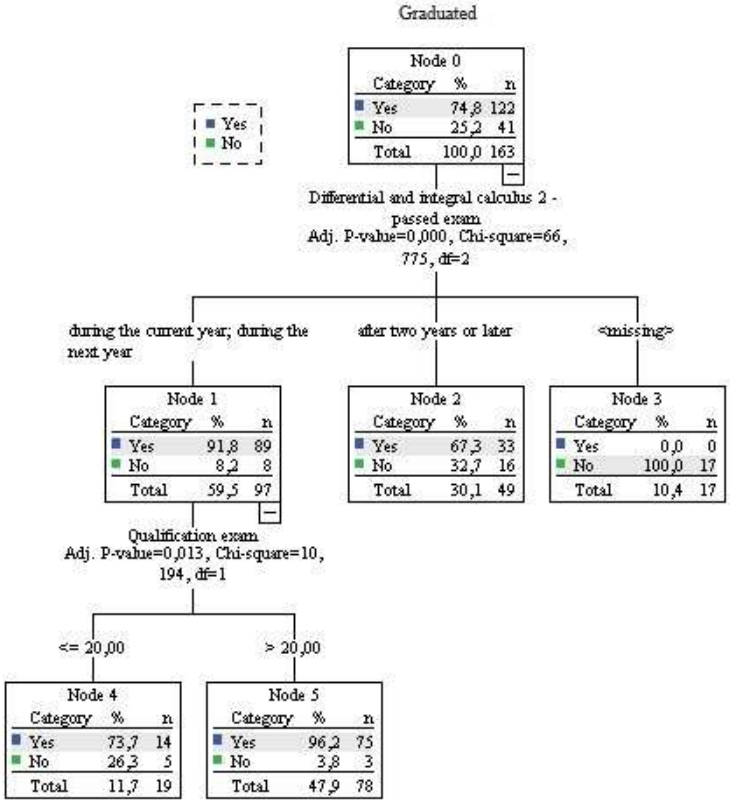

Figure 2. Example of the decision tree

Generated rules for three nodes are given as an example:

/ Node 4 */.*
IF (Differential and integral calculus 2 - passed exam = "during the current year" OR Differential and integral calculus 2 - passed exam = "during the next year") AND (Qualification exam NOT MISSING AND (Qualification exam <= 20))
THEN

Node = 4
Prediction = 1
Probability = 0.736842

/ Node 5 */.*
IF (Differential and integral calculus 2 - passed exam = "during the current year" OR Differential and integral calculus 2 - passed exam = "during the next year") AND (Qualification exam IS MISSING OR (Qualification exam > 20))
THEN
Node = 5
Prediction = 1
Probability = 0.961538

/ Node 2 */.*
IF (Differential and integral calculus 2 - passed exam = "after two years or later")
THEN
Node = 2
Prediction = 1
Probability = 0.673469
By forcing the variable „Entry exam“ we generated the tree (Figure 3) and rules.

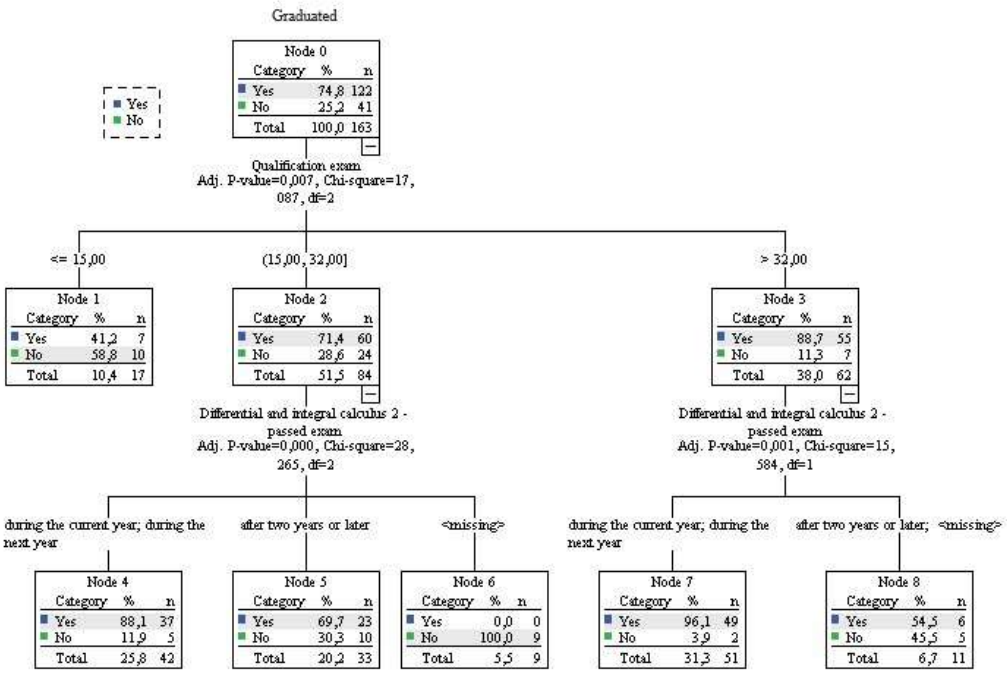

Figure 3. Generated tree by forcing the variable „Entry exam“

Generated rules:

/ Node 1 */.*
IF (Qualification exam NOT MISSING AND (Qualification exam <= 15))
THEN
Node = 1
Prediction = 2
Probability = 0.588235

/ Node 4 */.*
IF (Qualification exam IS MISSING OR (Qualification exam > 15 AND Qualification exam <= 32)) AND (Differential and integral calculus 2 - passed exam = "during the current year" OR Differential and integral calculus 2 - passed exam = "during the next year")

THEN
Node = 4
Prediction = 1
Probability = 0.880952

/ Node 5 */.*
IF (Qualification exam IS MISSING OR (Qualification exam > 15 AND Qualification exam <= 32)) AND (Differential and integral calculus 2 - passed exam = "after two years or later")
THEN
Node = 5
Prediction = 1
Probability = 0.696970

/ Node 7 */.*
IF (Qualification exam NOT MISSING AND (Qualification exam > 32)) AND (Differential and integral calculus 2 - passed exam = "during the current year" OR Differential and integral calculus 2 - passed exam = "during the next year")
THEN
Node = 7
Prediction = 1
Probability = 0.960784
/ Node 8 */.*
IF (Qualification exam NOT MISSING AND (Qualification exam > 32)) AND (Differential and integral calculus 2 - passed exam != "during the current year" AND Differential and integral calculus 2 - passed exam != "during the next year")
THEN
Node = 8
Prediction = 1
Probability = 0.545455

4. DISCUSSION

All the countries of Southeast Europe are faced with the problem of low birth rate, which is reflected on a number of secondary school students and their further education (studying). High education institutions implement a lot of activities to interest and select the best quality candidates for the continuation of education. Selection of candidates for enrollment is very complex and demands intense and permanent work with potential candidates during their secondary education.

FACEG initiated research in regards the passing of entry exams in 2012 [6] and has been implementing the workshops in secondary schools that educate the civil engineering and geodesy profiles and in gymnasiums, for the past 10 years, and also organizes preparation classes. Preparatory classes consist of 20 hours and, prior to the coronavirus period, were conducted in the classroom for two weeks in June. However, since the onset of the coronavirus period (in 2020) untill now, they have been held online for five weeks using Google Meet and Google Classroom applications [13]. The importance of preparation classes has been recognized among the faculties in the region that organize preparatory classes and/or enable candidates to use the solved tasks from mathematics entry exam [13]-[17]. The criteria for enrollment to undergraduate studies in Croatia is based on: achieved success in secondary school (400 points) and passed exams at the state prom test (Croatian language – 50, mathematics up to 450 and physics /not a condition for enrollment, but yields points/ up to 100 points); achievements at competitions – direct enrollment (1000 points)/participation in state-level competitions in mathematics and physics or winning one of the top three places in civil engineering technology/ [18].

Some faculties organize preparation of students also after the enrollment, to prepare the students for the future profession before the start of academic classes [19].

After a good selection of candidates at enrollment, it is necessary to research the influence of passing particular exams already in the first year of studying, to the successful completion of studies. For the prediction of results, it is necessary to use techniques that are more advanced. The paper [20] describes creation of a prediction model for students' success by means of Data mining and analyzing the factors that influence the achieved level of successfulness. We tested three methods of data mining: logistical regression, decision tree and neuron nets. The Study [21] aims to provide step-by-

step guidance set for teachers who are ready to apply the data mining techniques in order to predict students' success. Successful creation of a model that has 92% correctness in predicting the students' final outcome point to the potential of artificial neural nets [22]. The paper [23] analyzes data on studying success and exam passing rate on the first year of undergraduate studies for eight generations of students. Goals of research were: to make a predictive model that would enable identification of students with high probability of not making 30 ECTS points during the academic year, and offer students an information on probability for passing particular exams, i.e. achieving the targeted number of ECTS points at the end of the academic year.

5. CONCLUSION

The candidates yielded solid success during secondary education (during the whole 12 years period of enrollment the average score was 41,14), while the result of entry exam was worse (average score was 25,94). The total average score was 67,08.

Looking into the passing of mathematical exams it appeared that for the successful completion of the first cycle of studies, a more important predictor was the period of passing (when was the exam taken and passed) rather than the mark obtained at the exam.

Taking and passing particular mathematical exams during the current year of studying shows that prediction of successful graduation is from 82,1% to 91,5%.

The improvement of prediction for successful graduation of geodesy students is achieved by generating rules form the data.

Predicting factors influencing students' academic success is significant due to the organization and structure of the entrance exam itself, as well as the importance of certain academic subjects for successful completion of studies. This research can further be applied to other study programs at the Universities.

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