Chapter 8
Case Studies of Math Education for STEM in Georgia

8.1 Analysis of Mathematical Courses in ATSU

Tea Kordzadze
Akaki Tsereteli State University (ATSU), Department of Mathematics, Kutaisi, Georgia

Tamar Moseshvili
Akaki Tsereteli State University (ATSU), Department of Design and Technology, Kutaisi, Georgia

8.1.1 Kutaisi Akaki Tsereteli State University (ATSU)

The history of Akaki Tsereteli State University (ATSU) started eight decades ago and now it is distinguished with its traditions throughout Georgia and holds an honorable place in the business of cultural, intellectual and moral education of the Georgian nation. According to the Georgian government's resolution #39, February 23, 2006 the legal entities of public law Kutaisi Akaki Tsereteli State University and Kutaisi N. Muskhelishvili State Technical University were combined, the educational status being determined to be the university and the new entity was named Akaki Tsereteli State University. ATSU was merged with Sukhumi Subtropical Teaching University in 2010.

ATSU became one of the largest universities, with a wide spectrum of academic (on BA, MA, and PhD levels), professional teaching programs and research

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fields. Today in ATSU there are about 11,000 students, 9 faculties and 11 STEM disciplines.

8.1.2 Comparative Analysis of "Calculus 1"

Calculus 1 is a mandatory course for students of STEM specializations. This course was developed for engineering students. It is theoretical course with practical examples connected to real life problems. It was compared with "Engineering Mathematics 1" (EM1), which is similar to a course at Tampere University of Technology. The outlines of the courses are presented in Table 8.1. The Department of Mathematics is responsible for the course at Akaki Tsereteli State University. There are 4 full-time professors, 18 full-time associate professors, and 5 teachers.

There are no prerequisite courses. The course size is 5 credits, and it requires on average 125 h of work (25 h per credit). The credits are divided among different activities as follows: lectures 30 h, tutorials 30 h, homework 58 h, consultation 3 h, and exam 4 h. On the course organizer side, there are 60 contact teaching hours. From one to two teaching assistants work on the course to grade exams and teach tutorials. Unfortunately, there are no computer labs available for use on the course.

There are approximately 200 students on the course. The average number of students that finish the course is 170 (85%). The amount of international students is less than 1%.

The pedagogical comparison of the course shows that the teaching is very much theory based. Professors of the mathematics department are delivering the course, and they do not use modern teaching methods such as blended learning, flipped classroom, project or inquiry based learning etc.

Table 8.1 Outlines of Calculus 1 and EM1 course at ATSU and TUT

Course information	ATSU	TUT
Bachelor/Master level	Bachelor	Bachelor
Preferred year	1	1
Elective/mandatory	Mandatory	Mandatory
Number of credits	5	5
Teaching hours	60	56
Preparatory hours	58	75
Teaching assistants	1–2	1–3
Computer labs	Available	Available
Average number of students on the course	200	200
Average pass%	85%	90%
% of international students	Less than 1%	Less than 5%

The course's maximum evaluation equals 100 points. A student's final grade is obtained as a result of summing the midterm evaluation earned per semester and final exam evaluation results.

Assessment Criteria Students are evaluated in a 100-point system in which 45 points are given from midterm assessments, 15 points from Activities and 40 points from the final exam. Midterm assessments include the following components: Work in group (40 points) and two midterm examinations (20 points). Within the frames of 40-point assessment for working in a group students can be given an abstract/review work with 10 points. Students are obliged to accumulate no less than 11 points in midterm assessments and no less than 15 points at the exams. The course will be considered covered if students receive one of the following positive grades: (A) Excellent: 91 points and more; (B) Very good: 81–90 points; (C) Good: 71–80 points; (D) Satisfactory: 61–70 points; (E) Sufficient: 51–60 points. (FX) No pass—in the case of getting 41–50 points students are given the right to take the exam once again. (F) Fail—with 40 points or less, students have to do the same course again.

8.1.2.1 Contents of the Course

The comparison is based on SEFI framework [1]. Prerequisite competencies are presented in Table 8.2. Outcome competencies are given in Table 8.3.

Table 8.2 Core 0-level prerequisite competencies for Calculus 1 (ATSU) and EM1 (TUT) courses

Core 0		
Competency	ATSU	TUT
Arithmetic of real numbers	X	X
Algebraic expressions and formulas	X	X
Linear laws	X	X
Quadratics, cubics, polynomials	X	X
Functions and their properties	X	X

Table 8.3 Core 1-level outcome competencies for Calculus 1 (ATSU) and EM1 (TUT) courses

Core 1		
Competency	ATSU	TUT
Sets, operations on sets	X	X
Functions and their properties	X	X
Logarithmic and trigonometric functions	X	X
Limits and continuity of a function	X	X
Derivative	X	X
Definite integral and integration methods	X	
Minima and maxima	X	X
Indefinite integrals	X	
Definite integrals	X	

8.1.2.2 Summary of the Results

The main differences between Finnish (TUT) and Georgian (ATSU) courses that in TUT teaching is more intense. ATSU has 30 lectures and 30 tutorials—but TUT does all of this in 7 weeks, whereas ATSU uses 15 weeks. On the other hand Calculus 1 covers more mathematical areas than TUT's EM1. TUT also uses plenty of TEL and ICT technologies to support the teaching, ICT is not used in the study process in ATSU. Finnish students also answer in a pen and paper examination as ATSU student, but ATSU students must pass three exams; two midterm exams and one final exam, with no pure theoretical questions. Due to this comparison ATSU changed syllabus in Calculus 1. To achieve SEFI competencies ATSU modernized the syllabus by integration of Math-Bridge and GeoGebra tools in the study process. Modernization of Syllabus was done on September 2016. In 2016 ATSU has done pre- and post-testing in Calculus 1. During post-testing Math-Bridge tools were used for testing and analyzing results.

8.1.3 Comparative Analysis of "Modeling and Optimization of Technological Processes"

The course "Modeling and Optimization of Technological Processes" is offered for Master students of technological engineering faculty in the following engineering programs: Technology of Textile Industry, Food Technology, Technology of Medicinal Drugs, Engineering of Environmental Pollution and Ecology of Wildlife Management. ECTS credits for the course are 5 (125 h). The teaching language is Georgian, the average number of students is 30. It was compared with a corresponding course "Mathematical Modelling" from TUT. The course outlines are seen in Table 8.4.

Specific engineering departments are responsible for the course. A professor in each department teaches this course.

Table 8.4 Outlines of modeling courses at ATSU and TUT

Course information	ATSU	TUT
Bachelor/Master level	Master	Both
Preferred year	1	1
Elective/mandatory	Mandatory	Elective
Number of credits	5	5
Teaching hours	48	30
Preparatory hours	77	108
Teaching assistants	1	1
Computer labs	Yes	Yes
Average number of students on the course	30	60
Average pass%	75%	95%
% of international students	0%	Less than 5%

Prerequisite courses are the Bachelor courses of Higher Mathematics. The course size is 5 credits, and it requires on average 125 h of work (25 h for each credit). The credits are divided among different activities as follows: lectures 15 h, tutorials 30 h, independent work 77 h, exam 3 h.

On the course organizer side, there are 48 contact teaching hours. There is one teaching assistant to work on the course to grade exams and teach tutorials. There is one computer lab available for use on the course. There are approximately 30 students on the course. The average number of students that finish the course is 20 (75%). There are no international students in the technological engineering faculty. The pedagogical comparison of the course shows that the teaching process is not modern. Professors delivering the course do not use modern teaching methods such as blended learning, flipped classroom, project or inquiry based learning etc.

Grading is done on a 100 point scale with 51 points being the passing level. A score between 41 and 50 allows the student a new attempt at the exam, and every 10 point interval offers a better grade with 91–100 being the best.

Pen and paper exams are conducted three times in a semester.

- First midterm exam comprises 1–5 weeks materials and is conducted after the 5th week in compliance with Grading Center schedule.
- Second midterm exam comprises 7–11 weeks materials and is conducted after the 11th week in compliance with Grading Center schedule.
- Final exam is conducted after the 17–18th week.

For the final evaluation the scores of the midterm tests and independent work are summed up.

8.1.3.1 Contents of the Course

The comparison is based on SEFI framework [1]. Outcome competencies are given in Table 8.5.

8.1.3.2 Summary of the Results

The main differences between Finnish (TUT) and Georgian (GTU) courses are the following: The amount of contact hours in ATSU are 48 h. This consists of lectures,

Table 8.5 Core 2-level outcome competencies of the modeling courses at ATSU and TUT

Core 2		
Competency	ATSU	TUT
Simple linear regression	X	X
Multiple linear regression and design of experiments	X	X
Linear optimization	X	X
The simplex method	X	
Nonlinear optimization	X	

15 h (1 h per week), and practical work, 30 h, and midterm and final exam, 3 h. The amount of independent work is 77 h (62%).

In TUT the course is given as a web based course. Two hours of video lectures are implemented per week. 108 h are for laboratory work/tutorials. All of it is group work for weekly exercises and the final project. 100% of the student's time is for homework, which is mandatory for the students.

There are big differences of teaching methods between our courses. In ATSU the lectures are implemented by using verbal or oral methods: giving the lecture materials to the students orally according to the methods of questioning and answering, interactive work, explaining theoretical theses on the bases of practical situation simulation.

In TUT the course is given as a web based course. Different universities around Finland participate in the project. Each week a different university is responsible for that week's topic. The main coordination is done by TUT. Students form groups in each university and work on the given tasks as teams.

Modern lecture technology is used in TUT: e-Learning, with a hint of blended learning, Moodle, MATLAB or similar software, online lecture videos. Moodle is used for file sharing, course information, peer assessment of tasks and MATLAB for solving the exercises.

Video lectures online, weekly exercises are done in groups, posted online and then reviewed and commented on by other groups. Students are awarded points for good answers and good comments. At the end of the course a final project is given to the students to undertake. The final project work is assessed by the other students and by the course staff, and it is presented in a video conference.

ATSU will prepare new syllabi for modernized courses that are more in line with European university courses. This will be done in order to better prepare the Master students of ATSU for their future careers. The Georgian educational system teaches less mathematics on the high school level, and thus ATSU has to design courses that upgrade students' knowledge in these topics as well.

As the general level of the students is quite low, ATSU considers that the increase of the credits in mathematics on the Bachelor level is necessary. Also, the use of different software packages to support learning (Math-Bridge, GeoGebra, etc.) will increase the quality of knowledge of our students.

8.2 Analysis of Mathematical Courses in BSU

Vladimer Baladze, Dali Makharadze, Anzor Beridze, Lela Turmanidze, and Ruslan Tsinaridze
Batumi Shota Rustaveli State University (BSU), Department of Mathematics, Batumi, Georgia
e-mail: dali_makharadze@mail.ru

8.2.1 Batumi Shota Rustaveli State University (BSU)

Batumi Shota Rustaveli State University is deservedly considered to be one of the most leading centers of education, science and culture in Georgia. Educational and scientific activities of BSU go back to 1935. From the date of its establishment it has been functioning as the pedagogical institute providing Western Georgia with pedagogically educated staff for 55 years.

In 1990 the classical university with the fundamental, humanitarian and social fields was established on the basis of the pedagogical institute. In 2006, based on the decision of the Georgian government, scientific-research institutes and higher education institutions of various profiles located in the territory of Autonomous Republic of Ajara, joined Shota Rustaveli State University.

Currently 6000 students study at vocational, BA, MA and PhD educational programs. The process of education and research is being implemented by 244 professors, 55 scientists and researchers and 387 invited specialists.

BSU offers the students a wide-range choice in the following programs at all three levels: 43 BA, 44 MA, 28 PhD and 2 one-level programs. Based on the labor market demand some faculties implement vocational programs as well.

Shota Rustaveli State University is located in Batumi and its outskirts area, having six campuses. The university comprises seven faculties and three scientific-research institutes:

- Faculties:
  - Faculty of Humanities;
  - Faculty of Education;
  - Faculty of Social and Political Sciences;
  - Faculty of Business and Economics;
  - Faculty of Law;
  - Faculty of Natural Sciences and Health Care;
  - Faculty of Physics-Mathematics and Computer Sciences;
  - Faculty of Technology;
  - Faculty of Tourism.
- Scientific-research institutes:
  - Niko Berdzenishvili Institute (Direction of Humanities and Social Studies);
  - Institute of Agrarian and Membrane Technologies;
  - Phytopathology and Biodiversity Institute.

8.2.2 *Comparative Analysis of "Linear Algebra and Analytic Geometry (Engineering Mathematics I)"*

"Linear Algebra and Analytic Geometry" (or "Engineering Mathematics I)" (EMI) is a theoretical course with approximately 50 students. The course is a first year course for engineering students at the Faculty of Technology and is a mandatory course of engineering programs in BSU. The course is compared with the "Engineering Mathematics 1" (EM1) course at Tampere University of Technology. The course outlines are presented in Table 8.6.

The Department of Mathematics is responsible for the course. The staff of this department consists of three full-time professors, six full-time associate professors, four full-time assistant professors and four teachers. The Department of Mathematics conducts the academic process within the frames of the educational programs of the faculty Technologies, of the faculty Physics, Mathematics and Computer Sciences as well as other faculties.

The course does not have prerequisite courses. The course size is 5 credits, and it requires on average 125 h of student's work (25 h for each credit). The credits are divided among different activities as follows: lectures 15 h, tutorials 30 h, homework 80 h. Students should use about 30 h to prepare for their exam.

On the course organizer side, there are 60 contact teaching hours. From one to three teaching assistants work on the course to grade exams and teach tutorials. Unfortunately, there are no computer labs available for use on the course.

There are 50 students on the course. The average number of students that finish the course is 41 (82%). The amount of international students is 0%.

The pedagogical comparison of the course shows that the teaching is very much theory based. Professors of mathematics department are delivering the course, and they do not use modern teaching methods such as blended learning, flipped classroom, project or inquiry based learning etc.

Table 8.6 Outlines of EM I (BSU) and EM1 (TUT) courses

Course information	BSU	TUT
Bachelor/Master level	Bachelor	Bachelor
Preferred year	1	1
Elective/mandatory	Mandatory	Mandatory
Number of credits	5	5
Teaching hours	45	57
Preparatory hours	80	76
Teaching assistants	1–3	1–3
Computer labs	No	Yes
Average number of students on the course	50	200
Average pass%	82%	90%
% of international students	No	Less than 5%

Assessment Criteria Students are evaluated in a 100-point system in which 60 points are given from midterm assessments and 40 points from the final exam. Midterm assessments include the following components: Work in group (40 points) and two midterm examinations (20 points). Within the frames of 40-point assessment for working in a group students can be given an abstract/review work with 10 points. Students are obliged to accumulate no less than 11 point in midterm assessments and no less than 21 points at the exams. The course will be considered covered if students receive one of the following positive grades:

- (A) Excellent: 91 points and more.
- (B) Very good: 81–90 points.
- (C) Good: 71–80 points.
- (D) Satisfactory: 61–70 points.
- (E) Sufficient: 51–60 points.

(FX) No pass—in the case of getting 41–50 points students are given the right to take the exam once again.

(F) Fail—with 40 points or less, students have to do the same course again.

"Linear Algebra and Analytical Geometry/Engineering Mathematics I" at BSU does not have any TEL tools available on the course. Therefore, no TEL tools are used to support learning.

8.2.2.1 Contents of the Course

The comparison is based on SEFI framework [1]. Prerequisite competencies are presented in Table 8.7. Outcome competencies are given in Tables 8.8 and 8.9.

Table 8.7 Core 0-level prerequisite competencies for EMI (BSU) and EM1 (TUT) courses

Core 0		
Competency	BSU	TUT
Arithmetic of real numbers	X	X
Algebraic expressions and formulas	X	X
Linear laws	X	X
Quadratics, cubics, polynomials	X	X
Functions and their inverses	X	X
Sequences, series, binomial expansions	Excl. series	X
Logarithmic and exponential functions	X	X
Geometry	X	X
Trigonometry	X	X
Trigonometric identities	X	X

Table 8.8 Core 0-level outcome competencies for EMI (BSU) and EM1 (TUT) courses

Core 0		
Competency	BSU	TUT
Binomial expansions	X	X
Sets	X	X
Co-ordinate geometry	X	X

Table 8.9 Core 1-level outcome competencies for EMI (BSU) and EM1 (TUT) courses

Core 1		
Competency	BSU	TUT
Sets	X	X
Complex number	X	X
Mathematical logic	X	X
Mathematical induction	X	X
Conic sections	X	X
3D co-ordinate geometry	X	
Vector arithmetic	X	X
Vector algebra and applications	X	
Matrices and determinants	X	
Solution of simultaneous linear equations	X	

8.2.2.2 Summary of the Results

The main differences between Finnish (TUT) and Georgian (BSU) courses are the following: in TUT, teaching is more intense and covers less topics than BSU. The overall hours are somewhat different; TUT has 35 h of lectures and 21 h of tutorials; BSU has 15 lectures and 30 tutorials, and TUT does all of this in 7 weeks, whereas BSU uses 15 weeks. TUT also uses plenty of TEL and ICT technologies to support their teaching, BSU does not. Finally, the exams are somewhat different. Finnish students answer in a pen and paper exam, BSU students must pass three exams with theoretical questions, but with no proofs.

The main drawbacks of the old mathematics syllabi at BSU were that mostly the theoretical mathematical aspects were treated and the corresponding examinations contained only purely mathematical questions.

Moreover, it should be specially mentioned that in the BSU the mathematical syllabus "Engineering Mathematics 1" (= "Linear Algebra and Analytical Geometry") in engineering BSc programs does not include the following topics: Elements of Discrete Mathematics, Surfaces of second order. Therefore, modernization of the syllabus of "Linear Algebra and Analytical Geometry" is very desirable.

BSU will prepare new syllabi for modernized courses that are more in line with European technical university courses. This will be done in order to better prepare the students of BSU for their future careers. However, modernizing courses will not be trivial, since the university has to make up for the different levels of skills of European and Georgian enrolling students. The Georgian educational system teaches less mathematics on the high school level, and thus BSU has to design courses that upgrade students' knowledge in these topics as well.

As the overall level of students is relatively low, BSU finds that implementing remedial mathematics courses is necessary. This could be done using the Math-Bridge software.

8.2.3 Comparative Analysis of "Discrete Mathematics"

"Discrete Mathematics" (DM) is a theoretical course with 14 students. The course is a second year mandatory course for BSU students in the program of Computer Sciences at the faculty of Physics-Mathematics and Computer Sciences. It was compared with a corresponding course "Algorithm Mathematics" (AM) from Tampere University of Technology (TUT). Outlines of these courses are seen in Table 8.10.

The department of Mathematics is responsible for the course. The staff of this department consist of three full-time professors, six full-time associate professors, four full-time assistant professors and four teachers. The Department of Mathematics conducts the academic process within the frames of the educational programs of the faculty Physics, Mathematics and Computer Sciences as well as other faculties.

The course does not have prerequisite courses. Its size is 5 credits, and it requires on average 125 h of work (25 h for each credit). The credits are divided among different activities as follows: lectures 15 h, tutorials 30 h, homework 80 h. Students should use about 30 h to prepare for their exam.

On the course organizer side, there are 60 contact teaching hours. From one to three teaching assistants work on the course to grade exams and teach tutorials. Unfortunately, there are no computer labs available for use on the course.

There are 14 students on the course. The average number of students that finish the course is 11 (78%). The amount of international students is 0%.

Table 8.10 Outlines of the Discrete Mathematics (BSU) and Algorithm Mathematics (TUT) courses

Course information	BSU	TUT
Bachelor/Master level	Bachelor	Bachelor
Preferred year	1	2
Elective/mandatory	Mandatory	Elective
Number of credits	5	4
Teaching hours	45	49
Preparatory hours	80	65
Teaching assistants	1–3	1–2
Computer labs	No	Yes
Average number of students on the course	14	150
Average pass%	78%	90%
% of international students	No	Less than 5%

The pedagogical comparison of the course shows that the teaching is very much theory based. Professors of the mathematics department are delivering the course, and they do not use modern teaching methods such as blended learning, flipped classroom, project or inquiry based learning etc.

Assessment criteria are as follows: Students are evaluated in a 100-point system, in which 60 points are given on midterm assessments and 40 points on final exams. Midterm assessments include the following components: Work in group (40 points) and two midterm examinations (20 points). Within the frames of 40-point assessment for working in a group, students can be given an abstract/review work for 10 points. Students are obliged to accumulate no less than 11 points in midterm assessments and no less than 21 points at the exams.

Grading follows the same principles as with the course described above.

8.2.3.1 Contents of the Course

The comparison is based on SEFI framework [1]. Prerequisite competencies are presented in Table 8.11. Outcome competencies are given in Table 8.12.

The main differences between Finnish (TUT) and Georgian (BSU) courses are the following: in TUT, teaching is more intense but it covers less topics. The overall hours are somewhat different—TUT has 35 h of lectures and 21 h of tutorials, BSU has 15 lectures and 30 tutorials and TUT does all of this in 7 weeks, whereas BSU uses 15 weeks. TUT also uses plenty of TEL and ICT technologies to support the teaching, BSU does not. Finally, the exams are somewhat different. Finnish students answer in a written exam, BSU students must pass three exams with theoretical questions, but with no proofs.

Table 8.11 Core 0-level prerequisite competencies for DM (BSU) and AM (TUT) courses

Core 0		
Competency	DM (BSU)	AM (TUT)
Arithmetic of real numbers	X	X
Algebraic expressions and formulas	X	X
Linear laws	X	X
Quadratics, cubics, polynomials	X	X
Functions and their inverses	X	X
Sequences, series, binomial expansions	Excl. series	X
Logarithmic and exponential functions	X	X
Proof	X	X
Sets	X	X
Geometry	X	X
Data handling	X	x
Probability	X	

Table 8.12 Core 1-level outcome competencies for DM (BSU) and AM (TUT) courses

Core 1		
Competency	DM (BSU)	AM (TUT)
Sets	X	X
Mathematical logic	X	X
Mathematical induction and recursion	X	X
Graphs	X	
Combinatorics	X	
Simple probability	X	
Probability models	X	

The main drawbacks of the old mathematics syllabi at BSU were that mostly the theoretical mathematical aspects were treated and the corresponding exam lists contained only purely mathematical questions.

Moreover, it should be specially mentioned that the BSU mathematical syllabus "Discrete Mathematics" for Computer Sciences BS programs does not contain the following topics: Binary relation; Boolean algebra; Groups, Rings and Fields; Euclid's division algorithm and Diophantine equations; Coding theory and finite automata; Cryptography. Therefore, modernization of the syllabus "Discrete Mathematics" is very desirable.

BSU will prepare new syllabi for modernized courses that are more in line with European technical university courses. This will be done in order to better prepare the students of BSU for their future careers. However, modernizing courses will not be trivial, since the university has to make up for the different prerequisite skills between European and Georgian enrolling students. The Georgian educational system teaches less mathematics on the high school level, and thus BSU has to design courses that upgrade students' knowledge in these topics as well.

As the overall level of students is sufficiently low, BSU finds that implementing remedial mathematics courses is necessary. This could be done using the MathBridge software.

8.3 Analysis of Mathematical Courses in GTU

8.3.1 Georgian Technical University (GTU)

David Natroshvili (✉) and Shota Zazashvili
Georgian Technical University (GTU), Department of Mathematics, Tbilisi, Georgia
e-mail: d.natroshvili@gtu.ge; s.zazashvili@gtu.ge

George Giorgobiani
Georgian Technical University (GTU), Department of Computational Mathematics, Tbilisi, Georgia
e-mail: giorgobiani.g@gtu.ge

Georgian Technical University (GTU) is one of the biggest educational and scientific institutions in Georgia. The overall number of students is approximately 20,000, and there are in total 17 STEM disciplines.

In 1917, the Russian Emperor issued an order to found a polytechnic institute in Tbilisi, the first higher educational institute in the Caucasian region. In 1922, GTU was originally founded as a polytechnic faculty of the Tbilisi State University. Later, in 1928, the departments of the polytechnic faculty merged into an independent institute called Georgian Polytechnic Institute (GPI). GTU continued under this title until 1990, when the institute was granted university status and was renamed Georgian Technical University.

GTU adopted the Bologna process in 2005. Today, the university hosts approximately 20,000 students, 10 faculties and 17 STEM disciplines.

8.3.2 Comparative Analysis of "Mathematics 3"

"Mathematics 3" is a theoretical course with approximately 1500 students. The course is a second year course for engineering students at the university and is a final mathematical mandatory course of engineering programs in GTU. This course was compared with a corresponding course "Engineering Mathematics 4" (EM4) at TUT. The course outlines are seen in Table 8.13.

Department of Mathematics at GTU is responsible for the course. The staff of this department consists of 20 full-time professors, 21 full-time associate professors, 3 full-time assistant professors, 7 teachers, 16 invited professors and 5 technical employees.

Prerequisite courses are Mathematics 1 and 2. The course is a part of the Mathematics course cluster. The course size is 5 credits, and it requires on average 135 h of work (27 h for each credit). The credits are divided among different

Table 8.13 Outlines of Mathematics 3 (GTU) and Engineering Mathematics 4 (TUT) courses

Course information	GTU	TUT
Bachelor/Master level	Bachelor	Bachelor
Preferred year	2	1
Elective/mandatory	Mandatory	Mandatory
Number of credits	5	4
Teaching hours	60	49
Preparatory hours	75	56
Teaching assistants	1–4	1–3
Computer labs	No	Yes
Average number of students on the course	1500	150
Average pass%	75%	85%
% of international students	Less than 1%	Less than 5%

activities as follows: lectures 30 h, tutorials 30 h, homework 75 h, exam 3 h. Students should use about 10 h to prepare for their exam.

On the course organizer side, there are 60 contact teaching hours. From one to four teaching assistants work on the course to grade exams and teach tutorials. Unfortunately, there are no computer labs available for use on the course.

There are approximately 1500 students on the course. The average number of students that finish the course is 1125 (75%). The amount of international students is less than 1%. For this analysis, neither the overall student demographic nor the average rating of the course by the students was available.

The pedagogical comparison of the course shows that the teaching is very much theory based. Professors of the mathematics department are delivering the course, and they do not use modern teaching methods such as blended learning, flipped classroom, project or inquiry based learning etc.

Testing is done on a 100 point scale with 51 points being the passing level. A score between 41 and 50 offers a new attempt at the exam, and every 10 point interval offers a better grade with 91–100 points being the best. Exams are in three different forms: weekly intermediate exams, two midterm exams and a final exam. Testing methods are multiple choice answers or open ended answers done on computers. The final grade is computed by combining the different points in the different tests and normalizing to 100.

"Calculus 2 = Mathematics 3" at GTU does not have any TEL tools available on the course. Therefore, no TEL tools are used to support learning.

8.3.2.1 Contents of the Course

The comparison is based on the SEFI framework [1]. Prerequisite competencies are presented in Tables 8.14 and 8.15. Outcome competencies are given in Tables 8.16, 8.17, and 8.18.

8.3.2.2 Summary of the Results

The main differences between Finnish (TUT) and Georgian (GTU) courses are the following: in TUT, teaching is more intense. The overall hours are quite similar—TUT has 28 h of lectures and 24 h of tutorials, GTU has 30 lectures and 30 tutorials—but TUT does all of this in 7 weeks, whereas GTU uses 15 weeks. TUT also uses plenty of TEL and ICT technologies to support their teaching, GTU does not. Finally, the exams are quite different. Finnish students answer in a pen and paper exam, GTU students must pass three exams (two midterm exams and one final exam) on the computer, with no pure theoretical questions (proofs).

The main drawbacks of the old mathematics syllabi at GTU were that mostly the theoretical mathematical aspects were treated and the corresponding exam lists contained only purely mathematical questions. This means that the application of

Table 8.14 Core 0-level prerequisite competencies of Mathematics 3 (GTU) and EM4 (TUT) courses

Core 0		
Competency	GTU	TUT
Arithmetic of real numbers	X	X
Algebraic expressions and formulas	X	X
Linear laws	X	X
Quadratics, cubics, polynomials	X	X
Functions and their inverses	X	X
Sequences, series, binomial expansions	Excl. series, binomial expansion	X
Logarithmic and exponential functions	X	X
Rates of change and differentiation	X	X
Stationary points, maximum and minimum values	X	X
Indefinite integration	X	X
Proof	X	X
Sets	X	X
Geometry	X	X
Trigonometry	X	X
Co-ordinate geometry	X	X
Trigonometric functions and applications	X	X
Trigonometric identities	X	X

Table 8.15 Core 1-level prerequisite competencies of Mathematics 3 (GTU) and EM4 (TUT) courses

Core 1		
Competency	GTU	TUT
Rational functions	X	X
Complex numbers	X	X
Functions	X	X
Differentiation	X	X
Sequences and series	Excl. series, binomial expansion	X
Vector arithmetic	X	X
Vector algebra and applications	X	X
Matrices and determinants	X	X
Solution of simultaneous linear equations	X	X
Functions of several variables	X	

Table 8.16 Core 0-level outcome competencies of Mathematics 3 (GTU) and EM4 (TUT) courses

Core 0		
Competency	GTU	TUT
Sequences, series, binomial expansions	X	
Indefinite integration	X	X
Definite integration, applications to areas and volumes	X	X

Table 8.17 Core 1-level outcome competencies of Mathematics 3 (GTU) and EM4 (TUT) courses

Core 1		
Competency	GTU	TUT
Sequences and series	X	
Methods of integration	X	X
Applications of integration	X	X

Table 8.18 Core 2-level outcome competencies of Mathematics 3 (GTU) and EM4 (TUT) courses

Core 2		
Competency	GTU	TUT (Tampere)
Ordinary differential equations	X	
First order ordinary differential equations	X	
Second order equations—complementary function and particular integral	X	
Fourier series	X	
Double integrals		X
Further multiple integrals		X
Vector calculus		X
Line and surface integrals, integral theorems		X

taught mathematics had almost no emphasis on the course, which led to lack of motivation in the students.

Moreover, it should be specially mentioned that in the GTU mathematical syllabus "Mathematics 3" (*in Finland* "Calculus 2") for engineering BSc programs, the following topics are not included: Double integrals, Triple integrals, Curvilinear and Surface Integrals,Vector Calculus, Divergence Theorem and Stokes' Theorem. These topics are widely presented in the TUT mathematical curricula.

Due to the above, it seems that an essential modernization of the syllabus Calculus 2 (in GTU Mathematics 3) is very desirable.

At the same time it should be taken into consideration that modernization of a particular syllabus Calculus 2 (in GTU Mathematics 3) will require modification of the syllabuses of prerequisite courses Mathematics 1 and Mathematics 2.

GTU will prepare new syllabi for modernized courses that are more in line with European and American technical university courses. This will be done in order to better prepare the students of GTU for their future careers. However, modernizing courses will not be trivial, since the university has to make up for the different prerequisite skills of European and Georgian enrolling students. The Georgian educational system teaches less mathematics on the high school level, and thus GTU has to design courses that upgrade students' knowledge in these topics as well.

As the overall level of students is sufficiently low, GTU finds that implementing remedial mathematics courses is necessary. This could be done using the MathBridge software.

8.3.3 *Comparative Analysis of "Probability Theory and Statistics"*

"Probability Theory and Statistics" (PTS) is a theoretical course with approximately 200 students. The course is a second year course for engineering students of two departments of two faculties: Faculty of Power Engineering and Telecommunications and Faculty of Informatics and Control Systems. It will be compared with a corresponding course "Probability Calculus" (PC) at Tampere University of Technology (TUT). The outlines of the courses are presented in Table 8.19.

The department responsible for the course is the GTU Department of Mathematics. The staff of this department consists of 20 full-time professors, 21 full-time associate professors, 3 full-time assistant professors, 7 teachers, 16 invited professors and 5 technical employees.

The prerequisite course is Mathematics 2. The course is a part of the Mathematics course cluster. The course size is 5 credits, and it requires on average 135 h of work (27 h for each credit). The credits are divided among different activities as follows: lectures 30 h, tutorials 30 h, homework 75 h, exam 3 h. Students should use about 10 h to prepare for their exam.

On the course organizer side, there are 60 contact teaching hours. From one to two teaching assistants work on the course to grade exams and teach tutorials. Unfortunately, there are no computer labs available for use on the course.

There are approximately 200 students on the course. The average number of students that finish the course is 150 (75%). The amount of international students is less than 1%. For this analysis, neither the overall student demographic nor the average rating of the course by students was available.

The pedagogical comparison of the course shows that the teaching is very much theory based. Professors of mathematics department are delivering the course, and they do not use modern teaching methods such as blended learning, flipped classroom, project or inquiry based learning etc.

Table 8.19 Outlines of probability and statistics courses (PTS) at GTU and (PC) at TUT

Course information	GTU	TUT
Bachelor/Master level	Bachelor	Bachelor
Preferred year	2	2
Elective/mandatory	Mandatory	Elective
Number of credits	5	4
Teaching hours	60	42
Preparatory hours	75	66
Teaching assistants	1–2	1–2
Computer labs	No	Yes
Average number of students on the course	200	200
Average pass%	75%	90%
% of international students	Less than 1%	Less than 5%

Testing is done on a 100 point scale with 51 points being the passing level. A score between 41 and 50 offers a new attempt at the exam, and every 10 point interval offers a better grade with 91–100 being the best. Exams are in three different forms: weekly intermediate exams, two midterm exams and final exam. Testing methods are by multiple choice answers or open ended answers done on computers. The final grade is computed by combining the different points in the different tests and normalizing to 100.

GTU does not have any TEL tools. Therefore, no TEL tools are used to support teaching and learning.

8.3.3.1 Contents of the Course

The comparison is based on the SEFI framework [1]. Prerequisite competencies are presented in Tables 8.20 and 8.21. Outcome competencies are given in Tables 8.22, 8.23, and 8.24.

8.3.3.2 Summary of the Results

The main differences between Finnish (TUT) and Georgian (GTU) courses are the following: in TUT, teaching is more intense. The overall hours also are not similar—TUT has 28 h of lectures and 14 h of tutorials for statistics (7 weeks) and 28 h of

Table 8.20 Core 0-level prerequisite competencies of the probability and statistics courses (PTS) at GTU and (PC) at TUT

Core 0		
Competency	GTU	TUT
Arithmetic of real numbers	X	X
Algebraic expressions and formulas	X	X
Linear laws	X	X
Quadratics, cubics, polynomials	X	X
Functions and their inverses	X	X
Sequences, series, binomial expansions	Excl. series, binomial expansion	X
Logarithmic and exponential functions	X	X
Rates of change and differentiation	X	X
Stationary points, maximum and minimum values	X	X
Indefinite integration	X	X
Proof	X	X
Sets	X	X
Geometry	X	X
Trigonometry	X	X
Co-ordinate geometry	X	X
Trigonometric functions and applications	X	X
Trigonometric identities	X	X

Table 8.21 Core 1-level prerequisite competencies of the probability and statistics courses (PTS) at GTU and (PC) at TUT

Core 1		
Competency	GTU	TUT
Rational functions	X	X
Complex numbers	X	X
Functions	X	X
Differentiation	X	X
Sequences and series	Excl. series	X
Vector arithmetic	X	X
Vector algebra and applications	X	X
Matrices and determinants	X	X
Solution of simultaneous linear equations	X	X
Functions of several variables	X	X

Table 8.22 Core 0-level outcome competencies of the probability and statistics courses (PTS) at GTU and (PC) at TUT

Core 0		
Competency	GTU	TUT
Data handling	X	X
Probability	X	X

Table 8.23 Core 1-level outcome competencies of the probability and statistics courses (PTS) at GTU and (PC) at TUT

Core 1		
Competency	GTU	TUT
Data handling	X	X
Combinatorics	X	X
Simple probability	X	X
Probability models	X	X
Normal distribution	X	X
Sampling	X	
Statistical inference	Excl. issues related to hypothesis testing	

Table 8.24 Core 2-level outcome competencies of the probability and statistics courses (PTS) at GTU and (PC) at TUT

Core 2		
Competency	GTU	TUT
One-dimensional random variables	Excl. Weibull and gamma distributions	X

lectures and 12 h of tutorials for probability (7 weeks), GTU has 30 lectures and 30 tutorials (15 weeks). TUT also uses plenty of TEL and ICT technologies to support their teaching, GTU does not. Finally, the exams are quite different. Finnish students answer in a written exam, GTU students must pass three exams (two midterm exams and one final exam) on the computer, with no pure theoretical questions (proofs).

The main drawbacks of the old mathematics syllabi at GTU were that mostly the theoretical mathematical aspects were treated and the corresponding exam lists contained mostly purely mathematical questions. This means that the application of taught mathematics had almost no emphasis on the course, which led to lack of motivation in the students.

Moreover, it should be specially mentioned that in the GTU syllabus "Probability Theory and Statistics" for engineering BSc programs 12 lectures are devoted to the topics of probability theory, and only the last three lectures to statistics. The following topics are not included: Test of hypothesis; Small sample statistics issues like t-test, F-test, chi-square tests; topics of Analysis of variance; Linear regression etc. Due to the above, it seems that an essential modernization of the syllabus "Probability Theory and Statistics" is very desirable.

8.4 Analysis of Mathematical Courses in UG

Kakhaber Tavzarashvili and Ketevan Kutkhashvilii
University of Georgia (UG), School of IT, Engineering and Mathematics, Tbilisi, Georgia
e-mail: k.tavzarashvili@ug.edu.ge; k.kutkhashvili@ug.edu.ge

The University of Georgia (UG) was founded in 2004. UG is one of the largest private universities in Georgia. Throughout past years, improvement of the quality of education in Georgia has been one of the top priorities and, in this framework, the aim of UG has always been to develop and accomplish high standards as regards academic quality, and as regards student life for the benefit of both Georgian and international students. The University of Georgia is a place that generates and disseminates knowledge. It has created a diverse environment, which forms open-minded and educated persons with human values and the skills necessary to consciously and easily cope with the challenges of the modern world. The academic faculty of the university is represented by a team of creative and enthusiast individuals, willing to educate professionals equipped with the knowledge and skills required in the modern world and ready to make a significant contribution to the welfare of humanity. Today, the University of Georgia is one of the nation's leading universities, with the personal growth and professional development of its students as its main goal. Graduates of the university feel confidence and are ready to enter a competitive job market. Today, the university has the honor to offer its students modern facilities and the learning environment in which they can gain high quality education as well as practical experience. The knowledge and skills acquired at our

university are a guarantee of a successful career not only in Georgia, but also in the international labor market. UG is a classical university and it offers a wide range of specializations. From 2014 to 2016 overall numbers of UG students increased up to 50% from 4000 to 6000 students. These students are distributed in six main schools. They are:

- School of Humanities;
- School of Law;
- School of Social Sciences;
- School of IT, Engineering and Mathematics;
- School of Health Sciences and Public Health;
- School of Business, Economics and Management.

The School of IT, Engineering and Mathematics has a STEM profile. There are about 350 students enrolled totally in all academic level. The number of freshmen students for 2016 was 80 students. There are seven different academic programs, four of them on the BSc level, two on the Master level, and the seventh is a PhD level program. For the BSc programs, Informatics has 238 students, Electrical and Computer Engineering has 33, Engineering (for international students) has 10, Mathematics has 7, Computer Science has 181, On the master program, Applied Sciences has 5, and the Exact, Natural and Computer Science program, which is PhD level, has 7 students.

8.4.1 Comparative Analysis of "Precalculus"

Precalculus is an elective course for freshmen students of STEM specializations meant to increase their knowledge and Math skills. This course contains functions, graphs, linear and quadratic functions, inverse, exponential, logarithmic and trigonometric functions; polynomial and rational functions; solving of linear and nonlinear systems of equations and inequalities; sequences and their properties; combinatorial analysis and fundamentals of probability theory, binomial theorem.

Precalculus is a theoretical course but it is based on practical examples. This course was developed for engineering students and all practical examples are connected to real life problems. Earlier it was 26 h in semester and after course modernization practical work hours was added and now it is totally 39 h per semester. There have been 25 students in Precalculus in 2014. Precalculus was compared with "Remedial Instruction" course at Tampere University of Technology (TUT). The course is mandatory for TUT students who do not grasp mathematics well in the beginning of their studies. All the students enrolling at TUT will take a basic skills' test and the weakest 20% of them are directed to "Remedial Instruction". This remedial course is completely done with computers with a tailored introductory course in the Math-Bridge system at TUT. The courses' outlines are seen in Table 8.25.

Table 8.25 Outlines of Precalculus (UG) and Remedial Instruction (TUT) courses

Course information	UG	TUT
Bachelor/Master level	Bachelor	Bachelor
Preferred year	1	1
Elective/mandatory	Elective	Mandatory
Number of credits	6	0
Teaching hours	39	0
Preparatory hours	111	0
Teaching assistants	6	0
Computer labs	No	Yes
Average number of students on the course	200	140
Average pass%	75%	90%
% of international students	Less than 1%	Less than 5%

The Precalculus course was offered for freshmen students from STEM specializations (Informatics, Electrical and Computer Engineering). Also it was offered to students from Business and Economics specializations.

The Precalculus was prepared by the Department of Mathematics, which is responsible for all mathematics courses in UG. The staff of the Department of Mathematics consists of two full professors, three associated professors, six assistants and invited lecturers (depending of groups). Professors and associated professors are responsible for lectures, while assistants and invited lecturers are responsible for tutorials.

Before course modernization "Precalculus" was mainly a theoretical course. After modernization tutorials should be added and the course should become more applied.

Assessment contains midterm exams (60%) and final examination (40%). Midterm exams contain quizzes (24%) and midexams (36%). Totally, there are eight quizzes (each for 3 points), three midexams (each for 12 points) and final exam (40 points). The minimum number of points required for the final exam is 20. The course is passed when student has more than 50 points and in the final exam more than 20 points.

Each quiz (3 points) contains three tasks from the previous lecture. Each midterm exam (12 points) consists eight tasks including two theoretical questions. The final exam (40 points) consists of 20 tasks including six theoretical questions.

During the lectures professors use various tools for visualization, and presentation tools, in order to present some applications and some dynamic processes, in particular GeoGebra is an illustration tool. There are no mandatory parts of using TEL systems in the exams. We used the Math-Brige system for Pre- and Post-testing.

GeoGebra was used for illustration purposes. It was used to show properties of functions, intersection of functions by axis, finding of intersection points of two functions and so on. The role of TEL systems in the course has been in demonstrating basic mathematics and in visualizing different math topics.

8.4.1.1 Contents of the Course

The comparison is based on the SEFI framework [1]. Prerequisite competencies are presented in Table 8.26. Outcome competencies are given in Table 8.27.

8.4.1.2 Summary of the Results

The University of Georgia has changed the math syllabus in Precalculus. In order to achieve SEFI competencies [1] UG have introduced modern educational technologies in teaching methods. The aim of the modernization was an integration of Math-Bridge and GeoGebra in the study process. UG has done the following modification in curricula and in syllabuses.

Modernization of the syllabus was done since September of 2016 just only in Precalculus. Comparison of syllabuses in other subjects (Precalculus) have shown full compatibility with the subjects of TUT courses. UG have separated Precalculus in two independent courses for STEM and for Business and Economic specializations. In Precalculus for STEM specializations we added some subjects according to the TUT courses content. Also we added 12 h of practical work by using GeoGebra and MATLAB programs.

In 2016 UG has done pre- and post-testing in Precalculus and Calculus 1. Math-Bridge was used for testing. Theoretical and practical examples were prepared in Math-Bridge. Math-Bridge was used as a tool for analyzing the results.

Table 8.26 Core 0-level prerequisite competencies of the Precalculus (UG) and Remedial Instruction (TUT) courses

Core 0		
Competency	UG	TUT
Arithmetic of real numbers	X	X
Algebraic expressions and formulas	X	X
Linear laws	X	X
Quadratics, cubics, polynomials	X	X
Functions and their inverses	X	X

Table 8.27 Core 0-level outcome competencies of the Precalculus (UG) and Remedial Instruction (TUT) courses

Core 0		
Competency	UG	TUT
Graphs	X	
Linear and quadratic functions	X	X
Polynomial and rational functions	X	X
Power functions	X	X
Trigonometric functions	X	X
Sequences, arithmetic and geometric sequences	X	X
Combinatorics and probabilities	X	

8.4.2 Comparative Analysis of "Calculus 1"

Calculus 1 is a mandatory course for students of STEM specializations (Informatics BSc, Electronic and Computer Engineering BSc, Engineering BSc). This course contains the basic properties of inverse, exponential, logarithmic and trigonometric functions; limit, continuity and derivative of a function, evaluating rules of a derivative, function research and curve-sketching techniques, applications of derivative in the optimization problems, L'Hôpital's rule, Newton's method, indefinite and definite integral and their properties, rules of integration, integration of rational functions, evaluating area between curves and surface area using integrals, integrals application in physics, numerical integration.

Calculus 1 is a theoretical course, but it is based on practical examples. This course was developed for engineering students and all practical examples are connected to real life problems. Before the course modernization it was 26 h in a semester and after the course modernization practical work hours were added; now it is totally 39 h per semester. There are 25–50 students on the course each year. It was compared with the corresponding "Engineering Mathematics 1" (EM1) course from Tampere University of Technology (TUT). The course outlines are seen in Table 8.28.

This course was offered to STEM students (Informatics, Electrical and Computer Engineering). Also it was offered to students from Business and Economics specializations with modified content, with more focus on real Business applications.

The "Calculus 1" was prepared by Department of Mathematics, which is responsible for all mathematics courses in UG. The staff of the Department of Mathematics consists of two full professors, three associated professors, six assistants and invited lecturers (depending of groups).

Pedagogy and assessment are done similarly to "Precalculus". During the lectures the professor uses various tools for visualization, presentation tools in order to present some applications and some dynamic processes, in particular GeoGebra

Table 8.28 Outlines of "Calculus 1" (UG) and "Engineering Mathematics 1" (TUT) courses

Course information	UG	TUT
Bachelor/Master level	Bachelor	Bachelor
Preferred year	1	1
Elective/mandatory	Mandatory	Mandatory
Number of credits	6	5
Teaching hours	39	57
Preparatory hours	111	80
Teaching assistants	6	1–3
Computer labs	No	Yes
Average number of students on the course	25	200
Average pass%	80%	90%
% of international students	Less than 1%	Less than 5%

as an illustration tool. There are no mandatory parts of using TEL systems in exams. We have used the Math-Bridge system for Pre- and Post-testing. GeoGebra was used for illustration purposes. It was used to demonstrate the properties of functions, derivatives of a function, applications of derivatives, integrals and applications of integrals.

8.4.2.1 Contents of the Course

The comparison is based on the SEFI framework [1]. Prerequisite competencies are presented in Table 8.29. Outcome competencies are given in Table 8.30.

8.4.2.2 Summary of the Results

UG has changed the Math syllabus in "Calculus 1". In order to achieve SEFI competencies [1] UG has introduced modern educational technologies in teaching methods. The aim of the modernization was an integration of Math-Bridge and GeoGebra in the study process. UG has done the following modifications in curricula and in syllabi.

Modernization of the syllabus was done since September of 2016 just only in "Calculus 1". Comparison of syllabuses in other subjects (Calculus 1 and Calculus 2) have shown full compatibility with the subjects of TUT courses. Tutorials were added with 12 h of practical work by using GeoGebra and MATLAB programs.

Table 8.29 Core 0-level prerequisite competencies of the "Calculus 1" (UG) and "Engineering Mathematics 1" (TUT) courses

Core 0		
Competency	UG	TUT
Arithmetic of real numbers	X	X
Algebraic expressions and formulas	X	X
Linear laws	X	X
Quadratics, cubics, polynomials	X	X
Functions and their properties	X	X

Table 8.30 Core 0-level outcome competencies of the "Calculus 1" (UG) and "Engineering Mathematics 1" (TUT) courses

Core 0		
Competency	UG	TUT
Functions and their basic properties	X	X
Logarithmic and trigonometric functions	X	X
Limits and continuity of a function	X	X
Derivative	X	X
Definite integral and integration methods	X	
Minimum and maxima	X	X
Indefinite integrals	X	

In 2016 UG has done pre- and post-testing in “Precalculus” and “Calculus 1”. Math-Bridge was used for testing. Theoretical and practical examples were prepared in Math-Bridge. It was used for analyzing results as well.

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).