Students' Perceptions of Mathematics in Engineering Courses from Partners of MetaMath and MathGeAr Projects

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INTRODUCTION

Mathematics is considered as the foundation discipline for the entire spectrum of Science, Technology, Engineering, and Mathematics (STEM) curricula. Its weight in the curriculum is therefore high [1]. In Armenia, Georgia and Russia, all university students pursuing this kind of curricula are obliged to take a three semester standard course in Higher Mathematics. Special studies in Europe suggest that competencies

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gap in mathematics is a most typical reason for STEM students to drop out of study [2], [3], [4], [5], [6].

Epistemological features evident in the sciences include the aspiration to be objective [7]. From the intuitive perception of a phenomenon, a pre-scientific spirit needs to overcome a set of epistemological obstacles to reach a scientific stage.

Several research studies bring to the fore that students' perceptions of mathematics and of mathematics teaching have an impact on their mathematics performance [8], [9].

On the other hand, the findings of the studies conducted by [8], [9] found that students' perceptions of the subject matter have a significant relationship with students' academic performance. That is, the students' performance is depending on their perceptions toward the subject. Positive attitude and perceptions towards the subjects will encourage an individual to learn the subject matter better.

This article presents an analysis of the engineering students' perceptions of their mathematics courses. We present the methodology of data acquisition, the main themes that the study investigates and the preliminary results. We do validate the fact that each institution carries its own educational tradition which yields a very strong indicator of the origin of students.

1 THE PROJECTS METAMATH AND MATHGEAR

The overall objective of the two Tempus projects, MathGeAr[2] and MetaMath[3], is to improve the quality of STEM education in the South Caucasian region (Armenia and Georgia) and Russia, by modernizing and improving the curricula and teaching methods in the field of Mathematics. The process of modernization will start from the fundamental revision of the way math studies are organized in all universities of the participant countries offering degrees in STEM. After ensuring the consistency of the math curricula with the Bologna principles (http://www.ehea.info) and best European standards, the further steps will be taken to modernize the content and teaching methods by introducing principles of blended learning and new educational technologies.

More specifically, the two projects aim at:

- Implementing a comparative analysis of the national math curricula for engineering and science studies in order to define the recommendations for structural improvements in the line with the Bologna principles and identifying the areas most suitable for the introduction of Technology Enhanced Learning (TEL) tools.
- Modernizing math and statistics curricula for a selected set of engineering and sciences studies.
- Selecting the necessary math & statistics eLearning content to be used for modernization.
- Localizing the European TEL tools for partner universities, including TEL content localization and building a capacity in local universities to effectively implement, maintain and develop TEL for math education.
- Implementing a pilot trial in order to practically introduce the modernized curricula into the academic process and evaluating the impact of the new

[2] http://www.mathgear.eu
[3] http://www.metamath.eu

curricula on quality of studies in math and statistics, as well as on quality of engineering and sciences education in general.

The main objective behind studying the students' perceptions is to conclude some empirical indicators out of the students' perceptions patterns that can be used to guide the modernization process of mathematics engineering courses to better address good performance of engineering students on their mathematics courses.

2 THEORETICAL BACKGROUND AND THE RESEARCH QUESTION

[10] Claim that students' beliefs and attitudes about mathematics have a strong impact on their learning outcomes. The authors stress that studies in mathematics education present a variety of concepts related to beliefs, however the definition of the concept of belief itself remains vague. Some researchers acknowledge that beliefs contain some affective elements [11], while others situate beliefs rather on the cognitive side [12].

Talking about mathematics related perceptions, which are referred to as a belief system in the literature [10], [13]. [14] Claim that "there are four sets of beliefs about mathematics:

- beliefs about the nature of mathematics,
- beliefs about teaching and learning of mathematic,
- beliefs about the self in context of mathematics teaching and learning,
- beliefs about the nature of knowledge and the process of knowing."

Our interest has thus been oriented toward such perceptions of mathematics in students in engineering courses. These students, engaged in science have nevertheless different positions, whether philosophical, practical or epistemological towards mathematics.

The present article thus investigates the following question: "How far do the students' perceptions of mathematics in engineering courses regarding the usefulness of mathematics in real life, the teaching of mathematics (contents and methods) and the nature of mathematics knowledge differ in terms of university, country (France, Finland, Russia, Georgia and Armenia), region (Caucasian, European, Russian) and gender (female, male)?"

3 METHOD AND PROCEDURES

3.1 Questionnaire Design

We used 6-steps process to design the questionnaire, as follows:

3.1.1 Aim of the Questionnaire.

To address the research question, the main aim of designing the questionnaire is to obtain a validated and reliable tool that can be used to assess students' perceptions for their mathematics courses and get concrete indicators of their beliefs.

3.1.2 Dimensions of the Questionnaire.

Drawing on prior studies [15], [8], [16] related to students' mathematics perceptions, and in particular the four sets of beliefs about mathematics suggested by [14], we have designed a questionnaire to gather students' beliefs about the following:

1. Usefulness of mathematics.

2. Teaching of mathematics in engineering schools, its contents and methods.
3. Nature of mathematics knowledge.

Given the target audience, namely students in engineering courses, we assumed that they have a rather positive attitude toward mathematics. For this reason, we decide not to address beliefs about "the self in context of mathematics teaching and learning".

3.1.3 Preliminary form of the Questionnaire.

Based on the three above-mentioned dimensions of the questionnaire, we developed 35 questions that cover these dimensions as show in Table 1.

Table 1: Questionnaire dimensions and Numbers of items

Questionnaire dimensions	Number of Questions
Usefulness of mathematics	8
Teaching of mathematics in engineering schools, contents and methods	15
Nature of mathematics knowledge	12
Total	**35**

3.1.4 Content Validity Check

The first dimension of the questionnaire explores the students' beliefs about the usefulness of mathematics not only in the engineering careers (e.g. item 1.4 "Mathematics is essential in the engineering careers"), but also in the everyday life (e.g. item 1.1 "Mathematics is useful to solve real problems of human activity", or item 1.3 "Mathematics is useful to each individual to deal with various situations in life"), social sciences (item 2), or for the development of reasoning (e.g. item 1.5 "Mathematics is useful for developing human thinking").

The second dimension addresses the students' beliefs about teaching of mathematics in their engineering courses. Two main aspects about mathematics teaching are addressed. On the one hand, whether mathematics taught in engineering courses is rather theoretical or applied (e.g. item 2.1. "In your school, the teaching of mathematics is rather focused on pure mathematics (not applied mathematics)" or item 2.2 "In your engineering courses, applied mathematics is missing"). On the other hand, a set of items aims at highlighting whether the students think that mathematics teaching in their schools gives them tools for their future engineering careers (e.g., item 2.3 "Teaching of mathematics prepares for the reality of the workplace", or item 2.4 "Teaching of mathematics helps in understanding and application of tools in engineering sciences").

The third dimension attempts to unveil the students' beliefs about the nature of mathematics knowledge, e.g. item 3.1 "In mathematics, there is nothing more to discover", item 3.4 "Mathematics is only abstraction, they have nothing to with reality" or item 3.8 "The job of a mathematician is to prove theorems".

3.1.5 Questionnaire Reliability Coefficient

To calculate the reliability coefficient (Cronbach's alpha), we administered an online version of the questionnaire to a sample of 1548 students from all participant countries (See sample Section). Students' responses were analyzed to calculate the scores of each student. The reliability coefficient (Cronbach's alpha) for all the questionnaire items is calculated using R statistical package. It is 0.79, a high enough reliability coefficient. Consequently, the questionnaire prepared by the researchers is proven reliable to measure students' perception toward mathematics as a whole construct.

3.1.6 Experimental Validity of the Questionnaire

The experimental validity of the questionnaire as an estimation of the tool validity is also calculated by taking the square root of the test reliability coefficient [17]. Therefore, the experimental validity is 0.89, which shows that the questionnaire has a high experimental validity.

So, based on the preparation of the questionnaire, in this article students' perceptions of their engineering courses of mathematics referred to their opinions and judgments of usefulness of mathematics, mathematics teaching and learning in terms of contents and methods, and perceptions of mathematics. And, as an operational definition of students' perception of their engineering courses, in this article, it is defined as a random variable taking vector values represented by the Likert score of the students on the 35 items of the prepared questionnaire on 1 to 6 Likert-type scale.

3.2 Population and Sample

The population on which we base this study are students from partners' universities [4]in two Tempus projects, MetaMath in Russia and MathGeAr in Georgia and Armenia, and French and Finnish students on the European side. Out of this population a sample of 1548 students filled in the survey with 958 complete responses - See Table 2: Participants of the study.

Table 2: Participants of study

Country	Number of Students	Number of Students with Completed Responses
Armenia	24	12
Finland	189	112
France	430	245
Georgia	285	179
Russia	612	410
Total	**1548**	**958**

3.3 Data Analysis

To explore the students' perceptions of mathematics we produced an online survey to be distributed in all participant countries. After collecting the data from the online survey we used the statistical package R to analyze the data and draw preliminary conclusions. We performed a ***Principal Component Analysis*** (PCA) [18], [19], [20] to investigate patterns in the students' responses. Although the students' responses are not strictly speaking continuous but a Likert scale between 1 and 6, Multiple Factor Analysis where different Likert values are not numerically linked but used as simply ordered categories, didn't yield finer results. PCA uses a vector space transform to reduce the dimensionality of large data sets giving some interpretation to variability.

[4] Partners universities for MetaMath Tempus project (http://www.metamath.eu/partners/).
Partners universities for MathGeAr Tempus project (http://www.mathgear.eu/partners/).

The original data set, which involves many variables, can often be interpreted by projecting it on few variables (the principal components).

We used PCA to reveal patterns in students' responses. Using the two first principal components, explaining almost a quarter of the variability, we identify the main common trends and the main differences. In particular, the main result is that we can verify the hypothesis that methodology of teaching mathematics of each partner, and in particular each country, shapes the average students' perception towards mathematics.

4 RESULTS

During students' interviews and study visits in the project, we could point out the main trends in the way mathematics is taught in partners' institutions and the fact that mathematics in Europe are taught as a sophisticated tool to grasp real engineers issues stands out with respect to a more theoretical approach in the East. This fact does show in the data.

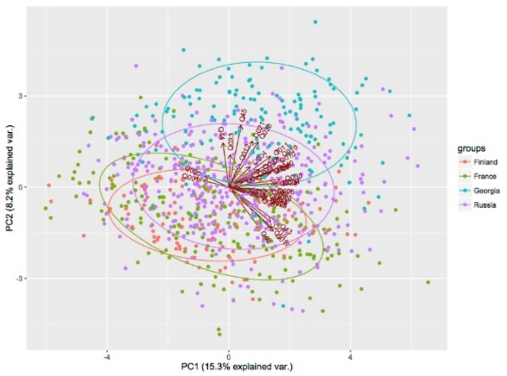

Fig.1. PCA grouped by countries

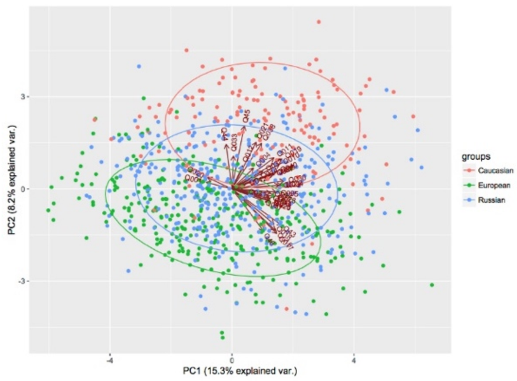

Fig. 2. PCA grouped by regions

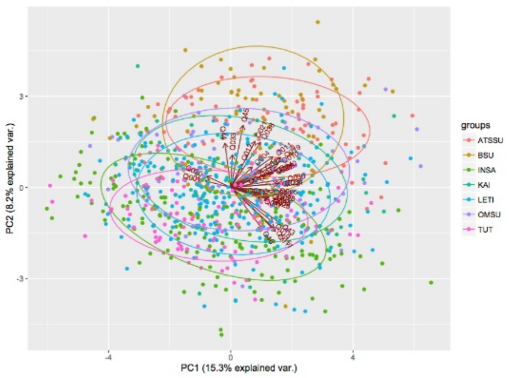

Fig. 3. PCA grouped by institution

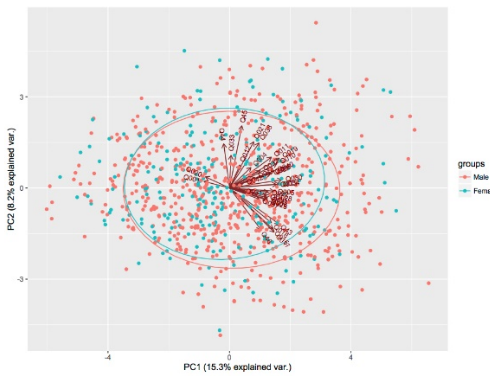

Fig. 4. PCA grouped by gender

The analysis shows that all students (15.2% of the variability) feel that math teaching is too theoretical, not practical enough and has not enough connection with other sciences and the engineer's job reality. Therefore, modernized curricula for engineers should address these issues. On the other hand, we identify that Finnish and French students (Fig. 1) share most of their perceptions while the Caucasian students notably differ from them, the Russian students lying in between with a broader variability. The semantic analysis of the second principal component (8.6% of variability) reveals that in the European universities mathematics are taught as tools to solve problems, that is to say mathematics by practicing, while in the Caucasian universities, mathematics are taught focusing on proofs and theorems, that is to say mathematics as an abstract game. Caucasian students tend to perceive that mathematics consists of knowledge rather than competencies, mainly of theoretical interest, with a discrepancy between early practical mathematics and theoretical engineer mathematics (Fig.2).

The European students feel that advanced mathematics is useful, that the role of a teacher is more to help students to apply mathematics than to only transmit knowledge. The Russian students fall in between the two groups and are more diverse in their opinions [21].

Apart from the country and the institution, which do explain a lot of the variability, we looked for characters separating students into groups in a statistically significant way. In engineering studies, gender is a major differentiating trait [22], [23]. And to our surprise, partner's institution explains much more the differences between students than gender: male and female students have very similar responses, only 6 out of 35 questions are statistically distinguishable (p-value < 0.05) and with no clear-cut semantic explanation of the slight differences: male students tend to disagree a little bit more strongly to the proposal that mathematics can be applied more easily to man crafted objects than to objects found in nature, while female students tend to find slightly more that mathematics courses are enough practical. But the differences are much higher between partners' institutions than between genders: there are statistically greater differences between the answers of a student in St Petersburg Electro Technical University (LETI) and another in Ogarev Mordovia State University (OMSU) (much lower p-values, with 16 out of 35 being less than 0.05) than between a male and a female student in each university (Fig. 3 and Fig. 4). And the differences are even higher between institutions belonging to different countries. We have to look at the 7th principal component in order to get a dimension whose interpretation of the variability is clearly linked to gender. The same relative irrelevance with respect to age appears: students' perceptions depend on the year of study, but to an extent much lower than the dependency on the institution. We find these results remarkable.

The main findings of this analysis is that there are indeed great differences between partners students' responses, with homogeneous European universities tending to see engineer mathematics as a professional tool on the one side, homogeneous Caucasian universities on the other, where advanced mathematics are felt as dealing with abstraction, and Russian universities in between.

5 DISCUSSION AND CONCLUSION

In this article we presented in detail the development of a questionnaire for engineering students' perceptions of mathematics and its qualification in terms of reliability and validity. We observed that European countries on the one hand and South Caucasian countries on the other are quite aligned. However, Russian students' perception is more spread out and in between those of the European and South Caucasian students. The country has a large influence but within these differences, institutions can be more finely differentiated and this difference is higher than most other criteria like gender: a student can be linked to her university in a more confident way than to her gender or her year of study. Comparison with other institutions would be interesting.

The main implication for the MetaMath and MathGeAr projects from this study is that if the European way is to be promoted, the project should put forward the applications of advanced mathematics and focus on competencies rather than transmission of knowledge.

This questionnaire has some limitations. For instance, its item-internal consistency reliability was not high enough regarding the three dimensions of the questionnaire, that we identified *a priori*. The item-internal consistency reliability measured by Cronbach's Alpha are 0.52, 0.65, 0.62 which tells us that reality is more complex than our question choices based on epistemology. It evokes the need for further study to qualify the questionnaire with a bigger homogeneous sample and/or redesign of the current questionnaire by adding more items that are related to these dimensions or qualify better these dimensions.

This study is part of a broader project aiming at understanding the cultural differences in the perception of mathematics for the engineers. Informed by this study, the MetaMath and MathGeAr projects are looking for ways to modernize both mathematics teaching and contents for mathematics. Because perceiving mathematics in a positive way would influence students' motivation and performance, it is desirable to change the mathematics contents and the way we teach it in order to address the negative aspects of the perceptions identified here, for instance teaching mathematics as a powerful modelling tool not abstractly but in actual students' projects. But we might as well try to directly modify students' perceptions by better informing them about some aspects of mathematics, its usefulness in engineer's profession for example. Therefore, we need to know which type of mathematics in-service engineers do use in a conscious way, what is their perceptions about the mathematics they received in their education.

The current study suggests further investigations avenues: the first one is to study deeper the influence of engineering students' perceptions on mathematics performance for each partner institutions. The second one is the elaboration of questionnaires targeting engineers in order to study the perception and actual usage of mathematics by professionals. Because the link between students and engineers goes through teachers, we need to study as well the perception of teachers themselves. We have already adapted this questionnaire in order to address these two targets and it will be the subject of subsequent articles. This study is only the first real size pilot of a series of further studies to come.

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