Role of MOOCs in teaching Mathematics to students majoring in Engineering

O A Vagaeva¹, N M Galimullina², E V Liksina¹, I N Efremkina¹ and D E Lomakin³,₄

¹ Chair of Pedagogics and Psychology, Penza State Technological University, 1a / 11 pr.Baydukova / Gagarina Str., Penza, 440039, Russian Federation
² Department for Sociology, Political Sciences and Management, Kazan National Research Technical University named after A.N. Tupolev – KAI, 10 Karl Marx Str., Kazan, Republic of Tatarstan, 420111, Russian Federation
³ Department of Algebra and Mathematical Methods in Economy, Orel State University named after I.S. Turgenev, 95 Komsomolskaya Str., Orel, 302028, Russian Federation
⁴ Orel branch of Emperor Alexander I St. Petersburg State Transport University, 2 Studencheskaya str., Orel, 302004, Russian Federation

⁵ E-mail: ngalimullina@gmail.com

Abstract. The research is dedicated to the features of providing mathematical training to would-be engineers through using the potential of mass open online courses. The article reveals the importance of mathematical training as the basis for forming the professional competence of engineers. A sociological poll among the participants of the educational process at Russian technical universities revealed high awareness of the professors about MOOCs (93.3%), while only 45.4% of students knew about such platforms. The undisputed leader by popularity among both professors (53.3%) and students (34.5%) is the project “National platform of open education”. The reasons impeding the use of mass open online courses are: the lack of spare time, the lack of skills of working in such format, and the lack of regulation for introducing the results of studying at MOOC into the formal educational process. At the same time, analysis of Coursera, EdX, Open Education, Intuit, Lektorium and Stepik platforms showed that, as of January 2021, 150 courses were available in the broad and specific mathematical domains. Intensification of using MOOCs in preparing for academic sessions may increase the efficiency of mastering knowledge and skills in solving practical mathematical tasks, which would improve training of the would-be engineers.

1. Introduction

The issues of teaching engineers are topical and attract special attention of researchers. For example, Azhar Syed et al. analyze 30 works (beginning from 2000), dedicated to the use of mass open online courses (MOOCs) in training engineers [1].

Today, technical and mathematical competence is considered to be the domain specification of 21st-century skills, which is of utter importance for would-be engineers [2]. One should agree with the Russian authors in that the digital economy poses new requirements to human resources. At the same time, the educational system faces the digital generation of students with special social-psychological
characteristics. This leads to the need to modify the process of mathematical training under digitalization of economy and education [3]. It is no coincidence that a research [4] on using MOOCs under COVID-19 emphasized the need to pay more attention to training learners in navigation and analysis of information.

Mass open online courses have an undoubted advantage in terms of education democratization, providing learners with an access to high-quality free-of-charge courses. This trend was confirmed by international comparisons of gender differences in matriculation and graduation in STEM-MOOC [5]. As of August 2019, course in the Physics and Mathematics domain were broadly represented on open education platforms; for example, on Open Education platform there were 52 such courses, i.e. 13.2% of the total number of courses, on Lektorium platform there were 16 (21.1%), and on Intuit platform – 80 such courses (8.6%) [6].

The Malaysian authors specify that Mathematical Statistics, as many other disciplines, is difficult both for teaching and studying, thus MOOCs are a convenient and effective tool for teaching mathematics [7]. A comparative analysis of students’ estimations of convenience and usefulness of LMS and MOOC in the educational process showed the advantage of the latter [8]. At the same time, the researchers mark certain drawbacks of MOOCs: after mastering a MOOC the students still have to pass the discipline in the traditional way to get a mark or a degree; there is a lack of direct contact and group activities in a classroom under a professorial guidance [9].

A number of work do not just analyze the pluses and minuses of MOOK, but present the experience of creating a mathematical MOOC at the Polytechnic Institute of Porto (Instituto Politécnico do Porto), in particular, a course “Introduction to Differential Calculus” [10]; or describe the methodological maintenance of such courses [11]. For example, the authors from Moscow State Technical University named after N. E. Bauman advocate a broad use of 3D-vizualization and animation, elements of computer games to increase the attraction of mathematical education [12].

In line with our research, a number of other works are devoted to learners’ perception of MOOCs in the sphere of Mathematics [13].

A separate place in researches [14, 15] is occupied by the issue of courses for teachers of mathematics. Researchers analyze the positions of teachers in the situation when mass open online courses are combined with other forms of training [16]. Our research also touches upon this issue.

2. Materials and methods
To achieve the research objective – to identify the MOOC possibilities for mathematical training of would-be engineers – a number of research methods were applied.

The theoretical aspects of the issue were studied relying on the analysis and synthesis methods. The data obtained were supplemented with statistical information on the educators’ and students’ opinions about using MOOCs, their popularity, advantages, and the factors impeding their use in the educational process. To collect this information, we applied questioning. The empirical basis of the research was comprised of Coursera, EdX, Open Education, Intuit, Lektorium, and Stepik platforms. During the analysis, we accounted for individual characteristics of each platform and accentuated the evaluation of the following parameters: the number of mathematical courses on the platform; the themes of the available courses; the category of users to which the course is oriented; the duration and features of training.

3. Results and discussion
In order to research the use of MOOCs, including those aimed at developing mathematical competence, we composed questionnaires for professors and students. The questioning was performed with 110 students and 30 professors of higher educational establishments.

Among the professors, 93.3% of the respondents were aware of the open online courses and only 6.7% knew nothing about them.

To the question “Which platforms offering mass open online courses do you know?”, 53.3% of the professors answered that they are well informed about Open Education platform, 46.6% – with Coursera
Answering the question “Which online platform do you use (or consider expedient to use) for your own education?”, 93.3% of the professors chose Open Education, 30% each – Lektorium, Intuit and Coursera respectively, 23.3% – Universarium and 6.6% – Infourok. In our opinion, such a choice may be due to the insufficient level of mastering English, or due to the requirement to pay for the courses or for the certificate on retraining.

90% of the respondents would recommend to themselves or their colleagues to use Open Education platform for professional activity, 46.6% – Coursera, 40% – Universarium and Intuit respectively, and 30% – Lektorium. Stepik and EdX would have been recommended by 3.3% of the respondents each. Such a choice is determined by the convenience of Russian-language resources for the Russian professors.

Drawing a conclusion, we should list the reasons which impede the active use of mass open online courses in the educational practice: 70% of the professors marked the lack of spare time, 53.3% – the need for additional training, 46.6% – the lack of the relevant normative base in the educational establishment where they work, 40% – the lack of skills and competences for working with such resources, 20% – the insufficient level of mastering English, 10% – the requirement to teach disciplines in strict compliance with the curriculum.

The results of questioning students were different. Only 45.4% of the students questioned were aware of mass open online courses.

To the question “Which platforms offering mass open online courses do you know?”, 34.5% of the students answered that they are well informed about Open Education platform, 28.1% – with Lektorium platform. 18.2% are well informed about Coursera platform, 13.6% – about EdX. 10.9% of the respondents are well informed about each of Universarium and Stepik platforms, 7.2% – about Intuit, and 4.5% – about Akademiya Khana platform.

Answering the question “Which online platform do you use (or consider expedient to use) for your own education?”, 42.7% of the students chose Open Education, 28.2% – Lektorium, 20% each – Coursera and Stepik, respectively, 7.27% – Universarium, 3.6% each – Intuit, Akademiya Khana and Stepik. 11% of the respondents answered that they never used any online courses when studying at a higher educational establishment. In turn, this is the reason why only 20% of the respondents used MOOCs to consolidate knowledge in the sphere of mathematics.

At that, 63.6% of the respondents believe that theory consolidation and developing the skill of solving mathematical tasks would have been the most demanded by students using mathematical open online courses. Demonstration of solving practical tasks was mentioned as an important aspect of MOOCs by 57.2% of students, the importance of studying the theoretical material – by 52.7%, while control and diagnosing the knowledge and formed skills was considered important by 43.6% of the respondents.

The students questioned marked a number of reasons which impede the active use of mass open online courses in the educational practice. Among them: the lack of the relevant normative base in the educational establishment where they study (57.2%), the lack of spare time (35.4%), the lack of skills and competences for working with such resources (32.7%), the need for additional training (24.5%), the insufficient level of mastering English (17.2%), and the absence of technological devices (3.6%).

The results of questioning show that both students and professors mark the lack of the relevant normative base in the educational establishment, which would have allowed offsetting the disciplines based on the open online courses studied. When this problem is solved, the interest to such educational content will undoubtedly increase, alongside with digitalization of education.
To analyze the degree of the Russian users’ involvement into online education, we researched the Russian and foreign platforms. The research considered the popularity of mathematical courses on international and Russian MOOC-platforms.

The analysis included the largest international and Russian online-platforms: Coursera, EdX, Open Education, Intuit, Lektorium, and Stepik.

Notably, most of the mathematical courses on these platforms are highly specialized. Thus, when evaluating the first two indicators we specified the following categories: Algebra, Mathematical Analysis, Geometry, Discrete Mathematics, Probability Theory, Statistics, and Computational Mathematics.

The summarized data on the number of courses in each category are shown in Table 1.

Table 1. Categories of mathematical courses on online platforms.

| Platform/category | Coursera | EdX | Open Education | Lektorium | Intuit | Stepik |
|-------------------|----------|-----|----------------|-----------|--------|--------|
| Algebra           | 3        | 15  | 5              | 3         | 3      | 2      |
| Mathematical Analysis | 1     | 15  | 5              | 1         | 5      | 3      |
| Analytical Geometry | 2     | 1   | 5              | 3         | 3      | 1      |
| Discrete Mathematics | 1    | 2   | 5              | 2         | 3      | 5      |
| Probability Theory | 3     | 10  | 4              | 1         | 5      | 4      |
| Statistics        | 3       | 7   | 3              | 3         | 3      | 5      |
| Computational Mathematics | 1     | 2   | 1              | 2         | 1      | 1      |
| Mathematics       | 2       | 1   | 2              |           |        | 27     |
| Total             | 14      | 50  | 29             | 11        | 25     | 21     |

The most even distribution of courses by the chosen categories can be seen on Open Education platform. These are Linear Algebra, Algebra: Introduction to the Theory of Groups, Analytical Geometry, Fundamentals of Algebra and Geometry, Geometry and Groups, Mathematical Analysis: Integration and Multivariable Functions, Discrete Mathematics, Fuzzy Sets, and others.

The number of courses is a little less on Lektorium platform, but courses of all categories are represented there, too. 75% of the courses are aimed at schoolchildren, a little less than 50% – at university entrants and specialists.

Interestingly, Stepik platform, although specializing in technical courses, yields to the Russian analogues in the number of mathematical courses. Most of the mathematical courses are aimed at schoolchildren and offer training for the Unified State Exams and mathematical contests.

Of the two foreign platforms analyzed, the leading position by the number of mathematical courses is occupied by EdX platform. It offers courses of the world leading universities. The Russian segment is represented by the courses of National Research Nuclear University (MEPHI): Differential Calculus, Multiple Integrals and Series, Integral Calculus, Complex Variable Theory.

Table 1 shows, however, that most of these courses (60%) are aimed at studying Linear Algebra and various parts of Mathematical Analysis. A large part is courses on Probability Theory.

Coursera platform offers almost three times fewer of such courses. The platform cooperates with the leading Russian universities, thus, it offers courses in the Russian language. These are: Probability Theory: a Science of Contingency; Discrete Mathematics: Calculations, Graphs, Random Walks; Introduction to the Data Science. They are often written by the same authors as on the Russian platforms.
Coursera offers courses in major disciplines, for example, Mathematics for Data Analysis. EdX offers an analogue of Coursera–MicromastersPrograms majors. These are series of courses at Master’s degree level.

All platforms offer courses of mixed categories. Foreign platforms offer versions in the Russian language.

Most of the mathematical courses (75.7%) are aimed at junior students. This trend is characteristic both for the Russian and foreign platforms. In our opinion, this is mainly due to the features of studying mathematical disciplines at higher educational establishments. Basic mathematical training serves as a foundation for studying professional and special disciplines in the senior academic years. Some courses imply a low entrance level and are aimed at broad audience: from schoolchildren to Bachelor and Master graduates (for example, Lektorium).

Attendance of MOOCs is characterized by strong seasonality. The peak periods of the platforms’ attendance are beginnings of semesters and terms at educational establishments. This also influences the duration of training. 43.2% of the courses are intended for 1-2 months, while 37.8% – for 3-4 months, which corresponds to the academic terms at universities. Also, there are year-long and short-term online programs. The platforms offer both flexible and scheduled regimes, with deadlines for mastering modules (often used on Coursera platform). The coronavirus pandemic has caused changes, like in the functioning of Open Education platform, resulting in larger freedom in organizing individual studying trajectories.

This said, it should be noted that the trend persists towards increasing the number of MOOCs and diversification of the offered programs and presentation forms – from video-lectures to gamification.

4. Conclusion

Thus, the need for democratization, increasing the accessibility and the trend towards digitalization of education lead the broad use of mass open online courses in education. The vast domain of the disciplines offered, a large number of organizers of such programs, involvement of the world leading educational establishments in the process of creating courses for such platforms as Coursera, EdX, Open Education, Intuit, Lektorium, Stepik and others make it possible to deepen the learners’ knowledge regardless of their place of residence.

Special attention should be paid to fundamental disciplines, which become the basis for mastering professional competences by the would-be engineers. Thus, only the six above-mentioned platforms host 150 courses of mathematical domain, including highly specialized disciplines. The use of these resources may promote the efficiency of mastering theory in the discipline under study and develop the skills of solving mathematical tasks.

At the same time, according to the questioning, only 20% of the students at technical universities use MOOCs in their educational activity. Among the most important problems one should note the insufficient awareness of the MOOC opportunities, the lack of skills for working with them and preparedness for mastering new studying tools, and high load during the studies. One more problem demanding special elaboration is broadening the practice of offsetting academic disciplines based on the studied open online courses, as this issue was highlighted by all parties of the educational process.

References

[1] Azhar S R, Mohd F D and Mohd N H 2016 MOOCs in Engineering Education - a Literature Review Regional Conf. in Eng. Education 2016 (Kuala Lumpur: Universiti Teknologi Malaysia) pp 1-5

[2] Van Der Wal N J, Bakker A and Drijvers P 2019 Teaching Strategies to Foster Techno-Mathematical Literacies in an Innovative Mathematics Course for Future Engineers ZDM-Mathematics Education 51(6) 885-97

[3] Temnyh V I, Pushkaryeva T P, Kalitina V V and Stepanova T A 2020 Information Technology in Mathematics Training Applied Inf. and Cybernetics in Intelligent Sys. 1226 329-39

[4] Gonda D, Pavlovicova G and Tirpakova A 2020 Analysis of Factors Influencing Students' Access
to Mathematics Education in the Form of MOOC Mathematics 8 1229

[5] Jiang S H, Schenke K, Eccles J S, Xu D and Warschauer M 2018 Cross-National Comparison of Gender Differences in the Enrollment in and Completion of Science, Technology, Engineering, and Mathematics Massive Open Online Courses PLoS ONE 13(9) 0202463

[6] Galimullina N M, Korshunova O N and Feoktistova I R 2020 The Role of MOOC Courses in the Development of Polytechnic Education Advances in Economics, Business and Management Research 128 1731-40

[7] Jamal N F, Ghafar N M A, Ismail I L, Awang C M and Baharuddin M S 2020 Learning Mathematical Statistics In Massive Open Online Courses (MOOCs) Int. Journal of Modern Education 2(5) 38-45

[8] Tarmuji N H, Abd Nasser A, Ahmad S, Abdullah N M and Idris A S 2018 Students' Acceptance of E-learning in Mathematics: Comparison between LMS and MOOC Using SEM PLS Approach Proc. of the 25th National Symp. on Math. Sciences (SKSM25): Math. Sciences as the Core of Intellectual Excellence vol 1974 ed Mohamad D; Akbarally A B et al (Kuantan: AIP Publishing) p 050008

[9] Manzoor A 2016 MOOCs for Enhancing Engineering Education Advances in Civil and Industrial Engineering Handbook of Research on Applied E-Learning in Engineering and Architecture Education ed Fonseca D and Redondo E (Hershey: IGI Global) pp 204-23

[10] Lopes A P, Soares F and Vieira I 2015 Challenges in the Creation and Development of a Mathematics MOOC Proc. of ICERI 2015 (Seville: IATED) pp 1862-867

[11] Lopes A P and Soares F 2017 "Flipped Classroom with a MOOC" an E-Learning Model into a Mathematics Course INTED2017: 11th International Technology, Education and Development Conf. ed Chova L G, Martinez A L et al (Valencia: IATED) pp 4643-9

[12] Dimitrienko Yu I and Gubareva E A 2018 Neural Network Model of Mathematical Knowledge and Development of Information and Educational Environment for Mathematical Training of Engineers J. of Phys. Conf. Ser. 1141(1) 012010

[13] You J L and Luo X Y 2017 Strategies on Teaching Reform of Advanced Mathematics from the Perspective of "MOOC" Advances in Social Sci. Education and Humanities Research 144 891-3

[14] Hollebrands K F and Lee H S 2020 Effective Design of Massive Open Online Courses for Mathematics Teachers to Support Their Professional Learning ZDM-Mathematics Education 52(5) 859-75

[15] Anat K, Einav K and Shirley R 2020 Development of Mathematics Trainee Teachers' Knowledge while Creating a MOOC Int. J. of Math. Education in Sci. and Technology 51(6) 939-53

[16] Vaz de Carvalho C, Intveen S, Zubikova O, Bruegmann T, Hakan C A, Toprak E, Genc-Kuntepe E and Mihaescu V 2020 Teachers’ Skills Required to Design and Deliver MOOCs in Engineering Education 2020 IEEE Learning With MOOCS (LWMOOCS) (Antigua Guatemala: IEEE) pp 8-13