RESEARCH IN MATHEMATICAL COMPETENCE IN ENGINEERS' PROFESSIONAL ACTIVITIES

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Abstract. Representatives of every profession apply mathematics in their professional activities in a different way. Moreover, every workplace is different and it needs different skills in mathematics. In this paper the employers' and the employees' (as experts of the professional field) survey results obtained in the Zemgale region are analysed by the respondents' professional field of occupation. The analysis includes the following aspects: enjoyment and abilities of mathematics, teaching mathematics at university, mathematics in professional practice and the need for improvement of mathematical knowledge as well as accordance of mathematical and professional competence. The survey was carried out in the framework of the project "Cross-border network for adapting mathematical competences in the socio-economical development (MATNET)". The results show that mathematics has a high status and include several potential values of mathematics: problem-solving and thinking developing means; tool for describing the real world and revealing human potential in working activities. The results also describe what mathematical competence is required in order to perform successfully professional tasks and to be able to analyse professional literature as well as fields of the deeper mathematical knowledge that are needed for engineers of different fields.

Keywords: mathematical competence, mathematics, mathematics study process.

Introduction

Rapid technological development is changing society and its attitudes towards education. This process is the cause for urgent needs to change the education environment. Mathematics is very much touched by this process. The main task of university is to contribute to the socio-economic development in preparing high quality competitive specialists for the labour market, integrate mathematic competences for problem solving, data analysis; raise awareness, competitiveness and qualification as well as improve the quality and enhance the accessibility of mathematical competencies. Why mathematics? Mathematics is a multi-faceted subject, and a unique construction of human thought. Despite its high degree of abstraction, the subject has many deep and living connections with our daily world in both, simple everyday events and advanced scientific matters. Mathematics is both, a basic scientific discipline with "a life of its own" and a powerful tool that is applied in numerous other disciplines. Increasingly mathematical models are being applied in dealing with both, economic and social conditions. Mathematical models are embedded in technical and social artefacts and are thus generally invisible to ordinary people. Mathematics is also a domain for a particular kind of aesthetic experience, it provides moments of clarity and beautiful patterns that can create highly euphoric feelings of unexpected insight and overall understanding [1].

What is the problem? Mathematics must appear understandable and relevant and be of practical use in the adults' living world. However, the subject of Mathematics is often represented as a long succession of facts to be memorized and reproduced. Many research findings show that innovative processes and the changing socio-economic situation requires practical knowledge, which could be easily adapted in the labour market. It is obvious that mathematic knowledge and competences have a great input in everyday life and in the workplace [2]. Mathematics must be integrated into the world it describes. In order to achieve all goals set before and integrate the mathematics connections with the daily world in mathematics syllabus the existing study programs have to be estimated and the needs of the labour market to be determined. Therefore, the Latvia University of Agriculture in cooperation with the Siauliai University implemented a project "Cross-border network for adapting mathematical competences in the socio-economic development (MATNET)" under which a questionnaire based research "Development of mathematical competencies in higher education institutions within socio-economical context" was carried out on the demands of the labour market and employers who represent the need of qualified specialists with mathematic knowledge and skills. Thus, the focus of this study is the employers' and the employees' survey results obtained in the Zemgale region describing what mathematical competences are required in order to perform successfully professional tasks and to be able to analyse professional literature as well as fields of deeper mathematical

knowledge that is needed for engineers of different fields. The research objective is achieved by the following research questions: (1) How do employed people with higher non-mathematical education assess their mathematical competences? (2) How do employed people with non-mathematical education assess teaching/learning of mathematics at higher education school? (3) How is mathematics applied in the professional environment of a person with higher education, which mathematical knowledge and competencies are necessary to him/her? (4) What is the image of mathematics as a real instrument of practical activities?

Materials and methods

A questionnaire based research was done to identify the needs of the labour market. Representatives of every profession apply mathematics in their professional activities in a different way. Moreover, every workplace is different and it needs different skills in mathematics. Thus, the most suitable method is a survey by questioning of specialists.

Employers and employees in the Zemgale region as experts of the professional field were asked to take part in the survey via Latvia – Lithuania cross-border cooperation programme home page. The LUA sent written request with the address of the webpage, where the electronic version of the questionnaire was placed for all enterprises and all performers of entrepreneurship registered in the Zemgale region. The invitation to participate in the survey was placed in several public information websites in Zemgale as well.

Part I. Attitude to mathematics - includes 5 diagnostic blocks: Self-assessment of mathematical abilities ($N = 3$); Conformity of mathematics at higher education school with a student's needs ($N = 6$); Mathematics in professional practice and need for improvement of mathematical knowledge ($N = 9$); Assessment of practical potential of mathematics ($N = 5$). There are presented 23 questions. The respondents should assess the statements by expressing their approval or disapproval on a 4-stage Likert scale: strongly agree, agree, disagree, and strongly disagree.

Part II. Accordance of mathematical and professional competence: the list of mathematical topics possibly used in professional practice by illustrating them with concrete tasks of application.

Part III. Information about the respondent: when graduated from the last education institution, field of the studies graduated, education field of occupation, kind of employment, gender.

There were 307 total responses, 294 of them full but 12 – incomplete in the Zemgale region. The survey respondents' structure: 145 women and 149 men. 54 % of the respondents graduated from the last education institution 1-5 years ago, 27 % – 6-15 years ago and 19 % – more than 15 years ago. The distribution between the genders is similar. Almost one-fourth of the respondents have a master's degree, but the third part of the respondents have higher vocational education. The survey involved more than one-third who studied engineering at university but one sixth of the respondents have studied technological sciences. The number of respondents who have studied humanities and arts or social sciences is similar (nearly one-sixth).

Results and discussion

The first diagnostic block "Self-assessment of mathematical abilities" is represented by three statements: Mathematics and the subjects, which require mathematical knowledge, have always been my favourite; I think mathematics, which I studied at high school (university, college), could have been more complicated and I did not understand most mathematical concepts that I studied at high school (university, college). It shall be emphasized that according to the subjective assessment of students, the following objectives were not fully achieved: 30.1 % of the respondents did not understand mathematics, which they studied at higher education school, whereas 36.7 % of respondents thought that mathematics, which they studied, could be more complicated, but reading this question in cross-section of the respondents professional fields, we see that the greatest dissatisfaction with mathematics courses is expressed by forestry workers and those whose work is related to information technology or electronics (Fig. 1). And so, part of students achieved the defined study results of mathematics only partially, and the expectations of others about a higher level of teaching of mathematics were not realized.

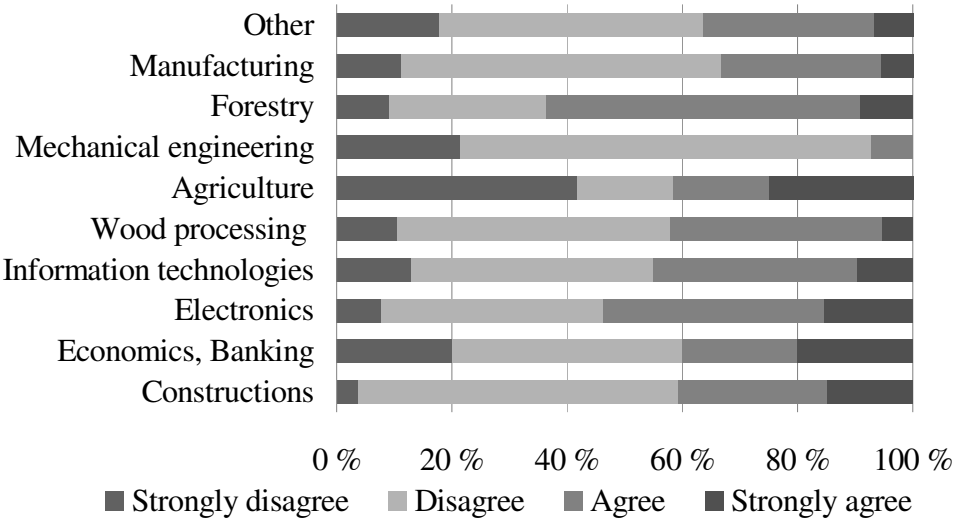

Fig. 1. **Assessment of the complexity of mathematics content**

On the other hand, Fig. 2 illustrates the respondents' answers to the question about understanding the mathematics concepts that were taught at university. The results show that manufacturing and mechanical engineering students had the greatest difficulty with mathematics understanding, but students of electronic studies have been the least which did not understand maths concepts.

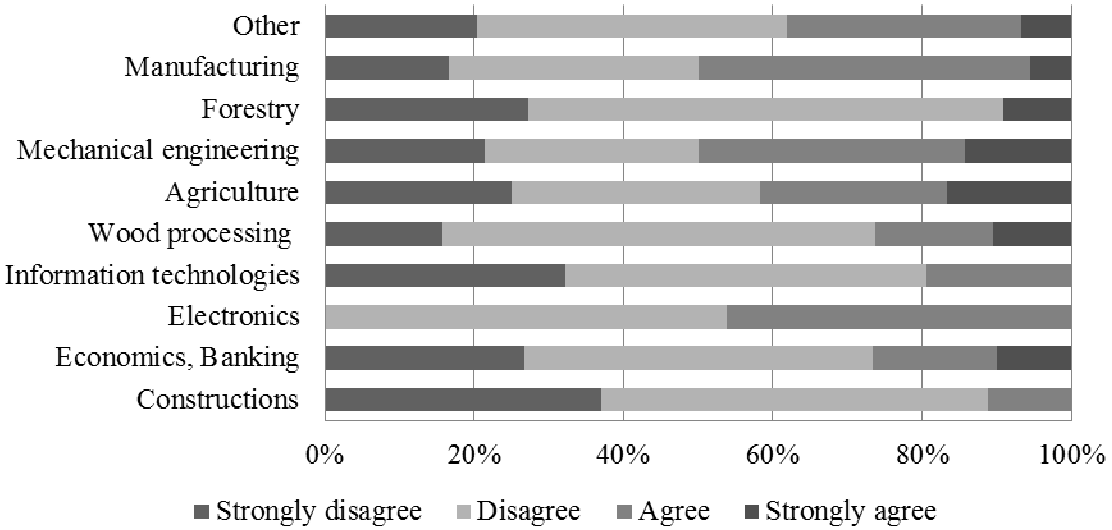

Fig. 2. **Assessment of understanding of the mathematical concepts**

In the diagnostic block "Conformity of mathematics at higher education school with a student's needs" respondents should remember the mathematics lectures at university or college and evaluate them through the time perspectives. This block consists of six statements. The positive side of this block is that most of the respondents understood the relevance of learning mathematics in correlation with the profession: 61.8 % stated that the level of the knowledge of mathematics in a secondary school was not sufficient to the representatives of their profession. This diagnostic block also presented statements including the meanings, which are attributed by employed adults to learning of mathematics at universities and colleges: integration with other subjects, meaningfulness and connection with practice. 63 % of the respondents pointed out the mathematical relationships to other subjects - maths knowledge helped them understand other study subjects. Analysing the help of mathematics in studying other subjects by the respondents' professional field of occupation, mathematical knowledge has helped understand other subjects for students in the agricultural sector, but has the least impact for the manufacturing students (Fig. 3).

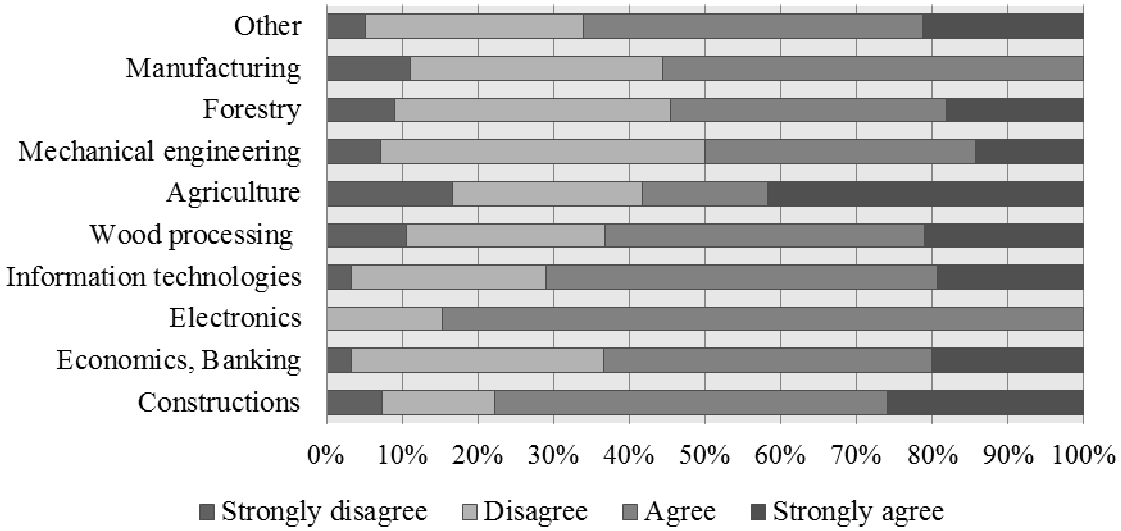

Fig. 3. **Help of mathematics studying other subjects**

It should be mentioned that changes in the social, technological, educational and other environments require seeking for effective teaching methods, approaches and resources that can be used in the process of studying to attain the objectives and competences fixed in the mathematics study program. Despite it, 44.2 % of the respondents think that mathematics was taught matter-of-factly and boringly. Most of the forestry, mechanical agriculture and agriculture students tried to learn the rules by heart. These results demonstrate that the teaching methods should not include the repetition of the law or the training of the tasks solving techniques but raising the mathematics awareness, making learning interesting and developing a link between the course materials with the profession.

It could be mentioned that the questionnaire has a free response question "In your opinion, what should be taught at mathematics lectures and how should it be taught at high school (university, college) to make acquirement useful in professional activity?". Most answers show that mathematics at universities and colleges should be taught in solving real life problems by the help of mathematics. The lecturers should explain examples of real life where particular teaching substance is used. It makes easier to perceive and understand the mathematics concepts. Differently, the question arises whether it is necessary at all.

The third diagnostic block "Mathematics in professional practice and need for improvement of mathematical knowledge" consists of nine statements which include two aspects of mathematics in professional activities: mathematics in a particular professional environment and the interest for deepening of mathematical knowledge in the professional area. This diagnostic block shows that mathematical knowledge is required in order to perform successfully professional tasks by the specialists of professional fields. The survey results show that mathematics is widely used in all professional activities of engineers, most of all in electronics and construction, but not so often – information technologies.

In recent years the main assignment of mathematics at universities was defined to give knowledge for the best learning of technical subjects. But nowadays the objectives of mathematics appear to be the following: students must be prepared for practical use of the subject and the basis of theoretical knowledge must be established as well for students who will need it in their future work in order to understand the available literature and to use it creatively [3].

The results of the research also indicate the level at which the learning outcome to understand the available literature has been achieved. About 80 % of the respondents agree or strongly agree that they understand mathematical symbols and a formal mathematical language which is used in their professional literature. The highest level of understanding the available literature is for forestry specialists, but the lowest – mechanical engineering (Fig. 4). In general, the respondents think that maths is most widely used in construction, but most - agriculture.

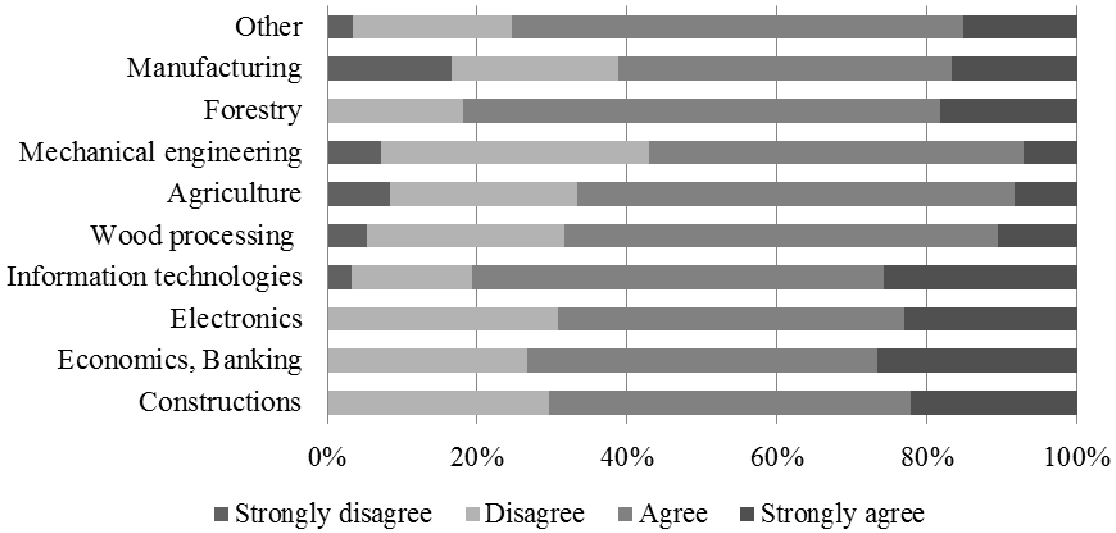

Fig. 4. **Understanding the available professional literature**

The results show that approximately one half of the respondents (48.2 %) stated that they had to apply their knowledge of mathematics directly in their professional activities, the other half (43.6 %) stated that they did not need any deeper knowledge of mathematics in their profession, it was sufficient to perform elementary calculations. However, 56 % of the respondents would like to attend the training that deals with mathematics application to solve the practical problems of their professional field. The greatest interest on mathematics continuing education was shown by wood processing and information technologies specialists (more than half of the respondents).

The results of the fourth diagnostic block show that mathematics has a high status and include several potential values of mathematics: problem-solving and thinking developing means; tool for describing the real world and revealing human potential in working activities (Fig. 5).

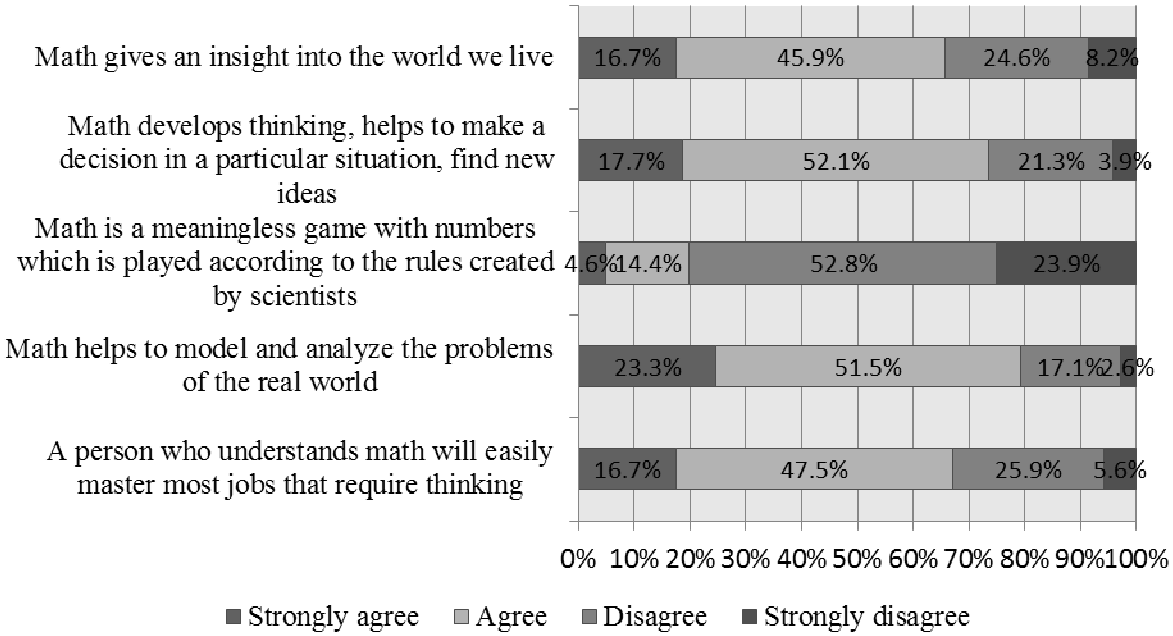

Fig. 5. **Assessment of the mathematics practical potential**

Teaching of mathematics at higher education school is usually criticized for insufficient correlation between the theory and practice. However, the survey highlights the essence and importance of mathematics by the impact of mathematics to the professional competence - 69.8 % of the respondents emphasided that mathematics develops thinking, helps make a decision in a particular

situation, find new ideas. In Fig. 6 the respondents' answers dependence on their professional field of occupation are given.

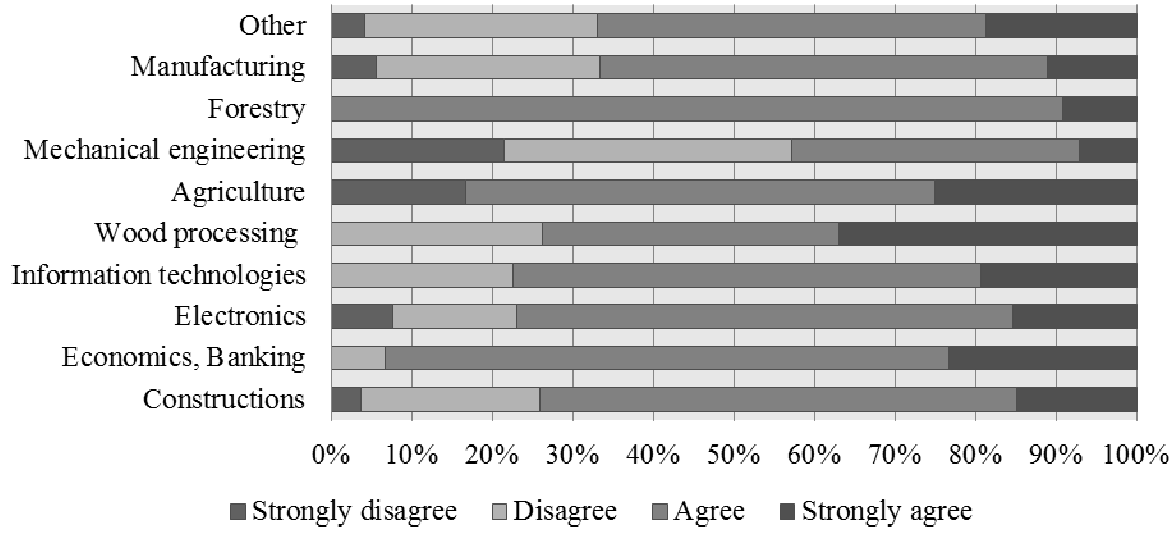

Fig. 6. **Assessment of mathematics impact to the professional competence**

Other aspect is a correlation between mathematics and professional activities characterized by the answers to the question: mathematics helps model and analyse the problems of the real world (74.4 %) and mathematics gives an insight into the world we live (62.6 %). The advantage of mathematics knowledge on the labour market is characterized by the answer to the question - a person who understands maths will easily master most jobs that require thinking (64.2 %).

Part II of the questionnaire included accordance of the mathematical and professional competence (Fig. 7): the list of mathematical topics possibly used in professional practice by illustrating them with concrete tasks of application.

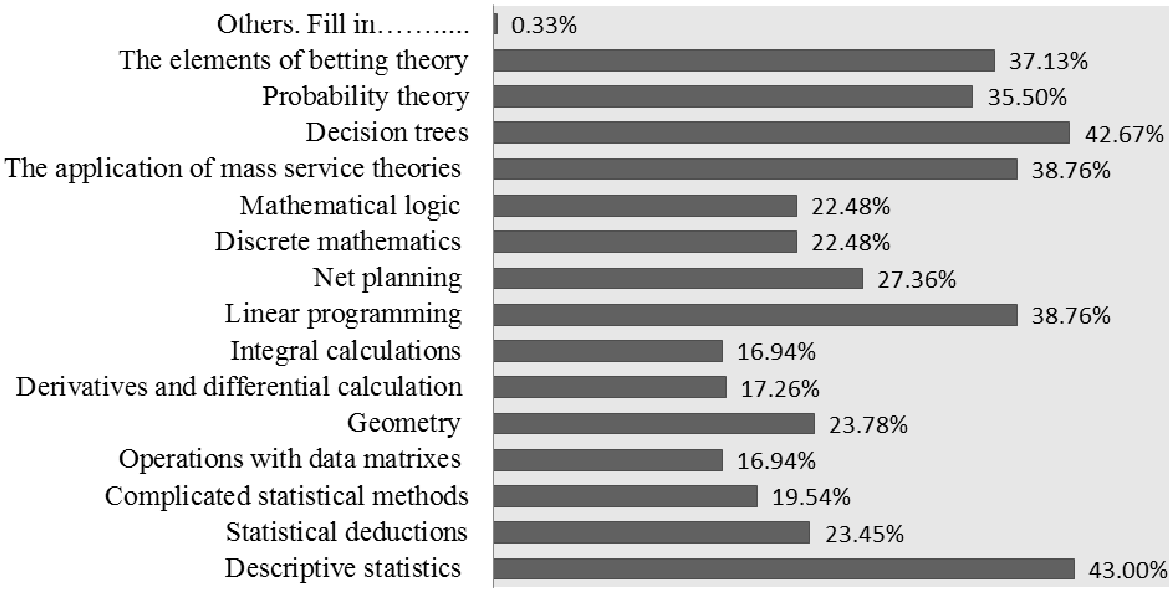

Fig. 7. **Accordance of the mathematical and professional competence**

Respondents were asked to mark those fields of the deeper knowledge of mathematics that are needed for the specialists of their field to accomplish their professional activities successfully and analyse professional literature.

The results show that statistics, decision making and probability theory etc. are not taught enough at universities. The analysis of the mathematical knowledge by the profesinal field of occupation is given in Table 1.

Table 1

Accordance of mathematical and professional competence by spciality (% of respondents)

	Wood processing	Forestry	Constructions	Iinformation technologies	Mechanical engineering	Economics Banking	Services, sales, business	Public administra-tion	Enviro-nment	Food Industry
Descriptive statistics	58.33	77.78	75.00	48.00	45.45	72.22	50.00	84.21	100.0	100.0
Statistical deductions	33.33	44.44	31.25	52.00	9.09	33.33	35.00	42.11	66.67	33.33
Complicated statistical methods	41.67	44.44	6.25	44.00	18.18	44.44	15.00	21.05	33.33	33.33
Operations with data matrixes	50.00	33.33	25.00	12.00	9.09	38.89	25.00	15.79	0.00	33.33
Geometry	50.00	55.56	87.50	24.00	72.73	38.89	30.00	26.32	100.0	33.33
Derivatives and differential calculation	41.67	22.22	31.25	24.00	36.36	27.78	25.00	15.79	66.67	33.33
Integral calculations	33.33	22.22	31.25	36.00	45.45	16.67	40.00	10.53	33.33	33.33
Linear programming	50.00	33.33	25.00	48.00	9.09	44.44	25.00	5.26	0.0	33.33
Net planning	8.33	22.22	18.75	28.00	27.27	22.22	25.00	26.32	0.00	0.00
Discrete mathematics	0.00	22.22	12.50	40.00	27.27	27.78	20.00	21.05	0.00	33.33
Mathematical logic	8.33	11.11	18.75	36.00	9.09	27.78	15.00	21.05	0.00	0.00
Mass service theories	25.00	33.33	12.50	28.00	36.36	33.33	25.00	26.32	0.00	0.00
Decision trees	25.00	44.44	50.00	36.00	27.27	33.33	15.00	42.11	0.00	33.33
Probability theory	41.67	33.33	43.75	44.00	45.45	44.44	20.00	15.79	33.33	33.33
Elements of betting theory	33.33	22.22	31.25	48.00	9.09	27.78	15.00	36.84	0.00	0.00

Conclusions

The research revealed the need for organising of differentiated teaching of mathematics, whereas some part of students achieved the defined results of teaching of the subject of mathematics only partially and the expectations of others regarding a higher level of teaching of mathematics were not realised.

The students understood the general educational relevance of mathematics, however, one half of them think that mathematics was taught drily and drag. On the basis of the research results, the following directions of teaching and improvement of the mathematics study process can be defined:

1. Learning as the result of teaching could be more related not only to repeating of a rule, algorithm, solving examples, but also with deeper understanding of mathematics;
2. Striving for the conformity of the methods of teaching/learning of mathematics with the expectations of a student, the process of studies could be more involving, interesting;
3. Develop positively expressed attitudes of students towards the relevance of mathematics in professional activities and enhancing their learning motivation on this basis.

Approximately one half of the respondents stated that they were applying the knowledge of mathematics directly in their professional activities, the other half stated that they did not need any deeper knowledge of mathematics in their profession, it was sufficient to know how to perform

elementary calculations, however, the practical relevance of mathematical thinking was raised by the majority of the respondents. About 60 % of the respondents specified the need to learn the applications of mathematics in relation with solving of tasks in their professional field. Whereas a very large number of respondents have the interest for deepening of mathematical knowledge, universities and colleges need to offer a variety of lifelong learning programs in mathematics.

In consideration of their experience in the field of professional activities, the respondents suggested (free answers) the following methods of the improvement of teaching of mathematics at higher education school: to correlate learning of mathematics with the major subjects of studies, to reveal the links of mathematics with other subjects, to pay more attention to the practical applications of mathematics, especially the methods of applied statistics, it was suggested to the lecturers of mathematics to take more interest into the applications of mathematics in the particular area of science, on the basis of which the study program was developed.

The main benefit from this research is that the research problems and their solutions will be used as a knowledge background for the improvement of the mathematics study process and teaching methods as well as for the development of new educational products.

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