Chapter 10
Overview of the Results and Recommendations

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10.1 Introduction

The two EU Tempus-IV projects MetaMath (www.metamath.eu) and MathGeAr (www.mathgear.eu) have brought together mathematics educators, TEL specialists and experts in education quality assurance from 21 organizations across six countries. A comprehensive comparative analysis of the entire spectrum of math courses in the EU, Russia, Georgia and Armenia has been conducted. Its results allowed the consortium to pinpoint and introduce several curricular modifications while preserving the overall strong state of the university math education in these countries. The methodology, the procedure and the results of this analysis are presented here.

During the first project year 2014 three international workshops were organized in Tampere (TUT), Saarbrucken (DFKI & USAAR) and Lyon (UCBL), respectively. In addition, national workshops were organized in Russia, Georgia and Armenia. The purpose of the workshops was to get acquainted with engineering mathematics curricula in the EU and partner countries, with teaching and learning methods used in engineering mathematics, as well as the use of technology in instruction of mathematics. Finally, an evaluation methodology was set up for degree and course comparison and development.

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S. Pohjolainen et al. (eds.), *Modern Mathematics Education for Engineering Curricula in Europe*, https://doi.org/10.1007/978-3-319-71416-5_10

10.2 Curricula and Course Comparison

To accomplish curricula comparison and to set up guidelines for further development SEFI framework [1] was used from the beginning of the project. The main message of SEFI is that in evaluating educational processes we should shift from contents to competences. Roughly said, competences are the knowledge and skills students have when they have passed the courses and this reflects not only on the course contents but especially on the teaching and learning processes, use of technology and assessment of the learning results. SEFI presents recommendations on the topics that BSc engineering mathematics curricula in different phases or levels of studies should contain. The levels are Core 0—prerequisite mathematics, Core 1—common contents for most engineering curricula, Core 2—elective courses to complete mathematics education on chosen engineering area and finally Core 3 for advanced mathematical courses. SEFI makes recommendations on assessing students knowledge and on the use of technology. Here it is also emphasized that learning should be meaningful from the students' perspective. Students' perceptions on mathematics in each of the universities were investigated and results were presented in Chap. 1, Sect. 1.3.

The SEFI framework and related EU-pedagogy was described in Chap. 1, Sect. 1.1. To make a comparison of curricula and courses, a methodology was created. This methodology was described in detail in Chap. 2. Comprehensive information on partner countries' curricula, courses and instruction was collected and organized in the form of a database. For comparison similar data was collected from participating EU-universities, Tampere University of Technology (TUT), Finland and university of Lyon (UBCL), France. This data includes:

- **University:** university type, number of students, percentage engineering students, number of engineering disciplines, degree in credits, percentage of math in degree.
- **Teaching:** Teacher qualifications, delivery method, pedagogy, assessment, SEFI depth aim, modern lecture technology, assignment types, use of third party material, supportive teaching.
- **Selected course details:** BSc or MSc level, preferred year, selective/mandatory, prerequisite courses, outcome courses, department responsible, teacher position, content, learning outcomes, SEFI level, credits, duration, student hours (and their division), average number of students.
- **Use of ICT/TEL:** Tools used, mandatory/extra credit, optional, e-learning/ blended/traditional, Math-Bridge, calculators, mobile technology.
- **Resources:** Teaching hours, assistants, computer labs, average amount of students in lectures/tutorials, use of math software, amount of tutorial groups, access to online material.

10.3 Comparison of Engineering Curricula

The overall evaluation of partner universities curricula shows that they aim to cover the SEFI core content areas, especially Cores 0 and 1 of BSc-level engineering mathematics.

Considering only coverage may, however, lead to erroneous conclusions, if the amount of mandatory ECTS in mathematics is not considered simultaneously. For example, one university may have one 5 ECTS mathematics course during a semester, while the second has two 5 ECTS courses, which cover the same topics in the same time. In this case much more time is allocated in the second university to study the same topics. This means that the contents will be studied more thoroughly, students can use more time for their studies, and the learning results will better.

The ECTS itself are comparable, except in Russia, where 1 Russian credit unit corresponds to 36 student hours compared with 25–30 h per ECTS in other universities. The amount of mandatory ECTS and contact hours used in teaching depends on the policy of the university and it varies more as is seen in Tables 10.1, 10.2, and 10.3 below.

To compare curricula, the following information was collected from EU and partner universities. Table 10.1 shows the amount mandatory mathematics in Engineering BSc programs in Finland (TUT), France (UCBL) and Russia (OMSU); the corresponding information for Armenia (ASPU), (NPUA), and Georgia (ATSU), (BSU), (GTU), (UG), is given in Tables 10.2 and 10.3. The first column presents the country and partner university. The second column shows one ECTS as the hours a student should work for it. It covers both contact hours (lectures, exercise classes, etc.) and independent work (homework, project work, preparation for exams etc.). The third column shows one ECTS as contact hours like lectures, exercise classes etc., where the teacher is present. The fourth column shows the mandatory amount of mathematics in BSc programs, and the fifth column shows all (planned) hours a student should use to study mathematics. It has been calculated as the product of mandatory ECTS and hours/ECTS for each university/BSc program.

In the first table, figures from Finland (TUT), France (UCBL), and Russia (OMSU) are given. As the educational policy in Russia is determined on the national level, the numbers from other Russian partner universities are very much alike. That is why we have only the Ogarev Mordovia State University (OMSU) representing the Russian universities for comparison.

Table 10.1 Mandatory mathematics in EU- and Russian engineering BSc programs

Country	One ECTS as student hours	One ECTS as contact hours	BSc program	Mathematics in ECTS	Mathematics in student hours	Notes
Finland (TUT)	26.67	11–13	All (except natural sciences)	27	720	Additional elective courses can be chosen
Finland (TUT)	26.67	11–13	Natural sciences	60	1600	Mathematics major
France (UCBL)	25–30	10	Generic	48	1200–1440	First 2 years of study
France (GPCE)			Generic		864	Higher School Preparatory Classes
Russia (OMSU)	1 CU = 36 h ≈ 1.33 ECTS	1CU = 18 contact hours	16 technical and engineering BSc programs	7–75 CU (9–100 ECTS)	252–2700	Russian CU = 36 h. Half of the programs have more than 20 CU (27 ECTS), half less than 20 CU (27 ECTS). Exploitation of Transport and Technological Machines and Complexes BSc has only 7 CU, Fundamental Informatics and Information Technologies has 75 CU
Russia (OMSU)	1 CU = 36 h	1CU = 18 contact hours	Informatics and Computer Science	35 CU (47 ECTS)	1260	Russian CU = 36 h. An example of a BSc program in OMSU

Table 10.2 Mandatory mathematics in Armenian engineering BSc programs

Country	One ECTS as student hours	One ECTS as contact hours	BSc program	Mathematics in ECTS	Mathematics in student hours	Notes
Armenia (ASPU)	30	13	GROUP 1 BSc Engineering programs	42	1260	Specialization—Informatics
Armenia (ASPU)	30	13	GROUP 2 BSc Engineering programs	32	960	Specializations—Physics and Natural Sciences
Armenia (ASPU)	30	13	GROUP 3 BSc Technology and Entrepreneurship, Chemistry	9	270	Specialization—Technology and Entrepreneurship, Chemistry
Armenia (ASPU)	30	13	GROUP 4 BSc Psychology and Sociology	9	270	Specializations—Psychology and Sociology
Armenia (NPUA)			GROUP 1 BSc Engineering programs	28		Faculty of Applied Mathematics and Physics
Armenia (NPUA)			GROUP 2 BSc Engineering programs	18		All remaining faculties

Table 10.3 Mandatory mathematics in Georgian engineering BSc programs

Country	One ECTS as student hours	One ECTS as contact hours	BSc program	Mathematics in ECTS	Mathematics in student hours	Notes
Georgia (ATSU)	25	12	GROUP 1 BSc Engineering programs	35	875	Faculty of Exact and Natural Sciences. BSc Informatics
Georgia (ATSU)	25	12	GROUP 2 BSc Engineering programs	32.5	812.5	Faculty of Technical Engineering
Georgia (ATSU)	25	12	GROUP 3 BSc Engineering programs	15	375	Faculty of Technical Engineering
Georgia (ATSU)	25	12	GROUP 4 BSc Engineering programs	10	250	Faculty of Technical Engineering
Georgia (BSU)	25	9	GROUP 1 BSc Engineering	10	250	Programs of Civil Engineering; Transport; Telecommunication; Mining and Geoengineering
Georgia (BSU)	25	9	GROUP 2 Architecture	5	125	Program of Architecture
Georgia (BSU)	25	9	GROUP 3 Computer Science	5	125	Program of Computer Science

Georgia (GTU)	27	12	GROUP 1 BSc Engineering programs	15	405	Faculties of Power Engineering and Telecommunications; Civil Engineering; Transportation and Mechanical Engineering; Informatics and Control Systems; Agricultural Sciences and Biosystems Engineering
Georgia (GTU)	27	12	GROUP 2 BSc Business-engineering programs	15	405	Business-Engineering Faculty
Georgia (GTU)	27	12	GROUP 3 BSc	10	270	Faculties of Architecture; Mining and Geology; Chemical Technology and Metallurgy)
Georgia (GTU)	27	12	GROUP 4 BSc	10	270	International Design School
Georgia (UG)	25–27	6.5	GROUP 1 BSc	24	600–648	Informatics (+elective courses)
Georgia (UG)	25–27	6.5	GROUP 2 BSc	30	750–810	Electronic and Computer Engineering (+ elective courses)
Georgia (UG)	25–27	6.5	GROUP 3 MSc	12	300–324	+ elective courses

Some differences may be detected from the tables. The amount of ECTS varies between engineering BSc programs from 10 ECTS to 75 Russian CUs, which is about 100 ECTS. The contact hours per ECTS are between 6.5 and 13. The time students use in studying engineering mathematics is different between the universities. If all the universities would like to fulfill the SEFI 1 Core, then some universities are resourcing less time for teaching and learning. This is unfortunate, as the quality of learning depends strongly on the amount of time spent on teaching and learning. This is not the only criteria, but one of the important criteria. As mathematics plays an essential role of engineering education it should have a sufficient role in engineering BSc curricula and it should be resourced to be able to reach its goals.

The major observations from the national curricula are the following:

- Russian courses cover more topics and seem to go deeper as well. The amount of exercise hours seems to be larger than EU. The overall number of credits is comparable, but the credits are different (1 cr = 36 h (RU), 1 ECTS = 25–30 h (EU)) therefore per credit, more time is allotted to Russian engineering students for studying mathematics. The amount of mandatory mathematics varies with BSc programs between 7–75 CU (9–100 ECTS). The medium is 20 CU, which is about 27 ECTS. This means that coverage of the SEFI topical areas varies with BSc program. The highest exceeds well the SEFI Core 1, but the lowest lacks some parts. The medium of mandatory mathematics among the programs (20 CU $\approx$ 27 ECTS) is close to European universities.
- In Armenia, the amount of engineering mathematics in engineering BSc programs varies from 42 ECTS to 18 ECTS. The contents of engineering mathematics is very much the same as in EU but Armenian courses must cover more topics for 18 ECTS than the EU-universities (27–40 ECTS). The amount of lecture/exercise hours/ECTS is about the same as in the EU and the overall number of credits are well comparable.
- In Georgia, the amount of engineering mathematics varies from 35 to 10 ECTS in engineering BSc programs. The minimum 10 ECTS is low compared with the comparable EU, Russian and Armenian degree programs. The coverage of engineering mathematics courses is still very much the same as in EU. This means that there is not as much time for teaching/studying as in other universities. This may reflect negatively to students' outcome competencies. In some cases Georgian credits seem to be higher for the same amount of teaching hours.

10.4 Course Comparison

For course comparison, each partner university selected 1–3 courses, which were compared with similar courses from the EU. In the SEFI classification, the selected courses are the key courses in engineering education. They are taught mostly on BSc and partly on MSc level. In general, the BSc level engineering mathematics courses should cover contents described by SEFI in Core 0 and Core 1. Core 0 contains essentially high-school mathematics, but it is not necessarily on a strong footing or studied at all in schools in all the countries at a level of mastery. The topical areas of Core 1 may vary, depending on the engineering field. Engineering mathematics curriculum may contain elective mathematics courses described in SEFI Core 2 or Core 3. Depending on engineering curricula, these courses can be studied at the BSc or MSc level.

Courses on the following topical areas were selected for comparison between the EU and Russia:

- Engineering Mathematics, Mathematical Analysis
- Discrete Mathematics, Algorithm Mathematics
- Algebra and Geometry
- Probability Theory and Statistics
- Optimization
- Mathematical Modeling

Courses on the following topical areas from the Georgian and Armenian universities were compared with EU universities:

- Engineering Mathematics, Mathematical Analysis
- Calculus
- Discrete Mathematics, Algorithm Mathematics
- Linear Algebra and Geometry
- Probability Theory and Statistics
- Mathematical Modeling

As mathematics is a universal language, the contents of the courses were always in the SEFI core content areas. The course comparison shows that the contents of the courses are comparable. Sometimes a direct comparison between courses was not possible because the topics were divided in the other university between two courses and thus single courses were not directly comparable.

In most of the courses the didactics was traditional and course delivery was carried out in the same spirit. The teacher gives weekly lectures and assignments related with the lectures to the students. The students try to solve the assignments before or in the tutorials or exercise classes.

Students' skills are assessed in exams. The typical assessment procedure may contain midterms exams and a final exam or just a final exam. In the exams students solve examination problems with pen and paper. The teacher reviews the exam papers and gives students their grades. Sometimes student's success in solving assignments or their activity during class hours was taken into account. In some Georgian universities there were tendencies to use multiple choice questions in the exam.

The use of technology to support learning was mainly at a developing stage, and the way it was used depended very much on the teacher. In some universities learning platforms or learning management systems like LMS Blackboard or Moodle was used. Mathematical tool programs (MATLAB, R, Scilab, Geogebra) were known and their use rested much on the teacher's activity.

10.5 Results and Recommendations

10.5.1 Course Development

The contents of the engineering mathematics courses is very much the same in the EU and Russian and Caucasian universities. However, in the EU engineering mathematics is more applied. In other words Russian and Caucasian students spend more time learning theorems and proofs, whereas European students study mathematics more as an engineering tool. We recommend changing slightly the syllabus and instruction from "theorem-to proof" style by putting more emphasis on applications. Topics, applications, examples, related to engineering disciplines, should be added to improve engineering student's motivation to study mathematics.

Traditionally mathematics has been assessed by pen and paper types examinations. Students' assessment could be enhanced so that it covers new ways of learning (project works, essays, peer assessment, epistemic evaluation etc.). Multiply choice questions may be used to give feedback during the courses, but replacing final exams by multiple choice questions cannot be recommended.

10.5.2 Use of Technology

Mathematical tool programs (Sage, Mathematica, Matlab, Scilab, R, Geogebra etc.) are common in EU in teaching and demonstrating how mathematics is put into practice. These programs are known in Russia, Georgia and Armenia, but their use could be enhanced to solve modeling problems from small to large scale. The use of e-Learning (e.g. Moodle for delivery and communication, Math-Bridge as an intelligent platform for e-learning), could be increased in the future to support students' independent work and continuous formative assessment.

10.5.3 Bridging Courses

In the EU, the practices for bridging/remedial courses have been actively developing in the last several decades. With the shift to Unified State Exam and the abolishment of preparatory courses for school abiturients, Russian universities lack the mechanisms to prepare upcoming students to the requirements of university-level math courses. There is also a lack of established practices for bridging courses in the Georgian and Armenian universities to prepare upcoming students to the requirements of university-level math courses. With the shift to Standardized SAT Tests, this becomes problematic, as many students enroll in engineering studies without even a real math test, hence with incorrect expectations and low competencies. Moreover, the needs differ from one student to the next and bridging courses have to be individualized and adapted to specific purposes.

10.5.4 Pretest

Many universities have level tests on Core 0 level for enrolling students to gain an understanding of the mathematical skills new students have and do not have. This makes it possible to detect the weakest students and their needs, providing them further specific support from the beginning of their studies. Math-Bridge system might be a valuable tool here.

10.5.5 Quality Assurance

Quality assurance is an important part of studies and development of education in the EU. Student feedback from courses should be collected and analyzed, as well as acceptance rates, distribution of course grades, and the use of resources in Russian and Caucasian universities.

A necessary, but not sufficient, principle to guarantee the quality of mathematics education is that mathematics is taught by professional mathematicians. This is one of the cornerstones which, in addition to mathematics being an international science, make degrees and courses in mathematics comparable all over the world.

Reference

1. SEFI (2013), A Framework for Mathematics Curricula in Engineering Education. (Eds.) Alpers, B., (Assoc. Eds) Demlova M., Fant C-H., Gustafsson T., Lawson D., Mustoe L., Olsson-Lehtonen B., Robinson C., Velichova D. (http://www.sefi.be).