Gender Stereotypes and the Choice of an Engineering Undergraduate Program

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Abstract

In Russia, as well as in the globe, there is a substantial imbalance in proportions of men and women who choose engineering undergraduate programs. As previous research demonstrated, this phenomenon can be explained by the gender stereotypes about better natural abilities of men to understand mathematical and engineering subjects. The paper is aimed to define the prevalence of gender stereotypes and gender differences in the choice of engineering majors, and explore associations between gender bias and the reasons for major choice. The survey data about undergraduate engineering students collected in one regional Russian university with strong focus on technical science was utilized (N = 1791). According to our results, the most widespread gender stereotypes among engineering students are that men better understand physical phenomena and patterns and have more developed technical and logical reasonings, while women are more neat and diligent. Reasons for engineering program choice do not significantly differ for men and women students. However, men students affected by gender stereotypes more often reported their wish to get a good job after graduation as a reason for major choice. While, women students, affected by gender stereotypes about better natural math abilities of men, more often reported that their major choice was made by the influence of family. Moreover, women are less satisfied with their choice of university and undergraduate program.

Keywords

major choice, engineering, gender stereotypes, gender inequality, satisfaction with the choice of university and undergraduate program, higher education.

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The previously existing inequality between young men and women in their access to higher education has already been overcome in many countries [OECD, 2015], and some states have even faced "reverse discrimination", that is, the proportion of females among those entering and graduating from universities significantly exceeds 50%. Thus, females were 58% of those who received a bachelor's degree in OECD countries in 2013. However, this figure varies greatly for different specialties: it reaches 64% in pedagogy, humanities and social sciences and does not exceed 31% in hard sciences and engineering [Ibid.]. In Russia, girls constituted only 26% of those who enrolled in engineering and technical profile programs in 2018 [Maloshonok, Shcheglova, 2020].

Gender disparity among student populations in the fields related to hard sciences, engineering, technical sciences, mathematics (STEM — Science, Technology, Engineering and Math) has a number of negative consequences for the social and economic spheres, in particular, it leads to economic losses [Bahr et al., 2017; Ferrante, Kolev, 2016]. In Australia, there are no more than 15% of females among STEM students in some disciplines, and a systematic review of studies conducted on an Australian sample reflected a common property for all female students studying in STEM fields as a lack of self-efficacy [Fisher, Thompson, Brookes, 2020]. Females are not inclined to choose STEM programs when planning their university studies and future careers [Goy et al., 2018], although objectively young men and women do not differ in innate abilities for hard sciences [Riegle-Crumb et al., 2012; O'Dea et al., 2018]. Therefore, the efforts of researchers are aimed at finding out the reasons for the low interest among girls in STEM programs and the nature of the difficulties they face in choosing such fields of study.

Gender stereotypes rooted in the public consciousness are recognized as an important factor causing disproportions between male and female populations in STEM fields, but the nature of their influence, as well as the mechanism of action have not yet been sufficiently studied. Within the framework of this study, we will not consider the entire range of STEM programs, because of their multiplicity and extreme heterogeneity. The study will focus on engineering and technical profile programs for several reasons. Firstly, the quality of education in these programs has recently received the most attention from the state due to their high importance for innovative and technical development and ensuring the competitiveness of the country [Frumin, Dobryakova, 2012]. Secondly, the largest number of state-funded places in universities is allocated for these programs[1]. Thirdly, the proportion of females was the small-

[1] https://www.minobrnauki.gov.ru/press-center/news/novosti-ministerstva/33254/

est among those enrolled in the group of specialties "Engineering, Technology and Technical Sciences" among all fields in 2018 [Maloshonok, Shcheglova, 2020].

In order to ensure the female participation in engineering and technical fields, it is necessary to understand the motivational choice for majors of this group and the role of the widespread ideas in society on the differences in the abilities of young men and women in mathematics and engineering.

Within this paper framework, we will answer the following research questions.

1. Are there any differences in the reasons for choosing engineering and technical majors between females and males?
2. To what extent are engineering students influenced by gender stereotypes prevalent in society, and are young females and males studying in such majors different in this regard?
3. Are gender stereotypes interrelated with the reasons for choosing engineering and technical majors?
4. How are gender stereotypes and reasons for choosing an engineering major interrelated with choice satisfaction?

1. Theoretical Review

The results of numerous studies conducted in different countries give grounds to assert that the gender gap in the number of university applicants for mathematics, engineering and natural sciences majors cannot be explained by differences in the female and male abilities to master these sciences [Riegle-Crumb et al., 2012; O'Dea et al., 2018; Stoet, Geary, 2018]. Girls' grades in hard sciences at school are not lower than boys'. And so, a team of Australian researchers compared the grades of 1.6 million schoolchildren and found that the girls' achievements in STEM majors do not differ significantly from the boys' achievements at the average, and the top 10% includes the same number of male and female students [O'Dea et al., 2018]. A sample of participants in the PISA international study, which comprised 472,242 students from 67 countries, showed that in most countries the results of girls in scientific literacy are not lower than those of boys [Stoet, Geary, 2018]. Researchers from the University of Texas and the University of Minnesota [Riegle-Crumb et al., 2012] also found that differences between girls and boys in the level of school preparation in the field of mathematical sciences are not a predictor of a gender gap in the frequency of choosing STEM specialties. Despite the success at the stage of school education, there are significantly more girls who would like to continue their education in STEM majors and could be successful in this field than those who actually enter these directions and complete their studies [Ceci, Williams, 2007; Stoet, Geary, 2018]. Female applicants

do not enjoy ample opportunities to choose even with higher USE results than male ones [Zamyatnina, 2017].

Gender inequality begins to form in childhood [Ceci, Williams, 2011]. In some countries, gender differences in preferences for engineering and technical subjects already arise in primary school due to the early placement of children into specialized classes: girls are more likely to enter classes with a humanitarian and linguistic bias [Gonzalez et al., 2020]. Researchers believe that such an early placement may be one of the reasons for the low interest among girls in an engineering career [Valla, Williams, 2012]. However, even in the range of countries without early distribution into specialized classes, there are gender differences in the preferences for certain school subjects [Delaney, Devereux, 2019; Khasbulatova, Smirnova, 2020]. Male schoolchildren are more likely to show their interest in the hard and technical sciences, while females tend to the subjects of the humanities cycle, and later on these preferences are manifested in the choice of the study direction at the university [Panina, 2018; Khasbulatova, Smirnova, 2020].

Gender differences in the preferences of certain fields are due not only to the male and female interest in various scientific and professional fields, but also to the motivation for choosing a future profession. Young men are largely guided by ideas about the economic needs of society and the level of wages when planning their career, while girls more often choose a profession under the influence of parents and tutors [Khasbulatova, Smirnova, 2020].

Researchers of gender differences in choosing the university major agree on the importance of social stereotypes for their formation. In this research, we will focus on studying their impact on the engineering and technical field. Social stereotypes are construed as widespread, simplified and generalized ideas about the engineering field in general, as well as about engineering and technical fields, about the social characteristics of people who study or work in these fields, and about the differences in the abilities to master them between males and females [Kessels, 2015]. Stereotypical judgments on engineering and technical fields in most cases relate to gender differences [Pickering, 2001]. Positive judgments are used in relation to young men and can act as a form of discursive support, while negative ones are more often applied to young women and create barriers, pushing them out of the professional group [Cheryan et al., 2017]. Vivid examples of gender stereotypes are the widespread beliefs that males have higher innate mathematical abilities (math-gender stereotypes) [Ashlock, Stojnic, Tufekci, 2022] and they are predisposed to study engineering disciplines (gender stereotypes in engineering) [Johnson et al., 2013]. Stereotypes are spread to varying degrees in different technical fields and in different social groups [Leslie et al., 2015; Ashlock Stojnic,

Tufekci, 2022]. In addition, there are gender stereotypes regarding learning strategies, where men are often credited to laziness and striving to get grades without effort, merely at the expense of personal abilities, while diligence, accuracy and perseverance are attributed to girls [Heyder, Kessels, 2015; McClowry et al., 2013; Jackson, Dempster, 2009].

Female adherence to gender stereotypes negatively affects their confidence in their own abilities and learning outcomes [Franceschini et al., 2014; Schuster, Martiny, 2017]. Gender stereotypes also influence social assessment, when even females, who outperform males in natural sciences results, are perceived as less capable students [Bloodhart et al., 2020]. A number of unrelated studies have empirically revealed a decrease in the mathematical testing results among girls when gender stereotypes are activated with the mention that young men usually perform the task better than girls [Spencer, Steele, Quinn, 1999; Good, Aronson, Harder, 2007; Reilly, Neumann, Andrews, 2019].

Many authors explain the differences between young women and men in choosing the major and future profession by the action of gender stereotypes [Ji, Lapan, Tate, 2004; Zamyatnina, 2017; Reilly, Neumann, Andrews, 2019; Kugler, Tinsley, Ukhaneva, 2021]. There is still a clear division of academic fields into “male” and “female” in society [Eccles, 1994; Wilbourn, Kee, 2010; Makarova, Aeschlimann, Herzog, 2019; Zamyatnina, 2017]. The American eighth grade population, according to own estimates, shows more interest in those majors, which people of the same gender work in [Ji, Lapan, Tate, 2004]. Schoolgirls who believe that mathematics is more of a male field of activity and endow it with “masculine” qualities are less likely to choose the STEM profession [Makarova, Aeschlimann, Herzog, 2019; Nosek, Banaji, Greenwald, 2002]. Girls who adhere to social stereotypes of the higher male abilities to study natural sciences, revealed weak identification with this field and low career expectations in this area [Cundiff et al., 2013]. On the contrary, young men with brightly expressed gender stereotypes of their higher abilities to study natural sciences show a stronger identification with this field and high career expectations in this area. Girls are often dissatisfied with the choice made in favor of STEM, and therefore they are less likely to work in their area[Beede et al., 2011; Ellis, Fosdick, Rasmussen, 2016] and are more inclined to change engineering majors [Kugler, Tinsley, Ukhaneva, 2021].

Gender disparity in the number of applicants for engineering and STEM studies may be in general exacerbated due to national specifics and institutional conditions. For example, in Japan, girls who choose a career in STEM are a priori assessed as unsuccessful [Kitada, Harada, 2019]. It is believed that they will definitely face restrictions in the choice of jobs and difficulties in arranging their

personal lives due to long-term training [Osumi, 2018]. The female choice of a future profession is influenced by the national policy in the field of family and maternity support. Assistance in the employment of mothers by freeing them from part of family responsibilities can contribute to the increase of women's economic activity, but it exacerbates gender inequality in the choice of professions and the concentration of women in fields of activity, which traditionally considered as female [Mandel, Semyonov, 2005].

In modern Russia, the influence of gender stereotypes on female choice for technical fields is partially offset by the "myth of gender equality" formed in the Soviet period [Antoshchuk, 2021]. In the 1980s, the female proportion among students of technical universities reached 60% [Ibid.]. Unlike Western countries, the gender policy of the USSR provided for women to exercise a professional role to the same extent as caring for children and housework [Abramov, 2016]. However, there is no need to report on the true equality of women and men in the USSR: despite the absence of a gender disparity in the number of engineering and technical personnel, women, as a rule, performed low-paid work and much less often occupied high official positions [Antoshchuk, 2021]. Nevertheless, the historical fact of the absence of gender disparity has significantly triggered discussions about gender inequality in engineering in modern Russia. Today, there is a significant gender imbalance in Russian higher education in engineering and technical fields [Zamyatnina, 2017; Maloshonok, Shcheglova, 2020; Antoshchuk, 2021], but many public figures deny the existence of this problem, which hinders the search for effective ways to solve it [Antoshchuk, 2021].

Despite a significant number of works showing the important role of gender stereotypes in the gender imbalance formation in engineering, the question of gender differences in the reasons for choosing engineering and technical directions, as well as the role of gender stereotypes in these differences remains open. In this paper, we will find out whether the reasons for choosing a profession in the field of engineering for females differ from the reasons that males are guided by, and how committed to gender stereotypes are the students studying in these fields.

2. Data

The empirical basis of the study is the data of the Monitoring of Student Experience, conducted within the framework of the "Evidence-Based Digitalization for Student Success" consortium in April-May 2020 at eight Russian universities in the CAWI (Computer-Assisted Web Interviewing) format. Students received an invitation to participate in the study via administrative mailing list. The Response Rate (RR) ranged from 2 to 53% in different universities. For this

study, we use the results of a survey for one university. The choice is due, firstly, to the technical orientation of this university, which means that it has a wide representation of STEM majors and, secondly, to a relatively high response rate (RR = 19%). This university has the status of a flagship university and participates in the "Priority 2030" program. According to the University Admissions Quality Monitoring, which is conducted by the National Research University Higher School of Economics in partnership with the Ministry of Higher Education and Science of the Russian Federation[2], the average admission score to this university in 2021 for state-funded places was more than 70 points, for paid places — more than 60 points.

The sample of the research included students, whose majors related to engineering, technology and technical sciences — 1,791 people — 82% of respondents at this university. The percentage of females in the sample is 50%, 94% of students study at undergraduate programs, 67% are at state-funded places, 30% are at places with tuition fees, 3% are at places with a target quota, the majority of students (66%) study at the 1st or 2nd year of undergraduate courses.

3. Measurement and Analysis

Three stages of empirical data analysis were carried out to answer the research questions. At the first stage, the frequency distributions of the male and female responses were analyzed and the statistical significance of their differences was estimated using the nonparametric criterion χ^2. Then factor analysis, using the Principal Component Analysis (PCA) with VARIMAX rotation, was carried out for a more detailed analysis of gender differences and the role of gender stereotypes in choosing the field of study. PCA made it possible to compress a feature space and move from a set of indicators measuring the reasons for choosing a field of study and gender stereotypes to factors (components) reflecting four reasons for choosing a field of study and three gender stereotypes. The number of factors was determined on the basis of the following criterion: the eigenvalue of the obtained factor is greater than 1, therefore, the resulting component explains more variance of the initial indicators than each initial indicator separately. The choice for this method of analysis is due, on the one hand, to a large number of initial indicators that are necessary to assess the reasons for choosing the field of study and gender stereotypes (to analyze them separately would significantly complicate the perception of the results), and on the other hand, to the use of secondary data in the study. The involvement of secondary data for analysis means that we rely on the questions formulated for data collection within the

[2] https://ege.hse.ru/

framework of the original project, and do not independently collect data using specially developed validated scales that measure the latent variables we study (for more details, see the section "Limitations of the study"). Since the development of these questions was not based on theoretical provisions that allow grouping the initial indicators into scales, PCA is the most appropriate analysis strategy.

To assess the reasons for choosing one or another major, the respondents were asked the following question: "For what reasons did you choose the field of study, which you study in?" The respondent could select multiple answer options from the following list.

1. It matches your abilities.
2. It will allow you to get an interesting and diverse job.
3. It will allow you to have good social security at work.
4. It will allow you to have good working conditions.
5. It will allow you to have a convenient work schedule.
6. It gives you the opportunity to make good money.
7. It makes it easy to find a job.
8. It provides an opportunity for career growth.
9. This is a respected field of study.
10. It is easy to study in this field.
11. Someone from relatives or acquaintances works in this field.
12. It was easier to enter this field.
13. This specialty has low tuition fees or free tuition.
14. I chose it on the advice of parents, friends, or school.
15. For the company with friends.
16. Applied for other fields of study, but managed to enter only this one.
17. I have already studied in this field of study at an undergraduate course (or college, technical school, etc.).
18. It was a random choice.
19. None of the above reasons.
20. Other (please specify).
21. I find it difficult to answer.

Student adherence to gender stereotypes was measured using two blocks of questions. The first one concerned ideas on the female and male abilities in mathematics and consisted of the following questions.

1. Who do you think is more capable of studying mathematics — males or females?
2. Who do you think your math teachers consider to be more capable of studying mathematics — males or females?
3. Who do you think most of your groupmates consider to be more capable of studying mathematics — males or females?

For all three questions, students were offered the following answers: 1) males are much better; 2) males are a little better; 3) males and females have the same abilities; 4) females are a little better; 5) females are much better.

The second block comprised six questions, in which students were asked to evaluate, basing on their personal observations, who — men or women — are more likely to have the following characteristics:

- ability to understand physical phenomena and laws;
- accuracy;
- logical thinking;
- technical thinking;
- perseverance;
- ability to do hard mental work.

Respondents chose one of five possible answers to each question: 1) definitely males; 2) rather males; 3) equally for both males and females; 4) rather females; 5) definitely females.

Dichotomous variables, reflecting common gender stereotypes, were constructed for further analysis:

1) young men are more capable of studying mathematics (1 — "young men are much better" and "young men are a little better" answers, 0 — other answers, 3 variables in accordance with the initial questions of the first block);
2) young men have better developed logical thinking, technical thinking, the ability to understand physical phenomena and laws and the ability to do hard mental work (1 — "definitely males" and "rather males" answers, 0 — other answers);
3) young women are more accurate and diligent (1 — "definitely females" and "rather females" answers, 0 — other answers).

To measure satisfaction with the choice of an educational program in the field of engineering and technical sciences, the following question was offered: "If you could make a decision about entering a university again, what would you choose?" The following answers were formulated.

- Study at the same university in the same field of study where I am currently studying.
- Study at the same university, at the same institute/faculty/school, but in a different field of study.
- Study at the same university, but at a different institute/faculty/school.
- Choose another university for admission.

- Do not enter the university at all.
- I find it difficult to answer.

At the third stage, the eigenvalues of the factors, identified with the PCA, were applied in correlation and regression analysis to assess the relationship between the reasons for choosing the field of study, adherence to gender stereotypes and satisfaction with the choice of the field of study.

Within this stage, firstly, four linear regression models were constructed for the entire sample, in which the dependent variables were the factors, obtained with the use of PCA, and reflecting the reasons for choosing the field of study. Three factors were selected as independent variables, reflecting three types of gender stereotypes (the superiority of males in mathematics, the superiority of males in engineering and the diligence of females as a learning style) and satisfaction with the choice of an educational program (the choice of the option "Study at the same university in the same field of study where I am currently studying", when answering the question "If you could make a decision about entering a university again, what would you choose?"). The regression models include the following control variables: gender, year of study, academic performance self-assessment for the previous semester. To measure the latter indicator, we used the questionnaire item "What grades did you get for exams/tests last semester?", suggesting the following answer options: only excellent grades; only excellent and good; mostly excellent and good, but there were also satisfactory grades; mostly good and satisfactory; mostly satisfactory grades.

Secondly, regression analysis for some reasons in choosing the field of study was carried out on male and female subsamples in order to assess possible differences in the relationships between the considered latent variables.

Thirdly, a binary regression analysis was performed to study gender differences in satisfaction with the choice made and the contribution of the reasons for choosing the engineering field of study and gender stereotypes to this choice.

4. Limitations of the Study

This study has a number of limitations. They are caused, firstly, by the nature of the sample. It was compiled with the students of one Russian university, who cannot fully represent all Russian students studying in engineering majors. The sample is convenience. Therefore, there may be displacements caused by the self-selection effect. At that point, it mainly included 1st and 2nd year students, whose student experience may differ from the experience of senior students. In future studies, it is necessary to take into account the shortcomings of the presented sample and expand the study to se-

veral Russian universities, and control the self-selection effect, for example, by turning the questionnaire into a mandatory element of the educational process.

Secondly, specific limitations may be connected with the organization of the questionnaire. For instance, questions about the choice for the field of study are retrospective, that it why the effect of forgetting is possible. Also, some of the respondents may perceive questions about gender stereotypes as sensitive and tend to choose socially desirable answer options. The limitation associated with forgetting can be overcome by using a longitudinal design: by organizing the study in such a way that students answer questions about the choice for the field of study in the questionnaire in the 1st year of study, and react to other questions (for example, questions about gender stereotypes) at senior courses.

Thirdly, the limitations of this study are caused by the use of secondary data collected as part of a large project. Since the questionnaire items were not specifically formulated for the purposes of this study, their psychometric characteristics may be dubious. The question of the reasons for choosing a field of study is borrowed from the Monitoring of the Economics of Education questionnaire and is not based on any concepts of choosing a future profession. Despite the fact that it has been previously applied in empirical studies (see, for example, [Lebedeva, Vilkova, 2022]), there are no works that would confirm its validity. Questions on gender stereotypes were also offered earlier to respondents in mass surveys (see, for example, [Malashonok, Shcheglova, 2020]), however they do not rely on theoretical provisions and have not been previously validated as well.

Fourthly, when solving the issue of extrapolating the results of this study to other groups of engineering students, it is worth taking into account the features of the analysis. To compress the feature space, the principal component method was implemented; such method enables to build a factor model for a specific sample. In other studies, applying the same indicators, other factors may be obtained. According to the procedure for constructing factors from the initial indicators in this method, the first found factor explains the largest part of the variance of the initial indicators, and each subsequent one explains a smaller part. In our analysis, the first factor has high factor loads for eight indicators, while the other three factors have high factor loads for only two or three indicators. In future studies, we recommend considering the results of this analysis when forming the questionnaire and adding more indicators that measure the family influence on the choice of the field of study, as well as the perceived ease of admission and training. In addition, we suggest evaluation of the reliability and validity of

the developed questionnaire. This has not been realized in this paper, which, of course, is its limitation.

In general, this study is of an exploratory nature and is primarily aimed at formulating hypotheses about the types of reasons for choosing an engineering major and about the nature of the relationship between these reasons and different types of gender stereotypes.

5. Results

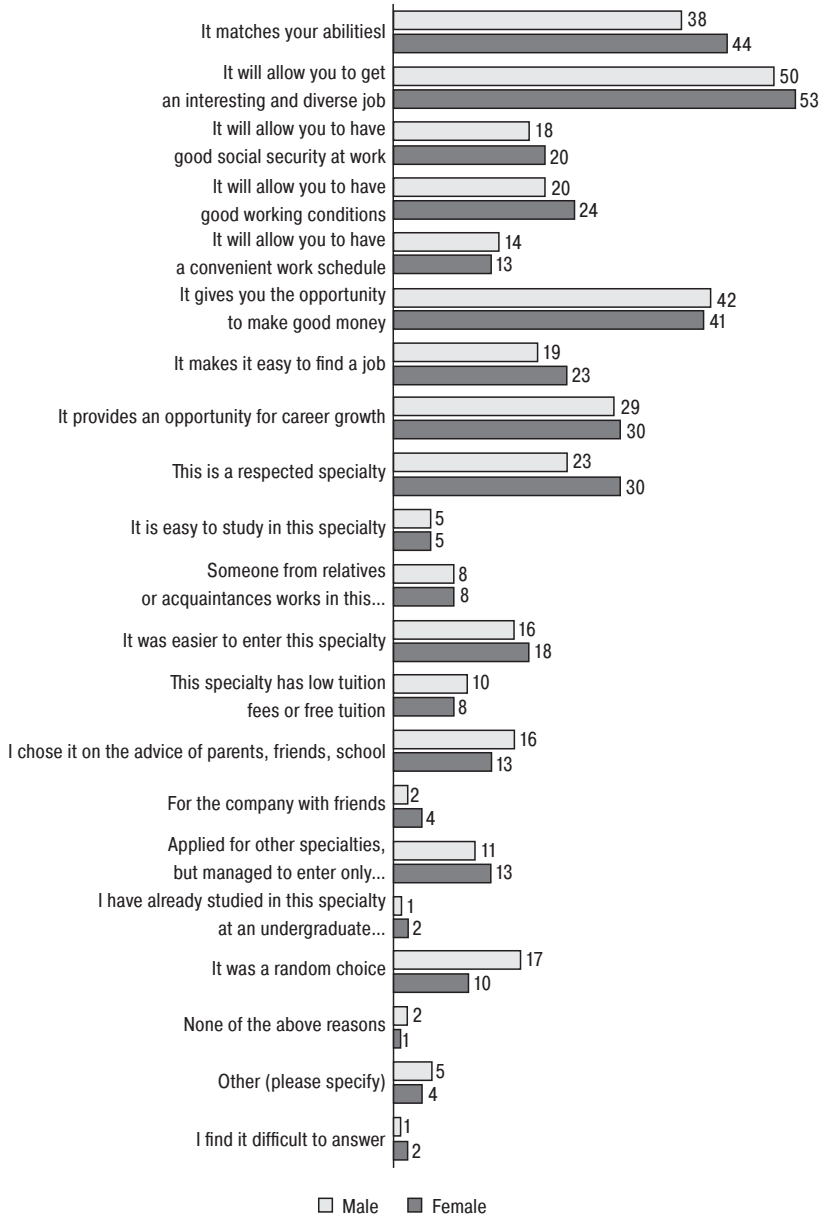
5.1. Gender differences in the reasons for choosing an engineering field of study

No radical gender differences were found in the reasons for choosing an engineering and technical field of study (Figure 1). The majority of both males and females expect to find an interesting, diverse and highly paid job in the future by obtaining this major. Statistically significant differences are observed only through selection of several reasons. Girls studying engineering majors were relatively less likely than young men to mention the following reasons for choosing a field of study: "This is a respected major" (less often by 7%; χ^2 = 10,227, *df* = 1, *p* = 0.002), "It matches your abilities" (less often by 6%; χ^2 = 5,936, *df* = 1, *p* = 0.016), "It will allow you to have good working conditions" (less often by 4%; χ^2 = 3,965, *df* = 1, *p* = 0.047), "For the company with friends" (less often by 2%; χ^2 = 8,630, *df* = 1, *p* = 0.004). At the same time, they more often indicated that it was a random choice (more often by 7%; χ^2 = 17,468, *df* = 1, *p* < 0.001) and/or that their choice was influenced by parents, school or family (more often by 3%; χ^2 = 4,258, *df* = 1, *p* = 0.045).

5.2. PCA results to highlight factors reflecting the reasons for choosing the field of study and gender stereotypes

To highlight the reasons for choosing the field of study, PCA was initially applied to all 18 possible response options to the question "For what reasons did you choose the field of study, which you study in?", listed in the section "Measurement and analysis" (excluding the answers "None of the above reasons"; "Other (please specify)" and "I find it difficult to answer"). However, the indicators for the options "I have already studied in this major at an undergraduate program (or college, technical school, etc.)" and "It was a random choice" were not included in the final factor model, since preliminary analysis showed that these options have low factor loadings and cannot be attributed to any factor. Factor loadings obtained as a compression result of the feature space from 16 indicators into four factors, reflecting the reasons for choosing a field of study, are presented in Table 1 in the Appendix. As a result of the analysis, four main reasons are identified: 1) the desire to get *a good job*, which means a highly paid and respected profession with good working conditions; 2) *it is easier to enter*, which is ensured by low passing scores, low tuition fees, and the fact that the respondent failed to enter other fields of study; 3) *the influence of family and environment* implies recommen-

Figure 1. **Reasons for choosing a field of study among males and females, %**



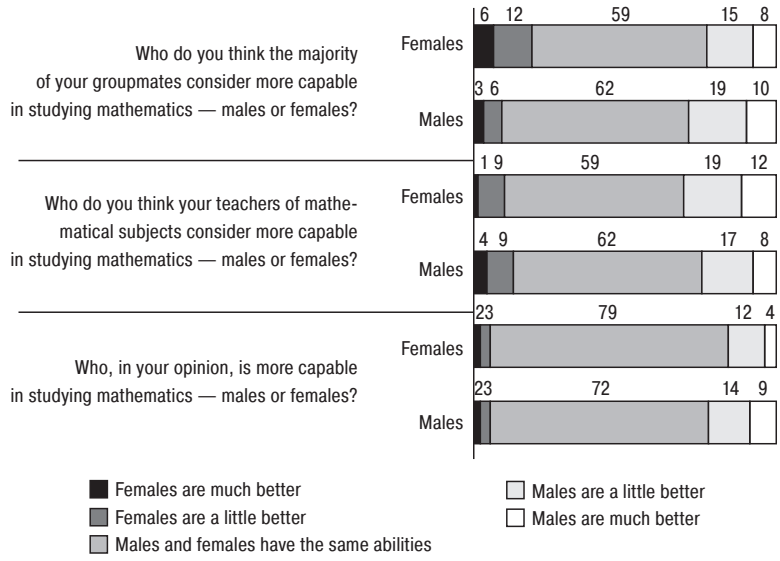
dations from relatives, friends, school or the fact that someone from the family works in this field (in addition, in our analysis, the variable "It matches your abilities" contributes to this factor with a negative factor loading); 4) the desire *to study easily and comfortably*, which reflects the respondent's confidence that this specialty corresponds to personal abilities, it is easy to study this field, and learning process is comfortable, as friends study here as well.

As an analysis result with the application of the PCA method to the initial variables measuring gender stereotypes, the following factors were obtained: 1) the stereotypical idea that males have better mathematical abilities; 2) the stereotypical idea that males have better developed engineering thinking; 3) the stereotypical idea that females study more diligently (see Table 2 in the Appendix). The three received factors explain 59% of the variance in the initial variables.

5.3. Prevalence of gender stereotypes among males and females studying in engineering and technical field of study

The majority of respondents indicated, when answering the questionnaire items, that neither students as future engineers nor their teachers believe that young men are naturally more capable of mathematics than girls (Figure 2). Nevertheless, students who showed adherence to a social stereotype regarding the male and female abilities in mathematics make up a significant part of the sample: almost a quarter (23%) of young men and 16% of girls, who participated in the study, believe that men have higher abilities in mathematics (χ^2 = 18,814, df = 4, p = 0.001). Females are relatively more likely to indicate the presence of gender stereotypes among teachers (31% versus 25%) (χ^2 = 18,386, *df* = 4, *p* = 0.001). However, among them there is also a high proportion (18%) of those who are sure that their groupmates consider girls to be more capable of mathematics. Males, in turn, are more often convinced that their groupmates consider young men to be more capable (29% versus 23%) (χ^2 = 38,171, *df* = 4, *p* < 0.001).

Figure 2. **Prevalence of gender stereotypes regarding mathematical abilities among males and females, %**



With regard to abilities for other types of activities, the most common gender stereotypes are in relation to the following qualities (Table 3 in the Appendix):

1) *ability to understand physical phenomena and laws*: 52% of males and 44% of females believe that girls comprehend physical phenomena and laws worse;
2) accuracy: 55% of males and 57% of females are convinced that accuracy is rather a feminine trait;
3) *logical thinking*: 54% of males and 21% of females consider logical thinking as a male ability;
4) *technical thinking*: 64% of males and 47% of females believe that technical thinking is better developed in men;
5) *perseverance*: 33% of males and 40% of females call perseverance more of a feminine trait.

5.4. Interrelation of the reasons for choosing the engineering and technical fields of study and gender stereotypes

The Tables 1 and 2 show the correlations between factors that reflect the reasons for choosing the field of study and the severity of gender stereotypes. Significant positive correlations for the entire sample are observed between the "good job" factor and adherence to stereotypical ideas that males have more developed engineering thinking and that females are diligent students. The "family influence on the choice of a field of study" factor is interrelated with the ideas of the best mathematical abilities in men, and students who chose their major because it is easy to enter it are also more likely to adhere to the social stereotype of the best mathematical and engineering abilities in young men. At the same time, correlations between the reason for choosing "good job" and stereotypes about the best mathematical abilities of young men are characteristic of male respondents, and the relationship between the influence of family and this stereotype is typical for females.

Table 1. **Pearson's correlations between factors that reflect the reasons for choosing the field of study and the severity of gender stereotypes**

Gender stereotypes	Good job	Easy to get into	Family influence	Easy and comfortable to study
Males have more developed engineering thinking	0.064**	0.050*	0.003	0.005
Males have better mathematical abilities	0.03	0.049*	0.080**	0.001
Females are diligent students	0.048*	0.007	0.002	–0.013

Note: * $p < 0.05$; ** $p < 0.01$.

Table 3 presents a regression analysis that reflects the contribution of gender stereotypes in explaining the reasons for choosing

the field of study for the entire sample, and Table 4 in the Appendix shows the results of the regression analysis through separation for males and females. Models based on the entire sample reveal a positive relationship between the adherence to stereotypes about the best mathematical abilities and engineering thinking in young men and the choice conditioned by the desire to get a good job. There is also a statistically significant correlation between stereotypical ideas about gender differences in mathematical abilities and the family influence on the choice of field of study.

Table 2. **Pearson's correlations between factors that reflect the reasons for choosing the field of study and the severity of gender stereotypes, separately for males and females**

Males	Good job	Easy to get into	Family influence	Easy and comfortable to study
Males have more developed engineering thinking	0.051	0.041	0.01	–0.005
Males have better mathematical abilities	0.078*	0.067*	0.031	0.008
Females are diligent students	0.074*	0.016	0.027	–0.003
Females	Good job	Easy to get into	Family influence	Easy and comfortable to study
Males have more developed engineering thinking	0.059	0.059	0.013	–0.007
Males have better mathematical abilities	–0.02	0.031	0.131**	–0.006
Females are diligent students	0.028	0	–0.027	–0.017

Note: * $p < 0.05$; ** $p < 0.01$.

Table 3. **Regression coefficients (B(SE)) for models with dependent variables as reason for field of study choice. Analysis on the entire sample**

	Good job	Easy to get into	Family influence	Easy and comfortable to study
Constant	–0.22** (0.08)	0.19* (0.08)	0.14 (0.08)	–0.08 (0.08)
Female gender	–0.04 (0.05)	<0.01 (0.05)	0.07 (0.05)	–0.07 (0.05)
Course of study *(ref. — 1st year)*				
2nd year	–0.10 (0.06)	0.03 (0.06)	0.22*** (0.06)	0.12* (0.06)
3rd year	–0.01 (0.06)	0.07 (0.07)	0.14* (0.07)	0.10 (0.07)
4th year	–0.25** (0.07)	0.04 (0.07)	0.15* (0.07)	0.16* (0.08)
5th year	–0.40 (0.37)	0.01 (0.38)	0.37 (0.37)	–0.32 (0.38)

	Good job	Easy to get into	Family influence	Easy and comfortable to study
Self-assessment of academic performance for the previous semester *(ref. — mostly satisfactory grades)*				
Only excellent grades	0.11 (0.10)	–0.09 (0.11)	–0.33*** (0.05)	0.12 (0.11)
Only excellent and good	0.09 (0.08)	–0.11 (0.08)	–0.27** (0.08)	–0.01 (0.08)
Mostly excellent and good, but there were also satisfactory grades	0.11 (0.08)	–0.13 (0.08)	–0.19* (0.08)	0.01 (0.08)
Mostly good and satisfactory	0.07 (0.08)	–0.04 (0.09)	–0.03 (0.08)	0.06 (0.09)
Males have more developed engineering thinking	0.05* (0.02)	0.06* (0.03)	0.02 (0.03)	<0.01 (0.03)
Males have better mathematical abilities	0.05* (0.02)	0.04 (0.02)	0.07** (0.02)	<0.01 (0.02)
Females are diligent students	0.04 (0.02)	0.02 (0.02)	0.02 (0.02)	–0.01 (0.02)
Satisfaction with the choice made	0.49*** (0.05)	–0.29*** (0.05)	–0.25*** (0.05)	0.03 (0.05)
R^2	0.079	0.030	0.047	0.007

Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. The standard deviation for the coefficient B is indicated in parentheses.

Regression models based on subsamples were used only for those reasons for choosing a field of study, for which a significant relationship with gender stereotypes was established in the previous analysis. This analysis shows that the positive relationship between the adherence to gender stereotypes and the "good job" reason, found in the entire sample, is characteristic of males, while the relationship between the family influence on the choice of a specialty and stereotypical ideas about mathematical abilities is typical for girls (Table 4 in the Appendix).

Regression analysis also revealed a high correlation between the reasons for choosing the field of study and satisfaction with the choice of an educational program. The choice of a specialty due to the desire to get a good job is positively correlated with the satisfaction with the choice made, while the desire to get into easily and the choice made under the family influence are negatively correlated with the satisfaction with this choice. Next, we will consider gender differences in satisfaction with the choice made and its relationship with gender stereotypes.

5.5. Gender differences in satisfaction with the choice of field of study and the role of gender stereotypes

Table 4 presents data on the satisfaction of males and females with the choice of the university and the field of study. Males are significantly more likely than girls (49% versus 43%) to choose the same educational program they are studying now if they had to choose a university and a field of study again.

Table 4. **Gender differences in satisfaction with the choice of a university and a field of study (χ^2 = 11.636, *df* = 5, *p* < *0.05*), %**

	Males	Females
Study at the same university in the same field of study where I am currently studying	49	43
Study at the same university, at the same institute/ faculty/school, but in a different field of study	10	12
Study at the same university, but at a different institute/faculty/school	9	9
Choose another university for admission	15	18
Do not enter the university at all	6	4
I find it difficult to answer	12	14

For a more detailed study of gender differences in satisfaction with the choice of an educational program, three binary logistic regression models with a dependent variable "satisfaction with the choice made" were constructed: on the entire sample and on subsamples of males and females (Table 5). As well as descriptive statistics, the results of regression analysis indicate that females are much less satisfied with their choice of an educational program. The satisfaction assessment is interrelated with the reasons to choose the engineering major for admission, as well as with the academic performance self-assessment for the last semester. The choice of a major due to the desire to get a good job is positively correlated with the satisfaction with the choice made, while the choice driven by the desire to get into easily or under the family influence has a negative correlation with the satisfaction. Students who highly rate their academic performance over the last semester are more likely to express the satisfaction with the choice of an educational program.

Adherence to gender stereotypes does not have statistically significant correlation with the satisfaction with the choice of an engineering major. Statistical significance at the level of 0.05 is observed only for the "males have better mathematical abilities" stereotype in the model for the entire sample, however, in the subsamples of males and females this relationship turned out to be insignificant. It can be assumed, based on these results, that adherence to gender stereotypes does not negatively affect the satisfaction with the choice of engineering major, if this choice has already been made. This hypothesis needs to be tested in future studies.

Table 5. **Coefficients (odds ratio) for the binary regression model. The dependent variable is the satisfaction with the choice of an educational program. Analysis on the entire sample and separately for males and females**

	The entire sample	Males	Females
Female gender	0.747**	—	—
Reasons for choosing a field of study			
Good job	1.720***	1.854***	1.600***
Easy to get into	0.716***	0.717***	0.708***
Family influence	0.743***	0.753***	0.723***
Easy and comfortable to study	1.033	1.044	1.011
Course of study (ref. — 1st year)			
2nd year	0.977	0.870	1.107
3rd year	0.787	0.921	0.684
4th year	0.833	0.841	0.846
5th year	1.480	3.067	0.675
Self-assessment of academic performance for the previous semester (ref. — mostly satisfactory grades)			
Only excellent grades	2.715***	2.121*	3.869**
Only excellent and good	2.595***	2.122**	3.555***
Mostly excellent and good, but there were also satisfactory grades	1.751**	1.828*	1.967*
Mostly good and satisfactory		1.411	1.701
Males have more developed engineering thinking	1.001	0.924	1.155
Males have better mathematical abilities	0.889*	0.900	0.915
Females are diligent students	1.090	1.102	1.074
R^2 Cox and Snell R^2 Nagelkerke	0.132 0.177	0.140 0.186	0.133 0.179

Note: * $p < 0.05$;
** $p < 0.01$;
*** $p < 0.001$.

6. Discussion

The purpose of the research is to study the differences between males and females in the reasons for choosing an engineering and technical major at a university and the role of gender stereotypes in them. As a result of the analysis of survey data collected at one of the Russian technical universities, no radical differences between males and females in the reasons they were guided by when choosing an engineering field of study were revealed. Nevertheless, there are some statistically significant differences: females more often indicate that their choice of engineering and technical major was accidental or that they succumbed to the family influence. Males

are comparatively more likely to explain their choice by saying that the given profession corresponds to their abilities and that it is a respected field of study. The results obtained are consistent with the conclusions of previous studies that girls, despite their high results in the hard sciences, tend to doubt their abilities to succeed in engineering [Ceci, Williams, 2007; Stoet, Geary, 2018; Zamyatnina, 2017; Franceschini et al., 2014; Schuster, Martiny, 2017] and are more influenced by parents in choosing the field of study [Khasbulatova, Smirnova, 2020].

In the research literature, the gender gap in the cohort of engineering students is mainly explained by the effect of gender stereotypes, therefore, at the next stage of the study, the prevalence of stereotypical ideas among engineering students was assessed in the point that females and males differ in the level of innate abilities in mathematics and engineering and in the approach to learning. The most common stereotypes among engineering students are that young men better understand physical phenomena and laws and have more developed technical and logical thinking, while girls are more accurate and diligent. Social stereotypes about the best innate abilities of young men to study and work in the field of engineering turned out to be more popular among the surveyed students than ideas about their higher mathematical abilities. Many of the surveyed students adhere to stereotypes about gender differences in learning strategies both at school and at university, which existence is empirically confirmed [Heyder, Kessels, 2015; McClowry et al., 2013; Jackson, Dempster, 2009]. The authors distinguish masculine and feminine learning styles. The masculine one is characterized as “effortless achievement” and suggests that males strive to get high marks due to their high abilities rather than hard work. This particular learning style is attributed to the image of “cool masculinity” [Jackson, Dempster, 2009]. The feminine learning style is hard work and diligence.

The next stage of the work was to identify the relationship between adherence to gender stereotypes and the reasons for choosing the field of study. It was found that male respondents, who believe that males have more developed mathematical abilities and engineering thinking, are more likely to choose an engineering specialty, hoping that it will allow them to get a good job. While females, who adhere to stereotypes about the best mathematical abilities in men, are relatively more likely to choose an engineering major under the family influence. Thus, while the desire to get a good job is the predominant reason for choosing an engineering and technical field of study for both females and males, the presence of gender stereotypes among girls can negatively affect the choice of major, making it less conscious and more susceptible to the influence of other people.

Judging by the results of the survey, females are relatively less satisfied with their choice of an educational program in the field of engineering and technical sciences. This result is consistent with the conclusions obtained in several foreign studies [Beede et al., 2011; Ellis, Fosdick, Rasmussen, 2016]. Their less satisfaction is supposedly due to the fact that they make their choice of a place of study relatively less consciously and are subject to the influence of the family.

Thus, based upon the results of the conducted research, it can be assumed that adherence to gender stereotypes can negatively affect the awareness of the choice made and cause dissatisfaction with the choice of the educational program among females, who chose the engineering field of study As a consequence, there may be difficulties in learning and a reluctance to complete the program or work in the acquired specialty. This hypothesis requires verification, however, it can be concluded that measures to bridge the gender gap in the contingents of engineering universities and in the engineering profession as such should be aimed not only at increasing the number of females choosing an engineering major. Females who have already chosen this field of study, due to the effect of gender stereotypes, may not be sure of the correctness of the decision made. In the final section, we will consider what measures can be taken to reduce the negative impact of gender stereotypes on female choice of engineering and technical training areas.

7. Conclusions for Educational Policy

The results of the material analysis of the survey of technical university students are consistent with the conclusions of previous foreign and domestic studies on the negative impact of gender stereotypes on the female choice of engineering and technical training areas [Riegle-Crumb et al., 2012; O'Dea et al., 2018; Stoet, Geary, 2018; Ceci, Williams, 2010]. Therefore, it can be argued that the practices of bridging the gender gap in the contingents of technical universities should be aimed primarily at combating social stereotypes. There is already a successful experience of informing females about gender stereotypes and their negative consequences for these purposes [Weisgram, Bigler, 2007], strengthening female confidence in personal abilities through the promotion of certain role models of successful female engineers [Jansen, Joukes, 2013], promoting the importance and public utility of engineering professions [Belanger, Diekman, Steinberg, 2017], as well as interventions aimed at developing the growth mindset [Lee et al., 2021].

The effectiveness of these practices depends on the age stage at which females receive the necessary information about social stereotypes and undergo training, as well as on the format of their conduct. The time of study in high school and secondary school seems to be a suitable period for such interventions, since by the

graduation time from general education, the formation of identity and basic ideas that influence the choice of the field of study is mostly completed [Kim, Sinatra, Seyranian, 2018; DeWitt, Archer, 2015]. In adolescence, beliefs in personal capabilities are formed and decisions are made that affect career choice, and it is at this stage that females will benefit from activities aimed at increasing their confidence, awareness and competence concerning a career in STEM [Falco, Summers, 2019]. The effectiveness of special training courses and classes within the school curriculum, as well as extracurricular activities, including summer camps and schools, museum programs, communication with mentors, with other girls interested in STEM, and female researchers successfully working in this field has been empirically confirmed [Kim, Sinatra, Seyranian, 2018]. It is advisable to introduce students to engineering and technical majors at an earlier age, particularly in primary school, moreover some studies show that sustained targeted interventions to promote STEM during this period have a stronger positive impact on girls than on boys [Emembolu et al., 2020].

Parental beliefs are significant for choosing the field of study, and, as the study showed, they have a stronger effect on females. The family rarely becomes the subject of attention and a possible attracting means for females to study in STEM s. Schools and teachers need to collaborate with parents of students through organizing various events and implementing special programs that raise awareness and positive attitude of parents to their children's career in STEM and teach them ways to convey the importance and usefulness of the relevant subject area to their children [Šimunović, Babarović, 2020].

The data obtained in this study indicate that females, who are committed to gender stereotypes regarding their abilities in mathematics and technical disciplines, as well as who nevertheless chose engineering and technical field of study, experience difficulties while studying at university and are less satisfied with the choice made than other females. Thus, interventions are substantial not only at school, but also at university. They can be aimed at creating a positive climate in the class by overcoming gender stereotypes among male teachers and students and by appropriate restructuring of their behavior [Bennett, Sekaquaptewa, 2014; Carnes et al., 2015] or by forming female small study groups for engineering training [Inzlicht, Ben-Zeev, 2000; Dasgupta, Scircle, Hunsinger, 2015; Ballen et al., 2019].

Short or one-time promotions can help to increase the attractiveness of engineering studies for females, but they are not enough to overcome the gender gap in technical university contingents. Longer-term and repeatable activities are needed, as well as a revision of curricula and materials in order to exclude the mani-

festation of gender stereotypes in them [Prieto-Rodriguez, Sincock, Blackmore, 2020]. Such programs are possible only with the support of the movement towards gender parity at the state level and the creation of national programs aimed at overcoming stereotypical ideas about the best abilities of males in mathematics and engineering, and at increasing female interest in exact sciences and strengthening their confidence in personal abilities.

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Appendix

Table 1. **Factor loadings for factors reflecting the reasons for choosing the field of study**

	Good job	Easy to get into	Family influence	Easy and comfortable to study
It matches your abilities	0.256	–0.125	–0.481	**0.451**
It will allow you to get an interesting and diverse job	**0.5**	–0.212	–0.28	–0.013
It will allow you to have good social security at work	**0.625**	0.024	0.035	–0.095
It will allow you to have good working conditions	**0.681**	–0.034	0.032	0.054
It will allow you to have a convenient work schedule	**0.549**	–0.036	–0.076	0.245
It gives you the opportunity to make good money	**0.729**	–0.144	0.047	–0.055
It makes it easy to find a job	**0.542**	–0.011	0.149	0.168
It provides an opportunity for career growth	**0.678**	–0.04	–0.001	–0.027
This is a respected field of study	**0.559**	–0.01	0.091	–0.211
It is easy to study in this field of study	–0.04	0.172	0.024	**0.695**

	Good job	Easy to get into	Family influence	Easy and comfortable to study
Someone from relatives or acquaintances works in this field of study	0.175	–0.037	**0.441**	0.045
It was easier to enter this field of study	–0.132	**0.781**	0.033	0.004
This specialty has low tuition fees or free tuition	0.098	**0.615**	–0.025	0.155
I chose it on the advice of parents, friends, school	0.026	0.076	**0.707**	0.079
For the company with friends	–0.083	–0.081	0.348	**0.473**
Applied for other field of study, but managed to enter only this one	–0.17	**0.701**	0.062	–0.087

Table 2. **Factor loadings for factors reflecting the severity of gender stereotypes**

	Severity of gender stereotypes		
	Males have more developed engineering thinking	Males have better mathematical abilities	Females are more diligent students
(Who do you think...) males are better at studying mathematics	0.403	**0.592**	0.029
(Your teachers think...) males are better at studying mathematics	–0.059	**0.802**	0.076
(Your groupmates think...) males are better at studying mathematics	0.15	**0.804**	0.051
Ability to understand physical phenomena and laws (males are better)	**0.568**	0.148	0.456
Logical thinking (males are better)	**0.743**	0.042	0.157
Technical thinking (males are better)	**0.652**	0.115	0.478
Ability to do hard mental work (males are better)	**0.67**	0.132	–0.177
Accuracy (females are better)	0.194	0.062	**0.72**
Perseverance (females are better)	–0.064	0.028	**0.795**

Table 3. **Prevalence of gender stereotypes regarding abilities for different types of activities among males and females**

		Definitely males	Rather males	Equally for both males and females	Rather females	Definitely females
Abilities in Mathematics $\chi^2 = 43.756$, $df = 4$, $p < 0.001$	Males	6	25	67	3	0
	Females	2	16	78	4	0

		Definitely males	Rather males	Equally for both males and females	Rather females	Definitely females
Abilities to learn languages $\chi^2 = 7.851$, $df = 4$, $p = 0.097$	Males	1	2	69	25	3
	Females	0	2	74	23	2
Abilities to understand physical phenomena and laws $\chi^2 = 35.333$, $df = 4$, $p < 0.001$	Males	10	42	46	1	0
	Females	4	40	56	1	1
Abilities for artistic creativity $\chi^2 = 6.696$, $df = 4$, $p = 0.153$	Males	1	1	61	32	5
	Females	0	1	64	31	4
Accuracy $\chi^2 = 5.198$, $df = 4$, $p = 0.268$	Males	1	1	44	45	10
	Females	0	1	42	45	12
Logical thinking $\chi^2 = 270.925$, $df = 4$, $p < 0.001$	Males	20	34	45	1	0
	Females	2	19	70	7	2
Technical thinking $\chi^2 = 85.792$, $df = 4$, $p < 0.001$	Males	19	45	36	0	0
	Females	6	41	52	0	0
Ability to generate new ideas $\chi^2 = 76.298$, $df = 4$, $p < 0.001$	Males	6	11	79	5	1
	Females	1	5	83	10	1
Perseverance $\chi^2 = 19.126$, $df = 4$, $p = 0.001$	Males	3	6	58	27	6
	Females	1	4	55	33	7
Ability to do hard mental work $\chi^2 = 59.224$, $df = 4$, $p < 0.001$	Males	7	13	74	5	1
	Females	2	7	81	8	2

Table 4. **Coefficients (unstandardized coefficient B and standard deviation SE in parentheses) for linear regression models with dependent variables as the reason for choosing a field of study. Analysis on subsamples (separately for males and females)**

	Good job		Family influence	
	Males	Females	Males	Females
Constant	–0.25** (0.10)	–0.24 (0.12)	0.08 (0.10)	0.30* (0.13)
Course of study (ref. — 1st year)				
2nd year	–0.06 (0.08)	–0.15 (0.08)	0.23** (0.08)	0.21* (0.08)
3rd year	–0.04 (0.10)	0.01 (0.09)	0.20* (0.10)	0.07 (0.09)
4th year	–0.25* (0.11)	–0.27** (0.10)	0.38** (0.11)	–0.04 (0.10)
5th year	–0.67 (0.50)	–0.03 (0.54)	0.04 (0.50)	0.78 (0.56)
Males have more developed engineering thinking	0.05 (0.03)	0.05 (0.04)	0.01 (0.03)	0.05 (0.04)

	Good job		Family influence	
	Males	Females	Males	Females
Males have better mathematical abilities	0.08* (0.03)	<0.01 (0.03)	0.04 (0.03)	0.12*** (0.03)
Females are diligent students	0.06 (0.03)	0.01 (0.03)	0.03 (0.03)	<0.01 (0.03)
Satisfaction with the choice made	0.57*** (0.07)	0.41*** (0.07)	–0.22** (0.07)	–0.28*** (0.07)
Self-assessment of academic performance for the previous semester (ref. — mostly satisfactory grades)				
Only excellent grades	0.19 (0.15)	0.04 (0.16)	–0.33* (0.15)	–0.34* (0.16)
Only excellent and good	0.07 (0.11)	0.12 (0.13)	–0.32** (0.11)	–0.25 (0.13)
Mostly excellent and good, but there were also satisfactory grades	0.03 (0.11)	0.19 (0.13)	–0.15 (0.11)	–0.24 (0.13)
Mostly good and satisfactory	0.08 (0.11)	0.06 (0.14)	0.01 (0.11)	–0.11 (0.13)
R^2	0.099	0.067	0.050	0.061

Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. The standard deviation for the coefficient B is indicated in parentheses.

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