ACADEMIA
ISSN, 2241-1402
http://hepnet.upatras.gr

Number 16-17, 2019

Linkage between Results of Unified State Exam in Mathematics and Education Outcomes in Calculus and Analytical Geometry in the First Half-Year Term

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Abstract
Linkage between the rating points in the first half-year term in Calculus and Analytical Geometry, and the points of USE (Unified State Exam), of first-year students of engineering specialization is studied. The training sample includes the data of 365 students (284 male and 81 female students). Statistical analysis of gender samples has established that the points obtained by female students in Analytical Geometry were significantly (at level 5%) higher than the points obtained by male students; the points in Calculus in both gender samples had no significant difference. A significant positive correlation of all variables has been revealed; hereby, in the female student sample, the correlation is stronger. The authors have constructed regression models purposing to predict the students' resulting term rating points in Calculus and Analytical Geometry in both gender samples by virtue of their USE points and ratings in both subjects before the exams. The adjusted coefficient of determination for the final rating in Calculus is about 0.85, as well as for the resulting rating in Analytical Geometry in the female student sample. In the male student sample, the coefficient of determination is 0.78. The mentioned differences make it preferable to use separate models for prediction of education outcomes for male and female students. The suggested regression model has been verified on a test sample of 161 students taught in the same specialization in the previous year. For the test sample, the regression model has shown good results.

Keywords
Academic Performance, Predictor, Rating, Regression Model, Unified State Exam.

Résumé
Les auteurs ont cherché la corrélation entre les notes au premier semestre en Analyse Mathématique et en Géométrie Analytique et les notes d'Examen d'État Unifié des étudiants en ingénierie de la première année académique. L'échantillon comprend 365 étudiants (284 hommes et 81 femmes). L'analyse statistique par sexe montre que le notes en Géométrie Analytique des femmes sont significativement plus élevées aux notes obtenues par les hommes ; les notes en Analyse Mathématique des deux sexes sont presque égales. Des corrélations positives des toutes les variables ont été révélées ; À cet égard, en l'échantillon des femmes la corrélation est plus forte.
Les auteurs ont construit des modèles de régression pour pronostiquer les notes finales du semestre en Analyse Mathématique et en Géométrie Analytique des étudiants des deux sexes en relation aux notes d'Examen d'État Unifié. Le coefficient de détermination ajusté pour le classement final des étudiantes en Analyse Mathématique est de 0.85, tout comme pour le classement final en Géométrie Analytique. En l'échantillon des étudiants, le coefficient de détermination est de 0.78. Ces différences prouvent la

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nécessité de construire deux modèles parallèles selon le sexe. Le modèle de régression proposé a été vérifié par un échantillon pilote de 161 étudiants qui a été établi en l'année précédente. Le modèle de régression a présenté de résultats convenables.

Mots clefs:
Performance Académique, Pronostic, Classement, Modèle de Régression, Examen d'État Unifié.

Introduction

A large amount of psychological and pedagogical researches has been aimed to reveal predictors of students' education outcomes, which demonstrate quality of the students' knowledge and influence their future success in professional activity (Goh & Moore, 1978). One of the most important directions of research is exploration of the first year students' outcomes, since they are in the transition between the elder school and the university; this is the starting stage of development of cognitive capabilities of the students and adaptation to a new organization of education system as compared to the school (Luk, 2005; Saprykina, 2017). In this stage, many students make the first steps in their professional adaptation, which significantly influence their professional success in the future (Garza & Bowden, 2014).

Learning mathematical subjects is the basis of engineering education, since the disciplines of the professional curriculum cannot be studied without knowledge of fundamental mathematical notions and laws (Harris, Black, Hernandez-Martinez, Pepin, & Williams, 2015; Kelley, Hosp, & Howell, 2008). For example, (Nilsen, Angell, & Grønmo, 2013) have distinguished the mathematical competences necessary for successful study of physics. Hereby, it is known that the a priori competences in physics and technology are very volatile for engineering students, and a significant share of the students meet difficulties in education due to lack of certain mathematical knowledge (Behrendt, Dammann, Ştefănică, Markert, & Nickolaus, 2015). Often engineering students do not regard learning mathematics itself as the priority task; moreover, many applicants and first year students of engineering specializations underestimate the amount of mathematical knowledge they have to master in the university. (Kümmerer, 2001).

The influence of informatics and communication technologies onto the processes of organization of information and knowledge is well studied. The researchers (Pushkarev & Pushkareva, 2019) have mentioned the increase of amount of knowledge with simultaneous decrease of quality of its reflection and personal adoption, and the necessity of development of the system, which would be able to overcome these difficulties. Many authors have suggested various education techniques, which make it possible to obtain the desired system and, consequently, higher education outcomes in mathematics by engineering students. These education techniques include usage of the system Moodle (Blanco Abellan & Ginovart Gisbert, 2012; Erokhin, Sadykova, Zhdankina, Korzhuev, & Semenov, 2018), CAS – computer algebra systems (Cretchley, Harman, Ellerton, & Fogarty, 2000; Mezhennaya & Pugachev, 2018; Mezhennaya & Pugachev, 2019), mobile applications (Jacinto & Carreira, 2017), etc.

Many researches have been concerned with linkage between the first year students' education outcomes and their apprehension of mathematics in general, their interest to solution of certain types of tasks, their previous experience (Faulkner, Earl, & Herman, 2019; Nortvedt & Siqveland, 2019), and their residual knowledge test results (Vlasova, Mezhennaya, & Popov, 2018). Hence, it is important to explore the means of forecasting the education outcomes in mathematics by virtue of the students' previous outcomes.

Many researches have confirmed statistically significant linkage between students' test results before entering universities and their subsequent academic performance (see, e.g., (Khavenson & Solovyeva, 2014; Kobrin, Patterson, Shaw, Mattern, & Barbuti, 2008; Vlasova et al., 2018)). Khavenson and Solovyeva have established that the first year students' academic performance is explained at average 20% by the only factor: the sum of USE (Unified State Exam) points. Pol'din (Pol'din, 2011) has detected significant linkages between the USE points (in all subjects) and the probability of expulsion and the average points at the first year of economist students of National Research University "Higher School of Economics". On the basis of the established linkage between USE in mathematics and the rating points in Calculus in the first half-year term, it is possible to prepare methodic recommendations for the entrance examination commission, to take into consideration during admission of students of certain specializations (Chusovlyankin, 2015). Many researchers (Kobrin et al., 2008; García-Ros, Pérez-González, Cavas-Martínez, & Tomás, 2018) have carried out analogous studies of linkage between students' outcomes and the results of school passing-out exams together with the average points in the school certificates. One can consider students' self-effectiveness, inclusion into social and scientific environment of a university and their labor responsibility as predictors of the students' academic performance (McKenzie & Schweitzer, 2001). Later (Zamkov & Peresetsky, 2013) have obtained a similar result: the USE points appeared to be significant for the prognosis of students' academic performance, but the first year final rating of a student almost completely accumulates the starting information contained in the results of USE and school Olympiads. Recently (Mezhennaya & Soldatenko, 2017) have investigated the linkage between the way of entering a university (by the results of USE or of the Olympiad in mathematics and physics "Step into the Future") and the students' academic performance, and established that the Olympiad participants were more motivated and professionally adapted. Hence, these students are more successful in mastering mathematical and other STEM-subjects and in carrying out control works within the modular-rating system; see (Peresetsky & Davtyan, 2011) as well.

Recently (Vlasova et al., 2018) have analyzed the linkage between the results of USE in profession-oriented mathematics, of the test of residual knowledge in mathematics, and the education outcomes in Calculus and Analytical Geometry of the first year students of engineering specialization. They have established that there exists a positive rank correlation between the results of USE and of the test of residual knowledge; hereby no explicit linkage between mathematics exam points in the first term and the USE results has been detected. A possible reason is that the authors analyzed the marks ("unsatisfactory", "satisfactory", "good", and "excellent") without considering the students' individual ratings in each subject before and after the exam, and USE points in other subjects. Similar results have been obtained in (Pereyaslavskaya & Pereyaslavsky, 2014).

The present research includes the investigation of linkage between a student's resulting rating after the first half-year exams in Analytical Geometry and Calculus, the rating points in both subjects obtained before the exams, and the results of USE in the profession-oriented mathematics. The main question of the research is whether it is possible to construct a regression model to predict the resulting rating and, hence, the half-year mark in each subject, depending on the factors mentioned, for the first-year engineering students. Groups of male and female students are considered separately, in order to detect significant differences in the indexes under consideration and, hence, in effectiveness of the model prediction.

Research Methodology

General Background of Research

The research explores the linkage between education outcomes in Analytical Geometry and Calculus, and the USE points, of the first year students taught in Bauman Moscow State Technical University (BMSTU) in the 2018-2019 year. The linkage between the half-year rating points before and after the exams in both subjects, and the USE points in mathematics in the groups of female and male students is explored. The authors consider regression models helping to predict the total sum of points by virtue of the known USE points and the half-year points obtained before the exam, in both subjects for both considered groups. The suggested models are verified on a test sample including the data of the first year students taught in the 2017-2018 year in the same specializations.

Research Sample

The training sample includes the data of 365 students (284 male and 81 female students) taught in BMSTU in the first (autumn) term of the 2018-2019 year in the specialist degree curriculum. The sample includes the students with known USE results, who passed the exams in Analytical Geometry and Calculus in the end of the term. The survey excludes the students, who were expulsed from the university or went away themselves during the term. The average age at the moment of entering the university (1 September 2018) was 18.20 years with standard deviation 0.63 years for the whole sample; 18.22 years with standard deviation 0.63 years for the male student sample; 18.13 years with standard deviation 0.61 years for the female student sample. There is no significant (at level 5%) difference of age distribution between the male and female student groups.

The test sample consists of 161 first-year students (127 male and 34 female students) taught in BMSTU in the autumn term of the 2017-2018 year in the specialist degree curriculum. The test sample includes the students with known USE results, who passed the exams in Analytical Geometry and Calculus in the end of the term. The survey excluded the students, who were expulsed or went away themselves during the term. The average age at the moment of entering the university (1 September 2017) was 18.14 years with standard deviation 0.73 years for the whole sample; 18.14 years with standard deviation 0.73 years for the male student sample; 18.12 years with standard deviation 0.72 years for the female student sample.

Instruments and Procedures

The research has used the following instruments:

1) Examination papers of USE in mathematics. Examples and analysis of such examination papers are presented in a large amount of works, see, e.g., (Gospodinova, Yanovskaya, & Ivanova, 2015);

2) Complete sets of control tasks (control works and home tasks) for checking knowledge within the half-year term, and examination papers of the courses of Analytical Geometry and Calculus.

A student obtains rating points for results of control tasks, according to the calendar plan. For a student having fulfilled all these tasks, the minimal rating is 42 points; the maximal rating is 70 points. A student has three attempts to perform each control task before the exam; if (s)he fails to perform a task at the first attempt, then the next attempts can add only minimum of points to the student's rating. If a student has not fulfilled some of the control tasks until the exam, (s)he receives the corresponding tasks in addition to the examination paper in the same day. An examination paper of any subject consists of two questions corresponding to the two education modules. A student gets from zero to 30 points as a result of the exam. Students produce all the control tasks in writing; if a disputable situation occurs, an expert teacher who has not taught the student's group checks the student's work. This way, a student's rating for the whole term can take value from zero to 100. The students receive resulting marks depending on their rating points, according to the rules listed below in the section 'Results of Research'.

Methods of Research

In the further research, the standard statistical methods of collecting and analysis of empirical data (distribution histograms, descriptive statistics), the tests of homogeneity (Mann–Whitney test for independent samples, Wilcoxon test for dependent samples), and the methods of regression analysis have been used.

Data Analysis

The collected data of students (USE points, term ratings before the exam, and exam points) have been carefully checked to have a correct form. The survey has excluded data of the students having not fulfilled one or several items. As a result, the researchers have obtained two samples of students: the training sample of 365 students taught in the first year in 2018-2019, and the test sample of 161 students taught in the first year in 2017-2018. All personal data of the students was deleted from the samples.

Limitations

Let us describe possible limitations of effectiveness of the considered regression model and possible ways of its improvement. It was shown that for reliable prediction of education outcomes, it is necessary to consider the results of USE in all subjects, especially in Russian, instead of only the results of USE in mathematics (Peresetsky & Davtyan, 2011; Pol'din, 2011; Zamkov & Peresetsky, 2013). The linkages established in these researches do not seem to be natural; at least, the linkage between students' education outcomes in mathematical subjects and their school marks in Russian is not evident at first sight. More probably, this linkage involves the general level of academic performance in all subjects. Indeed, school teenagers gaining high marks in many subjects are more motivated to obtain high results in a university.

Further, it would be possible to construct a regression model to predict students' resulting term ratings by virtue of their academic performance in the first module (the first half of the half-year term). In this stage, correction of individual curriculum within the modular-rating system is still possible, purposing to increase the students' motivation to achieve better education outcomes (Nigmatov, 2013). This way, the teachers could see the students' education problems and possible ways helping to solve them.

Moreover, freshman students may have certain difficulties in adaptation to the education system differing from the school. To the authors' opinion, one of the main difficulties is the lack of understanding of principles of the modular-rating system of knowledge monitoring (Sharonova, 2009). Often students are not acquainted with details of this system; they only receive sets of teaching materials for independent study. Freshman students underestimate importance of these materials and begin detailed consideration either at the end of the first module, or immediately before the exam. It is not a big factor for high-achieving students, since they perform all types of control tasks quite good. For weak students, who have not estimated the impending difficulties in time and have not chosen a suitable education strategy, this situation may cause a catastrophe. For example, one of possible strategies is to devote more time to performing the home task in order to get maximum of points for it; and at the control work, to choose the tasks, which are easier to the student, in order to get the minimum of points. The weak students, who have to deal with failures of the first module, perform the second module with failures too. Along with low academic outcomes, this situation leads to lower motivation to study Calculus and Analytical Geometry; in future, it may adversely affect the study of other mathematical subjects.

Among students' problems causing difficulties in education, there are the lack of professional adaptation and orientation, and difficulties during the school-institute transition (Gorbunova, 2013; Paunonen & Ashton, 2001). Therefore, since the first days of the study, it is necessary for teachers of mathematical departments and specialized graduate departments to explain the principles of the modular-rating system to the students. Moreover, the teachers have to elucidate to students the necessity of profound knowledge of fundamental mathematical disciplines as the basis of future professional activity.

Another means of involving students into the education process is usage of computer tools of analysis and visualization. For example, in the first module of Calculus, students study the theory of limits; hereby, many of them have certain difficulties (Bergsten, 2008). The study of limits is impossible without clear presentation of graphs of the basic elementary functions (Hardy, 2009). As a rule, for high-achieving students this is not a difficulty, but weak students often need supplementary materials and explanations. Usage of program packages makes students (with minimal knowledge of their interface) capable of constructing graphs of given functions in a large amount of particular cases, in order to further better guide themselves in the studied material.

One can make the suggested regression model more precise by using the data of school leaving certificate marks (considering each mark separately or uniting some of them). One can find other significant factors for the model by means of questioning the students with respect to the following parameters: self-effectiveness, participation in university life, assessment of education technologies used, students' dwelling and transport conditions, etc. Such researches may have certain disadvantages, since they use subjective estimates of parameters, which are impossible to evaluate quantitatively; hence, special methods of their calculation should be elaborated.

Another factor, which one can take in account in predicting education outcomes, consists in the results of students' participation in mathematical Olympiads (Vlasova, Popov, & Pugachev, 2017). Its consideration requires special approach since a quite small share of students takes part therein; but academic performance of students among the participants is very different. Not only high-achieving students take part in the competition; weak students hope to get some additional rating points. However, even successful participants of all-Russian mathematical Olympiads sometimes fail in exams. The mathematical Olympiads influence students' ratings and level of knowledge, but this influence is not synonymous. Hence, a questioning of these students is necessary in order to specify difficulties in their education. This way, for those students who take part in the mathematical Olympiads, one can regard the points obtained for the Olympiad tasks as a new factor in the predictor of academic outcome.

Results of Research

Analysis of distribution of points and marks in the training sample (N=365)

The histogram in Fig. 1 presents the distribution of points of USE in mathematics for the whole sample, and for male and female student samples, separately. Average USE points of the whole sample are 74.95 with standard deviation 8.39; in the male student sample, average points are 74.87 with standard deviation 8.69; in the female student sample, average points are 75.22 with standard deviation 7.32 (see Table 3).

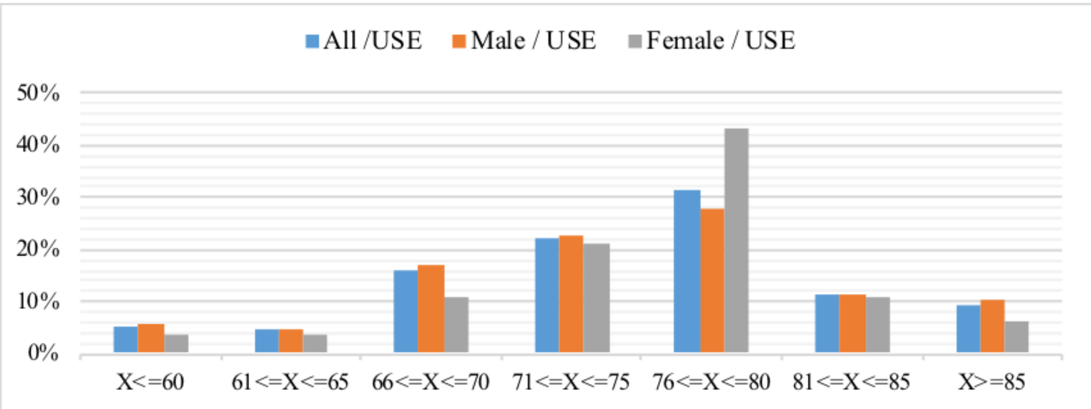


Fig. 1. Histogram of points of USE in mathematics for the whole sample, and for male and female student samples, separately

The majority of the students got from 71 to 80 points; hereby, the share of female students having received from 76 to 80 points (43%) is sufficiently higher than the share of male students with such points; in the interval from 71 to 75, the shares of both genders are almost equal. The shares of male students are bigger than the shares of female students in both the lowest (<71) and the highest (>84) ranges. Nevertheless, there appears no statistically significant difference in USE points in mathematics between the two gender samples (see Table 1).

Table 1. The values of Mann-Whitney statistics for comparison of points of USE in mathematics and the first term exams in Calculus and Analytical Geometry of the male (N=284) and female (N=81) student samples. The significant (at level 5%) values of the statistics are distinguished with bold type

Points	Z-statistic	p-value
USE in mathematics	-0.647	0.5175
Calculus (resulting term rating)	-1.319	0.1872
Calculus (exam)	-0.905	0.3654
Calculus (rating before exam)	-1.552	0.1207
Analytical Geometry (resulting term rating)	**-3.707**	**0.0002**
Analytical Geometry (exam)	**-3.714**	**0.0002**
Analytical Geometry (rating before exam)	**-2.492**	**0.0127**

The next two pictures present the distribution of rating points in Analytical Geometry and Calculus obtained in the term before the exam (Fig. 2) and including exam points (Fig. 3).

Before the exams, the average rating in Analytical Geometry is 52.95 with standard deviation 12.39 in the whole sample; 52.39 with standard deviation 12.42 in the male student sample; 54.91 with standard deviation 12.15 in the female student sample. The average rating in Calculus is 54.25 with standard deviation 12.30 in the whole sample; 54.01 with standard deviation 12.11 in the male student sample; 55.12 with standard deviation 12.99 in the female student sample.

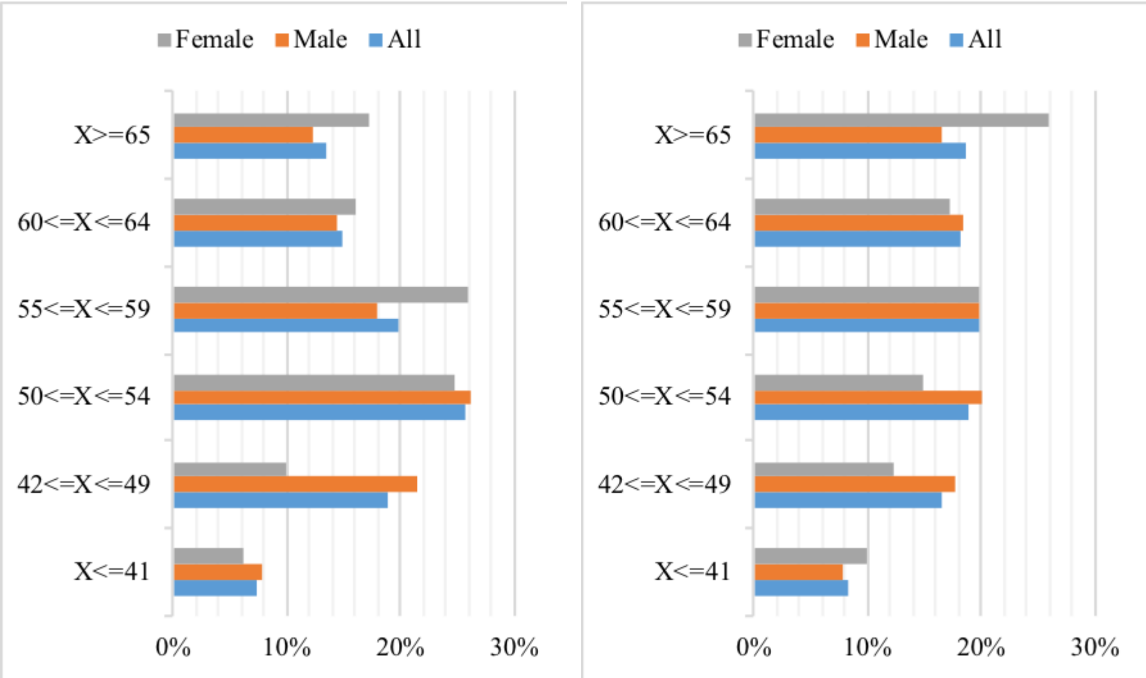


Fig. 2. Rating points obtained before the exam in Analytical Geometry (on the left) and Calculus (on the right).

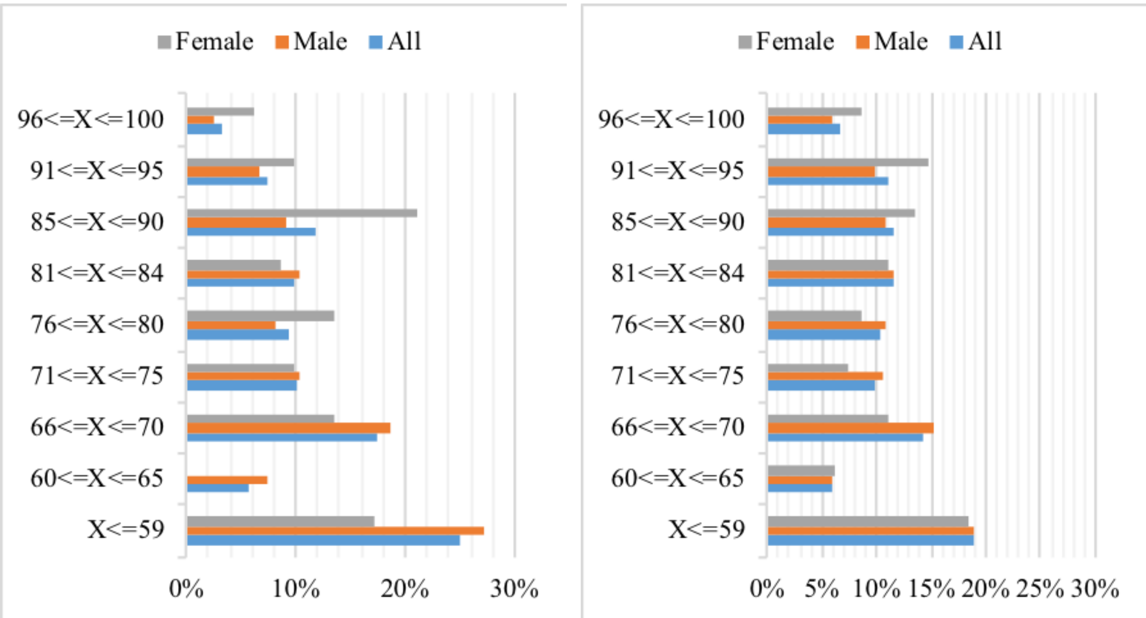


Fig. 3. Resulting term rating points (including the exam points) in Analytical Geometry (on the left) and Calculus (on the right).

The researchers have established (see Table 1) that the points obtained by female students (before the exam, during it, and resulting) in Analytical Geometry are significantly (at level 5%) higher than the male student' points. In Calculus, there is no significant difference between the two gender samples.

One should note that 25% of the students (27% of the male students and 17% of the female students) have finished the half-year term with unsatisfactory marks in Analytical Geometry. Slightly smaller shares of the students (19% in both genders) have finished the half-year term with unsatisfactory marks in Calculus.

The students receive resulting marks depending on their rating points. The mark '2' ("unsatisfactory") corresponds to a rating less than 60, the mark '3' ("satisfactory") to a rating from 60 to 70 points, the mark '4' ("good") to a rating from 71 to 84 points, the mark '5' ("excellent") if the rating is 85 or more. Fig. 4 shows the distribution of the half-year term marks.

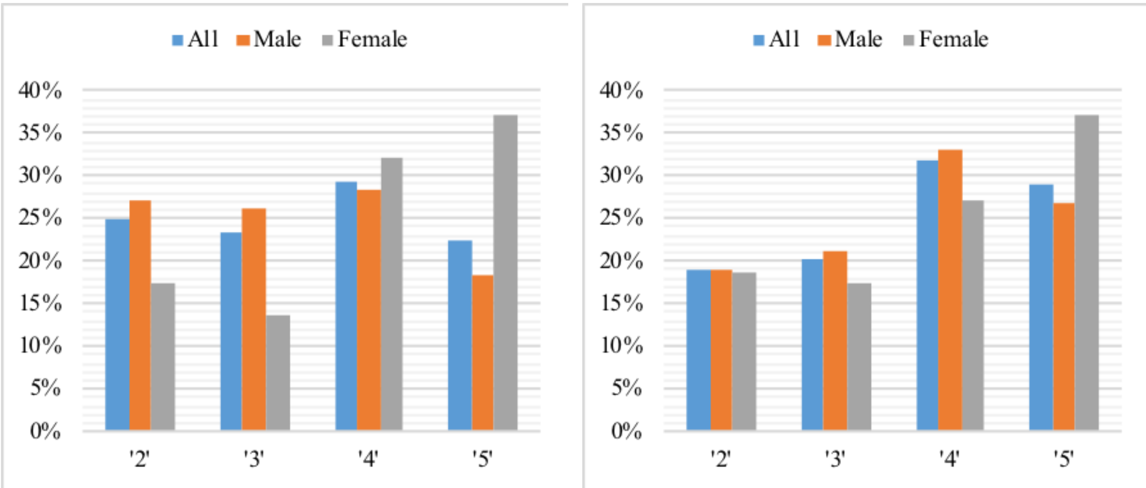


Fig. 4. Histogram of the resulting term marks in Analytical Geometry (on the left) and Calculus (on the right) for the whole sample, and for the male and female student samples, separately.

In Analytical Geometry, the shares of all students having marks '2', '3', '4', and '5' are almost equal. In Calculus, the shares of '4' and '5' are about 10% higher than the shares of '2' and '3'. However, in the male and female student samples these shares behave oppositely. One can see from Fig. 4 that female students got higher percentage of '5' as compared to the male students. Let us proceed to checking possible differences in distribution of marks in both subjects in the whole sample and in the gender samples by means of Wilcoxon test (Table 2).

Table 2. The values of Wilcoxon statistics for comparison of points in Calculus and Analytical Geometry in the whole sample (N=365), in the male sample (N=284), and in the female sample (N=81). The p-values are in the brackets. Significant (at level 5%) values of the statistics are distinguished with bold type

Sample	Rating points before the exam	Exam points	Resulting term rating
The whole sample	**3.298 (<0.001)**	**4.717 (<0.001)**	**3.099 (0.0019)**
Male students	**3.457 (<0.001)**	**5.286 (<0.001)**	**3.766 (<0.001)**
Female students	0.407 (0.684)	0.119 (0.905)	0.855 (0.393)

There appears a significant (at level 5%) difference in distribution of rating points in Calculus and Analytical Geometry (before, during, and after the exam) in the male student sample, causing similar differences in the whole sample.

One can assume the following reason of such difference. Many students have studied Analytical Geometry already at schools; solution of certain tasks requires more concentration and attention (e.g., to avoid arithmetical errors). Possibly, during the exams the female students were more concentrated, prepared and motivated than the male students.

Analysis of Correlation Coefficients for the Training Sample (N=365)

The purpose of the present section is to answer the question whether it is possible to predict reliably the education outcomes in Calculus and Analytical Geometry, by virtue of information about the points obtained in the term before the exam, and the USE results. For this sake, let us begin with analyzing correlation coefficients between these values (see Table 3).

From now on, the following notation is used:

AG_ – rating points in Analytical Geometry,

C_ – rating points in Calculus.

Suffixes:

_S – rating points obtained before the exam,

_E – exam points,

_T – resulting term points (i.e., **AG_T** = AG_S + AG_E, **C_T** = C_S + C_E).

The variables to predict are distinguished with bold type.

Table 3. Correlation coefficients between the rating points in Calculus and Analytical Geometry, and the points of USE, in the whole sample (N=365), the male sample (N=284), and the female sample (N=81). All the correlation coefficients appeared significant at level 5%

		Mean	Standard deviation	USE	AG_S	**AG_T**	AG_E	C_S	**C_T**	C_E
USE	All	74.95	8.39	1.000	0.242	0.293	0.263	0.318	0.367	0.346
	Male	74.87	8.69		0.223	0.261	0.219	0.293	0.337	0.314
	Female	75.22	7.32		0.320	0.430	0.465	0.420	0.488	0.482
AG_S	All	52.95	12.39	0.242	1.000	0.883	0.475	0.768	0.744	0.548
	Male	52.39	12.42	0.223		0.873	0.433	0.753	0.725	0.524
	Female	54.91	12.15	0.320		0.916	0.603	0.526	0.808	0.632
AG_T	All	69.40	19.70	0.293	0.883	1.000	0.833	0.751	0.748	0.578
	Male	67.89	19.43	0.261	0.873		0.817	0.734	0.722	0.541
	Female	74.70	19.84	0.430	0.916		0.873	0.821	0.848	0.715
AG_E	All	16.45	10.53	0.263	0.475	0.833	1.000	0.502	0.526	0.438
	Male	15.50	10.50	0.219	0.433	0.817		0.467	0.478	0.382
	Female	19.79	9.99	0.465	0.603	0.873		0.633	0.701	0.652
C_S	All	54.26	12.30	0.318	0.768	0.751	0.502	1.000	0.923	0.620
	Male	54.01	12.11	0.293	0.753	0.734	0.467		0.918	0.605
	Female	55.12	12.99	0.420	0.821	0.821	0.633		0.938	0.669
C_T	All	72.60	19.90	0.367	0.744	0.748	0.526	0.923	1.000	0.875
	Male	72.16	19.67	0.337	0.725	0.722	0.478	0.918		0.872
	Female	74.12	20.73	0.488	0.808	0.848	0.701	0.938		0.885
C_E	All	18.34	9.78	0.346	0.548	0.578	0.438	0.620	0.875	1.000
	Male	18.15	9.82	0.314	0.524	0.541	0.382	0.605	0.872	
	Female	19.00	9.65	0.482	0.632	0.715	0.652	0.669	0.885	

In the whole sample, as well as in both gender samples, one can note positive significant correlations between all the values under consideration. It is natural that especially strong is the linkage between the ratings before and after the exam, in both subjects, in all samples.

The points of USE have significant positive correlation with the rating points in Calculus and Analytical Geometry in the whole sample and in both gender samples; a closer linkage of USE points with education outcomes has been detected in the female sample. Also, note a strong linkage between the ratings in Analytical Geometry and

Calculus before the exams, especially in the female student sample. Correlation between exam points in both subjects is much weaker.

One should note the general tendency: the linkage between all the points in the female student sample is stronger, but the grade of differences varies by some indicators. The strongest is the difference between linkages of Calculus and Analytical Geometry exam points, in the male and female student samples.

Let us proceed to the analysis of the regression models for prediction of the resulting rating points by virtue of the sum of rating points in Calculus and Analytical Geometry before the exam and the result of USE in mathematics. See the results of calculation in Table 4.

Table 4. Results of the regression analysis of dependence of the variables **C_T** and **AG_T** on the factors C_S, AG_S, and the points of USE in mathematics. The values, which are not significant at level 5%, are distinguished with italic

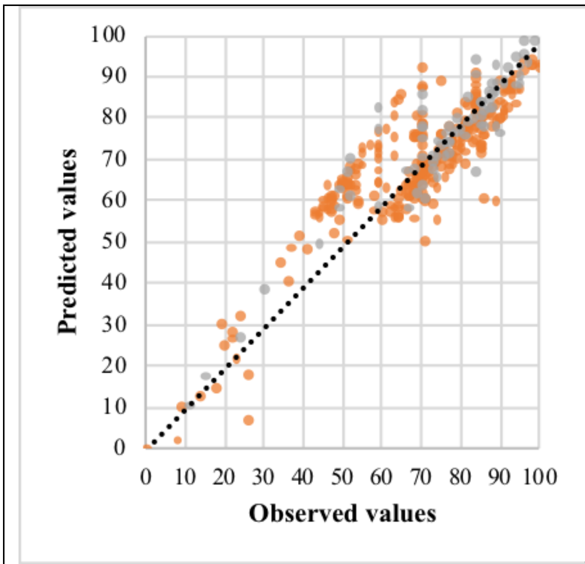
Samples	R^2_{adj}	F-statistic	D.-W. statistic	Variable			
				Constant	USE	AG_S	C_S
C_T							
All Students	0.86	741.4 (p<0.001)	1.839 (p<0.01)	-22.140 t-st.=-6.12 (p<0.001)	0.193 t-st.=3.93 (p<0.001)	0.138 t-st.=2.80 (p=0.006)	1.344 t-st.=26.44 (p<0.001)
Male Students	0.85	527.83 (p<0.001)	1.918 (p<0.01)	-20.419 t-st.=-4.98 (p<0.001)	0.169 t-st.=3.08 (p=0.003)	0.123 t-st.=2.21 (p=0.028)	1.360 t-st.=23.32 (p<0.001)
Female Students	0.89	221.56 (p<0.001)	1.923 (p<0.01)	-31.773 t-st.=-3.95 (p<0.001)	0.332 t-st.=2.90 (p=0.005)	*0.216 t-st.=1.97 (p=0.053)*	1.253 t-st.=11.67 (p<0.001)
AG_T							
All Students	0.80	467.94 (p<0.001)	2.054 (p<0.01)	-18.062 t-st.=-4.17 (p<0.001)	0.145 t-st.=2.46 (p=0.014)	1.185 t-st.=20.05 (p<0.001)	0.255 t-st.=4.19 (p<0.001)
Male Students	0.78	327.77 (p<0.001)	2.089 (p<0.01)	-14.911 t-st.=-3.03 (p=0.003)	*0.108 t-st.=1.64 (p=0.102)*	1.159 t-st.=17.33 (p<0.001)	0.259 t-st.=3.70 (p<0.001)
Female Students	0.86	166.57 (p<0.001)	1.687 (p<0.01)	-31.013 t-st.=-3.55 (p<0.001)	0.340 t-st.=2.73 (p=0.008)	1.225 t-st.=10.28 (p<0.001)	0.234 t-st.=2.01 (p=0.049)

The regression models under consideration appear significant for the whole sample, as well as for the male and female student samples taken separately (see the columns of F-statistic and R^2_{adj}); the adjusted coefficient of determination R^2_{adj} for the variable **C_T** turns out not less than 0.85. A similar result takes place for the variable **AG_T** in the female sample, but in the male sample one has R^2_{adj} = 0.78, hence it is lower in the whole sample as well. However, in all the cases under consideration, quality of the models is good.

In the regression model for the variable **C_T**, it turns out that the factor AG_S is significant at level 5% in the male student sample and in the whole sample as well. One can mention that in the female and male student samples this variable has opposite tendencies. In the regression model for the variable **AG_T** in the male student sample, the sum of USE points in mathematics appears insignificant at level 5%.

It turns out that, in both gender samples, the factor AG_S weakly influences the resulting rating points (and, consequently, the mark) in Calculus. At the same time, in the male student sample (unlike the female student sample) the resulting points in Analytical Geometry (**AG_T**) have a strong linkage with the factor C_S. The mentioned differences hint that it is reasonable to use separate models for prediction of education outcomes for male and female students, especially in Analytical Geometry.

Scatter plots of the observed and predicted resulting term points in both subjects shown in Fig. 5 illustrate quality of the obtained results.



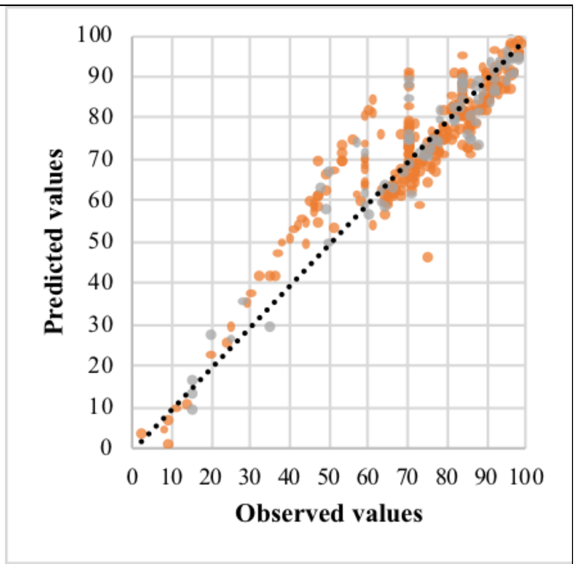


Fig. 5. Scatter plot of the predicted and observed values of **AG_T** (on the left) and **C_T** (on the right) for the male student sample (orange points) and female student sample (gray points).

One can see from Fig. 5 that the predicted and observed resu lting term points appear quite close to the diagonal (black dot line). At the same time, one can see that, for the students having the lowest resulting rating in both subjects (lower than 60 points, corresponding to the mark '2' = "unsatisfactory"), the predicted rating appeared 10-15 points higher than the actual rating. A small amount of rating points has no principle influence on the education outcome; but in the border situation (near 60 points) the model inclines to "overestimate" the result.

In some cases, the detected statistical differences appear significant at level 1% as well. However, since the volumes of the samples analyzed are not large, the results of their analysis at the level of 1% significance are not quoted here.

Verification of the model by the test sample (N=161)

It is necessary to compare the resulting term points in Analytical Geometry and Calculus, obtained by the students and predicted by the model from Table 4, on a test sample. Since the research has detected some differences in distributions of points in the male and female student samples, then two different regression models are to use for students of both genders.

In the test sample, the average USE points were 77.55 with standard deviation 8.47 in the whole sample, 77.15 with standard deviation 8.87 in the male student sample, 79.03 with standard deviation 6.69 in the female student sample. The average **AG_T** was 52.06 with standard deviation 11.81 in the whole sample, 51.06 with standard deviation 11.26 in the male student sample, 55.76 with standard deviation 13.20 in the female student sample. The average **C_T** was 51.21 with standard deviation 9.90 in the whole sample, 50.16 with standard deviation 9.38 in the male student sample, 55.15 with standard deviation 10.92 in the female student sample.

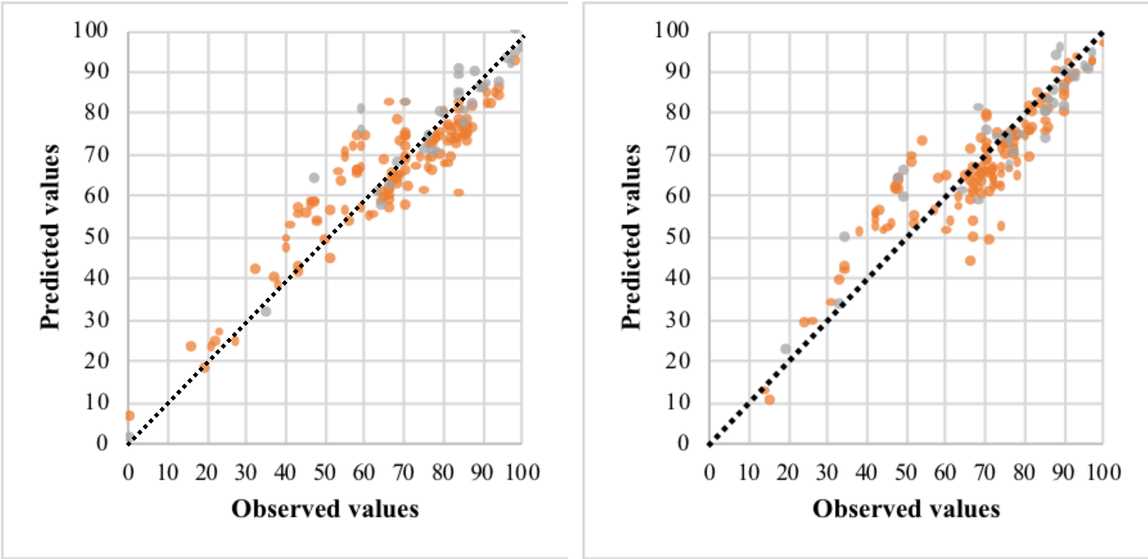


Fig. 6. Scatter plots of the predicted and observed values of **AG_T** (on the left) and **C_T** (on the right) for the male student sample (orange points) and female student sample (gray points) in the test sample.

Comparison of Fig. 5 and 6 demonstrates that the considered regression model behaves almost identically in both the training sample and the test sample. In the test sample, the determination coefficient for **AG_T** is 0.97 in the male student sample and 0.98 in the female student sample; the determination coefficient for **C_T** is 0.78 in the male student sample and 0.87 in the female student sample. Hence, in the test sample, quality of the model for predicting the value of **AG_T** appears slightly better than in the training sample. The model for predicting the value of **C_T** works slightly worse in the male student sample. Nevertheless, for the training sample, the percentage of total variation of the observed outcomes explained by the regression models still appears quite high; therefore, it is possible to use the constructed models in the future to predict education outcomes basing on the first term results.

Conclusion

The research explores the linkage between the rating points (within the modular-rating system) in the first half-year term in Calculus and Analytical Geometry, and the points of USE (Unified State Exam), of students of engineering specialization taught in the first year in 2018-2019. Statistical analysis of the training sample of 365 students (284 male and 81 female) has revealed significant positive correlations between the rating points obtained in the term before and during the exams in both subjects, and the USE points in mathematics; this agrees with the results of earlier researches (Chusovlyankin, 2015; Khavenson & Solovyeva, 2014; Vlasova et al., 2018).

In the present research, in the female group the aforementioned correlation is stronger. In the USE results, there is no significant difference between the female and male student samples. The authors have established that the points obtained by female students in the term (before the exam, during the exam, and the sum) in Analytical Geometry, were significantly (at level 5%) higher than the points obtained by male students; the points in Calculus in the gender samples have no statistically significant difference. A significant (at level 5%) difference in distribution of points in Calculus and Analytical Geometry (before the exam, during the exam, and the sum) in the male sample, and, consequently, in the whole sample, has been established. In the female student sample, such difference does not take place.

The authors have constructed a regression model describing how the resulting term rating points depend on the USE points and the points obtained during the term before the exam in Calculus and Analytical Geometry. The adjusted coefficient of determination for the final rating in Calculus has appeared not lower than 0.85 for the whole sample, as well as for the male and female student samples taken separately. A similar result takes place for the resulting rating in Analytical Geometry in the female sample. In the male sample, the coefficient of determination is 0.78. Therefore, the suggested model is suitable to predict education outcomes of the first half-year term by virtue of intermediate outcomes and the points of USE in mathematics. The regression model has been verified on a test sample of 161 students taught in the same specialization in the previous year (2017-2018). For the test sample, the regression model has shown good results. Hence, it is possible to use the proposed model to predict education outcomes in the first half-year term basing on intermediate outcomes and the points of USE in mathematics. Due to differences in the result obtained in male and female student samples, it is preferable to use separate models for prediction of education outcomes for male and female students.

The main advantage of the present research as compared to previous works (Chusovlyankin, 2015; Khavenson & Solovieva, 2014; Pol'din, 2011; Saprykina, 2017; Zamkov & Peresetsky, 2013) is the possibility to predict the resulting half-year term outcomes by virtue of current academic performance in the middle or at the end of the half-year term. Hereby, in prediction of each of the two exams, ratings in both mathematical subjects of the term are considered. The university educational process essentially differs from that in the school, since students find themselves in new surroundings and have to follow new rules; unlike school education, higher education is not a common duty, hence it requires much effort of students to stay in a university and to correspond to its demands. Penetration of live learning tools helps students to optimize their work.

It is well-known that often students themselves underestimate the level of difficulty in mastering their educational material before the exam, but they understand the depth of the challenge just in the day of the exam, in fact when they have not enough time to master the required volume of knowledge. Usage of the regression model suggested by the authors makes it possible to forecast future academic outcomes of each individual student before the final exams. This would help to focus the student's, the teachers', and the group curator's attention at possible difficulties ahead at the exams, already when the student still has enough time for comprehensive study of educational materials in one or two subjects. As a result, the student (with or without the curator's help) would be able to plan his/her independent work in order to minimize the revealed difficulties in the subject, and to ask the teacher's help. In the same time, the teacher can focus the individual student's attention on the topics, which are the most difficult for him/her. Such coordinated work of all parties can significantly improve the academic outcomes, even of the students having low initial training level.

Moreover, the revealed linkages between the USE outcomes and the academic performance make it possible already on the stage of applicants' preparation classes to identify those who would probably meet difficulties in studying mathematical subjects in the future. There is a clear need to inform such students about possible challenges ahead, in order to enable them either to devote more time to extra classes in mathematics, or to choose another specialization involving less mathematics in their university.

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