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MATHEMATICAL COMPETENCES AND COMPETENCE-BASED MATHEMATICS LEARNING FOR SUSTAINABLE DEVELOPMENT

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This paper is the result of scientific analysis and assessment of scientific literature and a number of information sources taking into consideration the authors' reflection experience and observations in connection with the mathematics role in sustainable development which may be characterized by a number of factors, including, mathematical competence compliance with competencies for sustainable development as well as coherence between mathematical competence and capacity which should have new professional. The methodology of the research is based on Danish KOM (Competencies and the Learning of Mathematics) project which set up eight mathematical competences: abilities to ask and answer questions in and with mathematics and he ability to deal with and manage mathematical language and tools. Students from Latvia University of Agriculture and Riga Technical University were asked to evaluate (using self-evaluation method) their mathematical competence by writing in the questionnaire numbers from 0 to 3, where 0 - I have not mastered this skill, but 3 - I can apply mathematical knowledge in different situations of life, I can formulate a mathematical problem, solve it. The survey results are analysed by respondents mathematics learning experience as well as needs for mathematics knowledge and skills in modern labour market conditions as well as in accordance with factor for social capital building.

Keywords: competence, mathematics, mathematical competence, rural engineering, sustainable development.

INTRODUCTION

The concept of sustainable development means development that meets present needs without compromising the ability of future generations to meet their own needs (WCED, 1987). In accordance with UNECE "Strategy for Education for Sustainable Development" – sustainable development understood as social well-being, environment and economic integrated and balanced development (UNECE, 2009).

In September 2015, the 17 Sustainable Development Goals (SDGs) to be achieved over the next 15 years were adopted by world leaders to which will achieve the global reduction of poverty and the sustainable development of the world (Sustainable Development Goals, 2015). With regard to rural development, all these goals are important. Seeing these goals in the context of preparation of agricultural professionals, three most important goals should to be emphasized: (2) End hunger, achieve food security and improved nutrition and promote sustainable agriculture; (7) Ensure access to affordable, reliable, sustainable and modern energy for all; (15) Sustainably manage forests, etc. Considering Latvia's geographical situation, attention should also given to Goal 14 which determines conserve and sustainably use sea and marine resources (Sustainable Development Goals, 2015).

Undeniably education plays an important role in achieving the above-mentioned goals. Through their pivotal and influential role in society, universities are key stakeholders in achieving a sustainable future (Cortese, 2003). Both normative documents and scientists emphasize the importance of inclusion of knowledge, skills and values necessary for sustainable development in each study program, paying particular attention to engineering programs. The Engineering Council (2009) has defined the role of professional engineers in sustainability using the six principles which determines that engineering activities have to be undertaken in a way that contributes to sustainable development (Engineering Council, 2009). It require understanding of the natural world and relationship with it. To acquire that understanding, progress in the mathematical sciences is essential (Vintere, Briede, 2006).

Pyle (2001) considered the mastering of a "distinctive" knowledge of mathematics to be an essential skill for engineers. Wide range of mathematical areas are needed in engineering disciplines, in order to create, manipulate, and interpret models relevant to the branches of engineering (Pyle, 2001). Although it is a "dense language", mathematics is the language of communication for scientists and engineers. Moreover, the logical rigour defined by mathematics encapsulates the quality of knowledge required for engineers (Blockley and Woodman, 2002). As a result, for engineering students, the mathematics education component of their studies has a major role to play (Mustoe, 2003).

Taking into account the above-mentioned aspects and to implement them into curriculum, the aim of the study was to explore the necessary mathematical competences for engineers as well as to identify the extent of students have obtained mathematical competences during their at Latvia University of Agriulture and Riga Technical University.
Both universities prepare mainly engineering specialists. Therefore, in terms of sustainable development in Latvia, mathematical competence is of paramount importance.

METHODOLOGY

In the context of life-long learning mathematical competence understood as ability to solve everyday problems and the determination of structure and commitment, repeatability and systematicity (European Commission, 20006). According to M. Niss (2003) mathematical competence is ability to understand, judge, do, and use mathematics in a variety of intra- and extra-mathematical contexts and situations in which mathematics plays or could play a role (Niss, 2003). In its turn, the competences acquired in the process of engineering education in the context of sustainable development are the ability to analyze different problems with a systemic approach and solve it (Mulder, Segalas-Coral, Ferrer-Balas, 2010). Therefore, there is no doubt that essential part of engineering work is work with mathematical models and solving problems usinf mathematics.

Mathematical education for the engineers as well as competencies to be acquired in the learning process is determined by "A Framework for Mathematics Curricula in Engineering" worked out by the European Society for Engineering Education (SEFI) Mathematics Working Group. The methodology of this study worked out based on recommendation for engineering mathematics curriculum.-The competence-based learning of mathematics as a result of the study process involves eight mathematical competences. According to Niss (Niss, 2003) can be said to form two groups linked to the ability to:

1) ask and answer questions using mathematics: mathematical thinking *(thinking mathematically)*, reasoning *(reasoning mathematically)*, problem solving *(posing and solving mathematical problems)*, Modelling *(modelling mathematically)*;
2) cope with the mathematical language and its tools: presentment *(representing mathematical entities)*, symbols and formalism *(handling mathematical symbols and formalism)*, communication *(communicating in, with, and about mathematics)*, Assistive aids and tools (making use of aids and tools).

The European engineering curriculum documents also define the depth of mathematical competence and knowledge that students have to acquirein the mathematics study process. OECD PISA "Assessment Framework" to characterise extent to which the person masters mathematical competence suggests to use three clusters: reproduction, connection and reflection (OECD, 2009).

Based on the mathematical competence assessment described above, the methodology of this study was developed. In 2016/2017 study year students from Latvia University of Agriculture and Riga Technical University were asked to evaluate their mathematical competence. The survey sample are 591 respondents. In diagnostic block *Competence in mathematics* the respondents had to assess the given eight statements regarding mathematical competence described above by writing in the questionnaire numbers from 0 to 3, where 0 - I have not mastered this skill, but 3 - I can apply mathematical knowledge in different situations of life, I can formulate a mathematical problem, solve it. This means that compared to the PISA clusters, this study uses four levels, adding the so-called "0" level, when competence is not mastered at all.

In general, the questionnaire also included other diagnostic blocks. The respondents had to assess the statements by expressing their approval or disapproval on a 4-stage (diagnostic block: *Teaching of mathematics at the univer*sity.) or 5-stage (diagnostic block: *Potential mathematics' values*) Likert scale. In the questionnaire were given also other types of questions: questions with given answers and an open question: *What should be taught in mathematics at a university and how exactly should this be done to promote the development of competences needed for sustainable development?* The questionnaire (in Latvian) is available at: http://www.iipc.lv/surv/index.php/393736/lang-lv.

In this article the survey results analysed by professional area, respondents' mathematics learning experience as well as needs for mathematics knowledge and skills.

RESULTS AND DISCUSSION

International studies have emphasized the importance of developing the mathematical literacy of students, with the aim of better preparing them for a number of disciplines, such as science and engineering, which rely heavily on mathematics and are in widespread demand (Petocz et al., 2007). Therefore since the subject of Mathematics increasingly becomes an instrument for promoting broad all-round education and personal development, many education courses are mathematics-intensive, students need a high level of competence in the subject (Gustafsson, Ouwitz, 2004). The results from empirical research suggest that students in Latvia highly evaluate the mathematical competence acquired at the university (Figure 1). Almost one third of all respondents think that they have acquired the method of mathematical thinking and asses the ability to abstract and generalize results at higher level. They are sure that they can apply mathematical knowledge in different situations of life, can formulate a mathematical problem and solve it. At the same time, modelling skills could be higher (13.2%). For more than 10% of students, ability to cope with the mathematical language and its tools is not obtained at all or at low level.

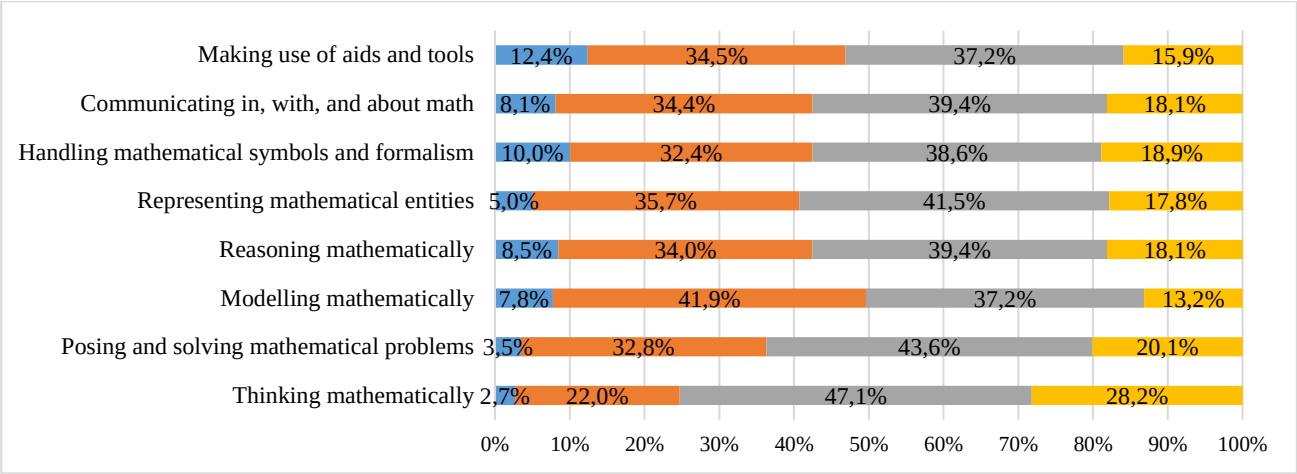

Figure 1. Summary of studnets mathematical competence self- assessment (N=591)

Analysing survey results by specialty, the most confident in mathematics feel students whose future profession is related to contructions, evironment, energy and hydro engineering. Seeing these results from sustainability perspective the students answers are promising. Although Latvia University of agriculture prepares specialists for mainly rural areas, the self-assessment of the knowledge of mathematics is the lowest in the field of agricultural engineering students.

Respondents were also invited to express their knowledge of mathematics by excellent, good, satisfactory, unsufficient. If look at the results of students who asses they math knowledge as excellent, it is seen that alsmost two third of respondents ability to ask and answer questions using mathematics: mathematical thinking, reasoning, problem solving, modelling – rated as very high (Figure 2).

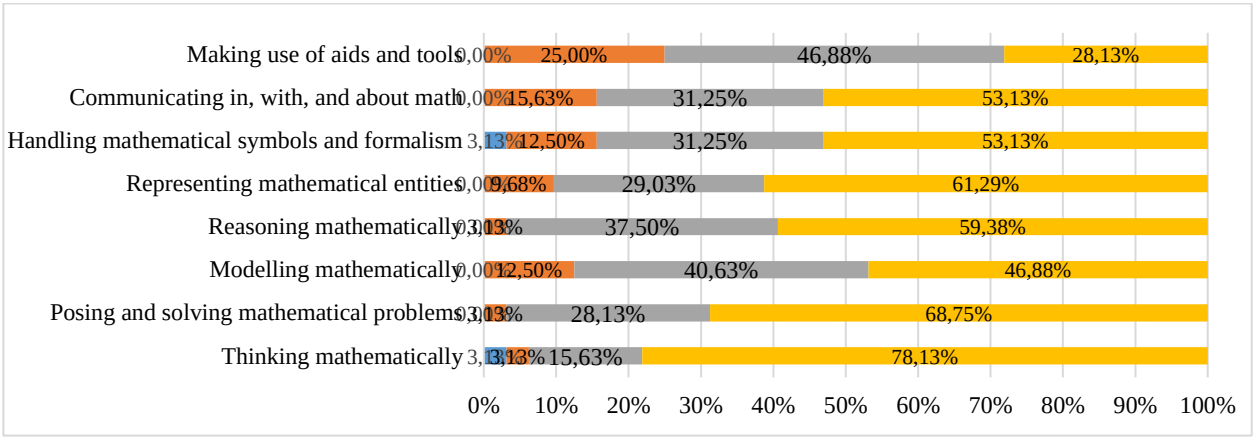

Figure 2. Self-assessment of mathematical competence of students with excelent mathematical knowledge (N=261)

The different answers were given by students whose mathematical knowledge is unsufficient (Figure 3). Answer "I have not mastered this skill" was given by one fifth of respondents. Inthis case only one third of students value their math competence. The most problematic ability is to deal with and manage mathematical language and tools.

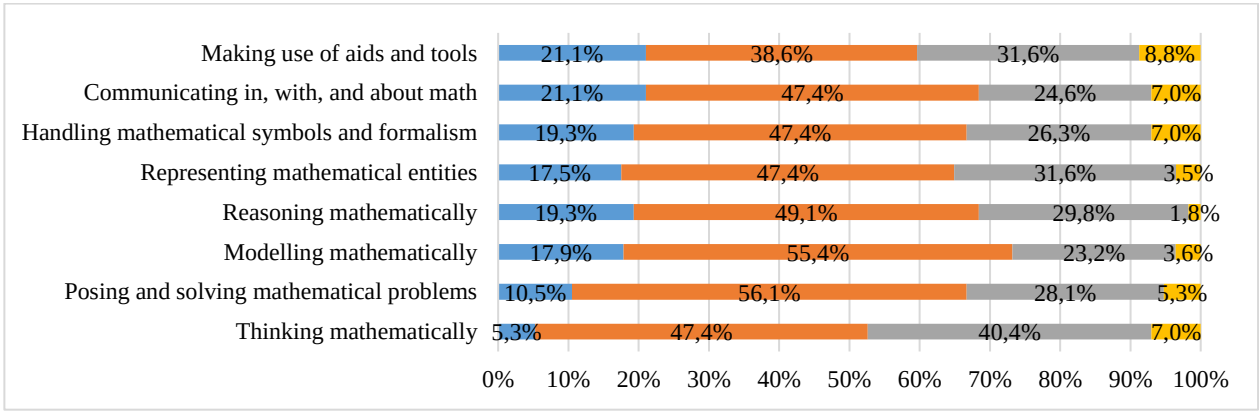

Figure 3. Self-assessment of students' mathematical competence with insufficient mathematical knowledge (N=461)

54% of studnets claimed that mathematics, which they studied at university could have been more complicated. Almost half of these students think that they mathematical thinking competence as well as problem solving competence is very high. They are sure that they can apply mathematical knowledge in different situations of life.

For 76.9% of students, mathematics helped to understand other subjects. They mathematical competences which characterized by abilities to ask and answer questions in and with mathematics are very high.

It has been shown to be common across all disciplines in which mathematics is studied that mathematics is frequently disliked (Freeman et al. 2008) and studies have shown points of interest and correlations between students' beliefs and attitudes towards mathematics and their performance in the subject. The results of this research also demonstrate the coherence of students math competence self-esteem and attitude and knowledge. The higher the student values his knowledge in mathematics, the higher the self-assessment of mathematical competence.

As mentioned before tehre was also an open question: *What should be taught in mathematics at a university and how exactly should this be done to promote the development of competences needed for sustainable development?* The majority of respondents emphasized that the major changes in the teaching of math in the higher education school should be related to the enhancement of the link between the teaching of math and practice. The respondents suggested to lecturers to be more interested in the application of mathematics in real life situations as well as in particular profession, which would include implementation of the study program, to transform the module of mathematics in such a way, that it would better meet the speciality. They emphasized that learning should be directed towards understanding, revealing of correlations within the subject. Students suggested also to seek out and implement new teaching methods in higher mathematics studies. At the moment, the teaching of mathematics in the universities involved in the study is mainly based on the definition of key concepts and the acquisition of mathematical tasks solving technics, e.g., derivatives techniques, acquisition of different integration methods, differential equations solving techinics, etc. But, on the other hand, students from mathematical studies at university expect raising the mathematics awareness, developing a link between course material with the profession. It is a challenge for teachers today to introduce new learning approaches and methods in the study process, making mathematics studies more attractive to students and contributing to the development of competences that are necessary for sustainable development.

CONCLUSIONS

1. There are eight mathematical competences for the engineers to be covered for sustainable development. Four competences characterise abilities to ask and answer questions in and with mathematics and four - ability to deal with and manage mathematical language and tools.
2. The study shows that the competence to think mathematically, posing and solving mathematical problems, as well as ability to solve mathematical problems are the best, the worse - competences which reflect ability to deal with and manage mathematical language and tools.
3. Evaluating the results of the survey among the specialties - the highest assessment of mathematical competence is for constrctors, but the lowest - for agricultural engineering students.
4. Interpreting studnets answers to an open question within the context of teaching/learning of mathematics, might be envisaged three factors, which probably would allow pursuing better results:
    a) The first one is learning how the learning result could be more correlated not only with repeating of a rule, algorithm solving examples, however it could be correlated with deeper understanding of mathematics;
    b) The second factor is such that pursuing of the conformity of the methods of teaching/learning of mathematics with a student's expectations, the process of learning could be more involving, interesting;
    c) The third factor is to develop positive attitudes of students towards the relevance of mathematics in professional activities and to enhance learning motivation on this basis.

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