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Possibility for using engineering MOOCs in university education

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Other publications related to the dissertation topic:

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3. Semenova T., Vilkova K. , Shcheglova I. The MOOC market: prospect for Russia // Educational Studies Moscow. 2018. № 2. P. 173-197. https://doi.org/10.17323/1814-9545-2018-2-173-197.

4. Semenova T., Rudakova L. Barriers to Taking Massive Open Online Courses (MOOCs) // Russian Education and Society. 2016. Vol. 58. No. 3. P. 228-245. https://doi.org/10.1080/10609393.2016.1242992.

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INTRODUCTION

The relevance of research

One of the promising ways to develop the education is the use of massive open online courses (MOOCs). MOOC differs from other online learning formats in two ways: it is presented on international or national online platforms and any Internet user can sign up for it, regardless of education level, level of skills, gender, age, and social status[1] (Baturay, 2015; Saadatdoost et al., 2015). Even though MOOCs are focused on providing wide access to educational resources for different groups of the population, this format is increasingly used as part of the educational process in universities (Literat, 2015). The integration of MOOCs into the educational process makes it possible to expand the catalog of disciplines, individualize the educational trajectories of students, increase the availability of high-quality courses taught at top universities, disseminate innovative pedagogical practices, and optimize the workload of university research and teaching staff, freeing up their time for scientific work (Sandeen, 2013; Hollands, 2014; Belenko et al., 2019). In addition, this course format facilitates the scaling up of academic programs, reducing their cost by using the resources of several organizations to develop and deliver courses (Graham, Woodfield & Harrison, 2013; Bruff et al., 2013; Griffiths et al., 2015; Littenberg-Tobias & Reich, 2020). Therefore, over the past 5-7 years, both foreign and Russian universities have been integrating massive open online courses into their educational process, actively experimenting with different models of their integration: from using them as additional material to completely replacing full-time courses (Sandeen, 2013; Isael, 2015; Bogdan, Bicen & Holotescu, 2017; Bralić & Divjak, 2018). At the same time, there is not only the practice of embedding "foreign" MOOCs created by third-party organizations that are equivalent in their status to a consumer university, but also the use of MOOCs created by selective universities in non-selective universities (Sandeen, 2013).

[1] In this study, xMOOC is considered as an online learning format based on interaction with course content (Conole, 2014).

In the Russian education system, this practice began to institutionalize since the advent of the national platform "Open Education" (NOEP) in 2015. The main task of NOEP was to provide the opportunity for non-selective Russian universities to integrate xMOOCs of selective universities into their educational process[2]. This process reached its greatest scale during the COVID-19 pandemic, when the traditional learning format became almost impossible. In the spring semester of the 2019-2020 academic year, on more than 3,500 Russian educational programs, at least one course was partially or completely conducted using open online courses (Klyagin et al., 2020).

However, there is still no understanding whether MOOCs can be an equivalent for traditional face-to-face courses. Previous empirical studies have shown that MOOCs have a number of disadvantages that may prevent this replacement (Toven-Lindsey, Rhoads & Lozano, 2015; Reich & Ruipérez-Valiente, 2019). First, MOOCs have extremely high dropout rates, reaching 95% in some courses (Jordan, 2014; Pursel et al., 2016; Reich & Ruipérez-Valiente, 2019; Dai et al., 2020). Even among those who set the goal to obtain a certificate, the dropout rate from MOOCs is high and reaches 65-80% (Rieber, 2017; Rohloff & Meinel, 2018). Secondly, the current MOOCs have significant limitations. In practice, many MOOCs are created by simply transferring a face-to-face course to an online environment, while traditional formats and teaching practices are less effective in online format than face-to-face format (Toven-Lindsey, Rhoads & Lozano, 2015). In most cases, they do not sufficiently support students towards the completing the course, do not provide timely feedback and the opportunity to interact with the course instructors (Grünewald et al., 2013; Nawrot & Doucet, 2014; Meneses et al., 2020). Therefore, in such an educational environment, it becomes especially important to have academic motivation, which will stimulate students' activity in the course (Fryer, Bovee & Nakao, 2014; Fryer & Bovee, 2016; Vanslambrouck et al., 2018). However, it is not clear what types of academic motivation will play a significant role in completing MOOCs.

[2] https://npoed.ru/about

The study of the possibilities of using MOOCs in engineering programs is becoming especially relevant due to the high demand for specialists in this field. The demand for engineers is due to the fact that the quantity and quality of their preparation is one of the key factors in the innovative development and global competitiveness of the country (Carnoy et al., 2013; Xie, Fang & Shauman, 2015; Hanushek & Woessmann, 2015). In Russia, this is confirmed by the enrollment targets for Russian universities (Maloshonok & Shcheglova, 2020). In the 2018/2019 academic year, up to half of the state-subsidized places for undergraduate programs (47%) were allocated to engineering programs (Maloshonok & Shcheglova, 2020); in 2021, every third applicant (32%) enrolled in undergraduate engineering programs, and more than half of them (65%) were state-subsidized[3]. At the same time, employers do not always highly evaluate the quality of preparation of engineers (Frumin & Dobryakova, 2012), which may be due, among other things, to the selectivity of the university (Prakhov, 2015) and the age structure of its faculty staff (according to data for 2021, every fifth Russian university instructor is over 65 years old[4]). In this situation, the use of MOOCs produced by selective universities in the educational process can contribute to the scaling of engineering educational programs by reducing their cost without loss in the quality of preparation and solving the issue of hiring and retaining qualified instructors of engineering courses, which is especially important for non-selective universities experiencing a funding gap (Koksharov et al., 2021).

Considering the widespread practice of using MOOCs in the educational process at universities around the world in general and due to the threat of COVID-19 spread, as well as the importance of scaling up engineering programs and reducing their costs, which is possible by embedding MOOCs in curricula, getting answers to the following questions is highly relevant: 1) will the spread of the practice of using engineering MOOCs in universities lead to a decrease in the level

[3] The calculations were made by the author based on the data presented on the website of the Ministry of Science and Higher Education of the Russian Federation (https://minobrnauki.gov.ru/action/stat/highed/)
[4] The calculations were made by the author based on the data presented on the website of the Ministry of Science and Higher Education of the Russian Federation (https://minobrnauki.gov.ru/action/stat/highed/)

of student preparation due to the identified problems with online courses? 2) How applicable is the model of using engineering MOOCs of selective universities in non-selective universities, given the institutional conditions created for its development in the Russian Federation? 3) What types of academic motivation will contribute to student success in MOOC?

This dissertation partially answers the above practical questions, allowing to evaluate the possibilities of using engineering MOOCs in university education. Following the tradition adopted by researchers to assess the effect of new technologies, including online courses (Shachar & Neumann, 2003), this dissertation uses two indicators: an objective indicator that reflects the educational outcomes of students, and a subjective indicator that reflects the level of their satisfaction with the course. The educational outcomes show the level of acquired knowledge in course, and the level of satisfaction with the course shows the affective assessment of the course.

This dissertation uses the results of a mixed-design study, including the results of a field experiment conducted with students from three non-selective universities in the Russian Federation, to determine the possibility of using engineering MOOCs in universities.

Research background and scientific novelty of the dissertation research

Since 1928, researchers have been trying to assess how effective distance learning is compared to traditional learning and which combinations of online and offline learning components give the best results (Shachar & Neumann, 2003), using two indicators: educational outcomes and the level of satisfaction with studying. However, the results of such studies are controversial. B.W. Brown, S.R. Hiltz, W.T. Alpert, D. Figlio, E. Bettinger and others, in their works, captured the negative effect of the distance format on educational outcomes due to the low level of activity shown by students of distance courses (Hiltz et al., 2000; Brown & Liedholm, 2002; Figlio, Rush & Yin, 2013; Xu & Jaggars, 2014; Alpert, Couch & Harmon, 2016; Bettinger & Loeb, 2017). Other researchers, including P. Navarro, A.P. Rovai,

W.G. Bowen, J. Collins and E.T. Pascarella noted the neutral or positive effect of distance and blended formats due to a high level of engagement and group cohesion among students (Navarro & Shoemaker, 2000; Collins & Pascarella, 2003; Shachar & Neumann, 2003; Burns & Ungerleider, 2003; Rovai & Jordan, 2004; Means et al., 2009; Feeley & Parris 2012; Bowen et al., 2014). Such contradictory results are mostly the consequence of applying different research methodology (for example, using a quasi-experimental approach led to a self-selection bias), different samples, and different configurations of distance and blended courses.

In addition to the lack of certainty in the answer to the question about the direction of the effect of distance format on the educational outcomes and level of satisfaction, these studies have another limitation – contextual. The effect of distance format was tested in courses developed by university professors for their students. In turn, the use of MOOCs for the realization of distance learning involves referring not only to courses developed within the organization, but also to "foreign" courses prepared by instructors from other universities. Therefore, we cannot rely on the obtained results of the effectiveness of the distance learning format when assessing the possibility of using MOOCs of selective universities in non-selective universities.

The few studies that have assessed the effectiveness of using massive open online courses in the educational process have primarily compared different variations of the blended format (which differ in the percentage of MOOC integration) or evaluated the blended format compared to traditional or online ones (Bruff et al., 2013; Caulfield, Collier & Halawa, 2013; Firmin et al., 2014; Holotescu et al., 2014; Griffiths et al., 2015; Israel, 2015; Tomkins & Getoor, 2019). Blended format with MOOCs condition has been as effective as traditional (Najafi, Evans & Federico 2014; Griffiths et al., 2015), and in a number of studies, the educational outcomes of students studied in blended format were significantly higher than those students who studied in traditional face-to-face group, including a lower rate of dropout from the course (Ghadiri et. al., 2013; Lee & Pak, 2018; Wang & Zhu, 2019; Tomkins & Getoor, 2019; Sidek et al., 2020; Lisitsyna et al., 2020). However, these

studies have methodological limitations due to the use of either descriptive or quasi-experimental design, which does not allow us to determine the impact of MOOCs on the educational outcomes and level of satisfaction.

We can add one more shortage to the contextual and methodological limitations of the results of previous studies, evaluated the effectiveness of the distance learning format, which is the undeveloped models for an explanation of the mechanism of the influence of learning formats on the educational outcomes and level of satisfaction. Researchers rarely turn to theoretical models that would clarify the nature of the cause-effect relationships between the learning format and the educational outcomes of students, their level of satisfaction. The main approach used by researchers is to look for problems that distance learners face because they are less satisfied with their learning (Allen et al., 2002; Griffiths et al., 2015; Li et al., 2015; Robinson, 2016; Wang & Zhu, 2019). The main difficulties include: the need for more self-control over the learning process and the need to independently search for answers to questions due to the absence of an instructor, as well as the lack of a peer effect in the online environment (Tuckman, 2005; Jaggars, 2014; O'Neill & Sai, 2014; Zheng et al., 2015; Broadbent & Poon, 2015).

Studies that evaluate the effectiveness of the distance format were carried out mainly on a sample of students from foreign universities, and there are no studies that would assess the possibility of using engineering MOOCs in Russian universities. Most Russian authors are primarily focused on describing the advantages and risks associated with the MOOC integration in the educational process (Timkin, 2017; Krasnoshchekov, 2018; Ibatova & Ilyin, 2019; Shaposhnikov & Shaposhnikova, 2019; Yakushenko, 2019; Bukhantsova, 2020; Khoroshilova, 2020; Doskach, 2021; Eremitskaya & Akhunzhanova, 2021; Patrunina, 2021), as well as presenting their experience of using such courses or a case with the procedure for embedding MOOCs in a particular university (Polyankina, 2014; Babanskaya, 2015; Malyuga, 2016; Vaganova & Telegina, 2017; Borshcheva, 2017; Babaeva, 2019; Starostina, 2019; Tatarskaya & Ganyushkina, 2020).

This study allows us to partially overcome all the indicated contextual, methodological and theoretical limitations of previous works and makes a theoretical, methodological and empirical contribution to understand the mechanism of the influence of online and blended course format on the educational outcomes and level of satisfaction compared to traditional face-to-face courses for engineering students. Contextual limitations are overcome by studying the practices of Russian universities in integrating MOOCs into the educational process and taking them into account while planning of experimental research. The study allows us to show how universities integrate “foreign” MOOCs into the educational process and examines the possibility of using engineering MOOCs in higher education, taking into account this context specificity. The theoretical advantage of this work lies in the development of a theoretical model that explains the mechanisms of influence of the course format on educational outcomes and student satisfaction. In this dissertation, the methodological limitations of previous work are overcome by conducting a field experiment with randomized assignment of students to the course format. Thus, the scientific novelty of our study lies in filling the gaps in scientific knowledge about the possibility of using engineering MOOCs for engineering students through partial overcoming theoretical, methodological and contextual limitations.

Objective of the research

The goal of this research is to study the possibility of using engineering MOOCs for educating students of Russian universities.

To achieve the goal of the research, the following tasks were set:

1. Classification of formats of using MOOCs in the educational process of Russian universities.

   The solution of the first task will allow us to identify the existing types of MOOC integration into the educational programs of Russian universities for the subsequent assessment of their impact on the educational outcomes and level of satisfaction with the course.

2. Specification of a theoretical model that explains the mechanism of the influence of learning formats on the educational outcomes and level of satisfaction with the course.

   The solution of the second task will allow us to describe the learning formats and show their relationship with two indicators: the educational outcomes and level of satisfaction with the course.

3. Assessing the impact of the formats of using engineering MOOCs on educational outcomes of engineering students.

   The third task is aimed at determining the effect of the formats of using MOOCs, identified in the first task, on the educational outcomes of students, reflecting the level of acquired knowledge in course. The solution of this problem will allow us to find out whether the integration of engineering MOOCs into the educational process will lead to a decrease in the educational outcomes of engineering students.

4. Evaluation of the relationship between the formats of using engineering MOOCs and the level of satisfaction with the course among engineering students.

   The fourth task is aimed at determining the relationship between the formats of using MOOCs, identified in the first task, and the level of satisfaction with the course. The solution of this problem will allow us to find out how satisfied engineering students are with the formats of using engineering MOOCs in the educational process.

5. Refinement of the theoretical model that describes the mechanism of the influence of learning formats on the educational outcomes and level of satisfaction through meeting the needs of students.

   The fifth task is aimed at refining the theoretical model, developed in the second task. Its solution will help explain the results obtained in the third and fourth tasks of assessing the effect of MOOCs on educational outcomes and the level of student satisfaction.

6. Evaluation of the relationship between students' academic motivation and educational outcomes in MOOCs.

   The sixth task is aimed at determining the role of motivation in MOOCs completion, which is included as one of the indicators in the theoretical model proposed in the second task. Its solution will allow us to identify the types of academic motivation that significantly increase the chances of successfully completing a MOOC while controlling the level of students' engagement.

THEORETICAL BASIS OF THE RESEARCH

In this research, to explain the mechanisms of the influence of learning formats on the educational outcomes and level of satisfaction with the course, the concepts of two theories are used, which accept the relationship between the subject and the structure: the hierarchical theory of self-determination by R.J. Vallerand (Vallerand, 1997), which is an addition to the model of the same name by E.L. Desi and R.M. Ryan (Deci & Ryan, 2004), and Giddens' structuration theory (Giddens, 2005).

In the hierarchical theory of self-determination, several important components are added to the typology of motivation identified by Desi and Ryan in accordance with the degree of autonomy in performing actions: (1) levels of functioning of motivation (global, contextual and situational), (2) social factors, which are conditions in which the action takes place, (3) the mediators through which social factors influence motivation (these mediators are the needs for competence, autonomy, and relatedness), and (4) the consequences of actions, to which Vallerand attributed cognition, affect, and behavior.

The learning format in this model refers to the conditions in which the course is taught. It influences the motivation of students and the consequences of their actions through the satisfaction of needs. In this model, Vallerand points out the importance of taking into account the conditions, the context in which the action

takes place, but does not conceptualize it. Therefore, in order to reveal the concept used in his study, several postulates of Giddens' structuration theory are used.

According to the structuration theory, the actor reproduces the structure in his social practice, which, on the one hand, imposes certain restrictions on it, and, on the other hand, allows changes to be made. Structure is a set of rules and resources by which a certain degree of unity of social practices in time and space is maintained, which Giddens calls a social system. A social system has structural properties that allow it to legitimize social practice (through norms), exercise dominance (through resources), and give meaning (through signs).

In this study, the learning format is considered as a social system in which social practices are reproduced in accordance with certain rules and resources. Each learning format has its own set of rules and resources. Rules legitimize certain social practices and restrict others, while resources ensure dominance of specific agents. However, agents (i.e. the main stakeholders of the university, in particular students) have the opportunity to make changes to the set of rules and resources, thereby changing social practice.

In the traditional (full-time) format, the norms are set by the course instructor, and the student is required to follow them. Norms can be both formalized (prescribed in the curriculum of the course) and non-formalized. In addition, they can be weakly or strongly sanctioned (for example, the instructor can postpone the deadlines for submitting course papers). In the traditional format, the student has the right to receive knowledge, skills and feedback from the instructor during lectures, seminars/laboratory classes, as well as during his consulting hours. The student also has the opportunity to interact with peers during studying. The instructor of the course has more authoritative resources (i.e., the ability to control the behavior of students).

In a blended format, norms are set by both the course instructor and the online course; and the student must follow them. Norms can be both formalized (prescribed in the curriculum of the course) and non-formalized. Also, norms can be weakly or strongly sanctioned within the face-to-face course and strongly sanctioned within

the online course. A student has the right to receive knowledge, skills and feedback from the instructor during seminars/laboratory classes, as well as during his consulting hours. The student also has the opportunity to interact with peers during studying. The instructor of the course continues to have more authoritative resources.

In the online format, the norms are set by the online course, not by the instructor of the face-to-face course. In this case, the norms are only formalized and strictly sanctioned. A student does not have the opportunity to receive knowledge, skills and feedback from the instructor of his university (he receives them from the materials of the online course). The instructor of a full-time course no longer has authoritative resources; the structure of the online course, as well as the platform on which it is launched, imposes a limitation on the behavior of students.

The hierarchical theory of self-determination allows us to show the relationship between the learning format and the cognitive and affective consequences of social practice. If the learning format meets the needs of students, then students are successfully involved in the study of the course material, show a high level of educational outcomes, as well as positive emotions. The opposite situation related to the dissatisfaction of needs leads to the fact that students experience negative emotions and may receive low educational outcomes. We use two needs as mediators in the proposed theoretical framework: autonomy and relatedness, as they refer to the format of the course as opposed to the need for competence, which refers to the content of the course.

The traditional format is characterized by a low level of autonomy delivered to students. Offline learning is highly regulated: the learning process is planned for the students (for example, the time and place of classes are set), the course instructor controls the fulfillment of all requirements (Stansfield, McLellan & Connolly, 2004; Elvers, Polzella & Graetz, 2003). At the same time, the level of relatedness provided in this format is high: students have the opportunity to interact both with the course instructor and with other students.

Blended learning is less regulated than traditional learning: students have more freedom to complete part of the course material in online format (Singh, 2021). Therefore, the blended format provides students with an average level of autonomy and relatedness (part of the interactions is reduced by integrating an online component into the course).

The online format is characterized by the highest level of autonomy: online learning requires students to independently plan their learning process, select effective strategies, control the process of completing the course and evaluate the results achieved (Elvers, Polzella & Graetz, 2003; Michinov et al., 2011; Levy & Ramin, 2012; Kizilcec, Pérez-Sanagustín & Maldonado, 2017). This autonomy is provided by the flexibility of the system, according to which it is not the manager or instructor of the course who determines the temporal and spatial boundaries of learning, but the student himself. This format provides a low level of relatedness: online does not involve intensive interaction with the instructor and other students. An online format as MOOCs provides a particularly high level of autonomy and low level of relatedness, where students study without the possibility of communication with the university instructor.

Figure 1 shows the theoretical framework of this study, which combines the postulates of the structuration theory, allowed us to describe learning formats, and the hierarchical theory of self-determination, where we used the link between social factors, mediators/needs, and consequences to explain the influence of the learning format through satisfaction of needs, motivation, and social practice on educational outcomes, showing how much the student has mastered the subject, how he is satisfied with the course and how much he was engaged in the process. The proposed model also allows us to explain why an independent choice of a learning format for taking a course leads to the fact that students receive, on average, higher educational outcomes in an online group. The chosen format is aligned with their needs, increasing academic motivation and shaping social practices leading to high cognitive, affective and behavioral outcomes.

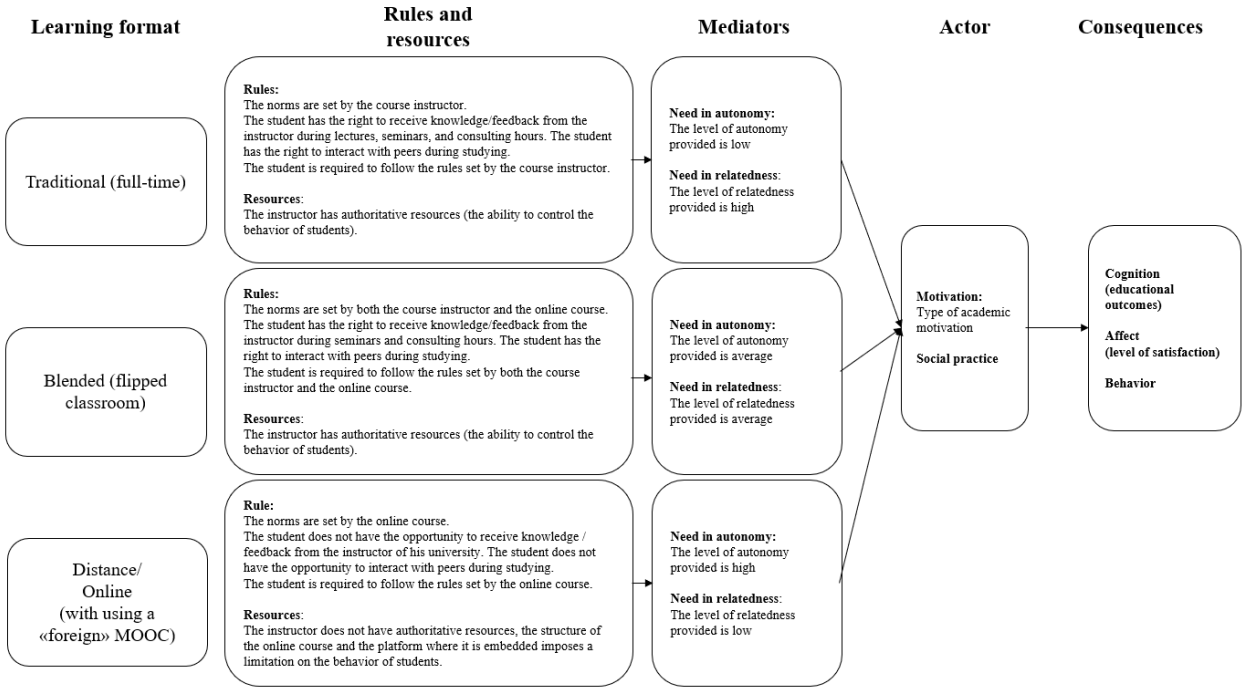

Figure 1 - Theoretical model for studying the impact of learning formats on the educational outcomes and level of satisfaction with the course

In accordance with the theoretical model of this study, we assume that, unlike traditional and blended formats, the online format puts students in new conditions: there are no familiar rules of the game, there is a change in resources, there is a low level of relatedness, and there are new requirements for a high level of autonomy for students that is imposed by the system. New conditions for learning in online format may lead to a decrease in the educational outcomes of students and the level of satisfaction with the course. Therefore, we make two assumptions to test the effect of the practice of using MOOCs in the educational process:

H1: Students who completed engineering courses in online format with using a MOOC will get significantly lower educational outcomes compared to those who took engineering courses in a traditional (full-time) or blended format with using a MOOC.

H2: Students who completed engineering courses in online format with using a MOOC will be less satisfied with engineering courses compared to those who took a traditional (full-time) and blended format with using a MOOC.

RESEARCH METHODOLOGY: METHODS AND DATASETS

I. To solve the first task of the study – the classify the formats of using MOOCs in the educational process of Russian universities – we used the data from the study "Development and approbation of models for including online courses in curricula in order to improve the quality and cost-effectiveness of the educational program" (hereinafter referred to as the data set for identifying models of MOOCs integration). The study was conducted in 2016-2017 to identify the experience of integrating MOOCs into the educational process of Russian universities. The data sources were, firstly, data from open sources: publications in Russian journals describing cases of using MOOCs at a university; information from the official websites of Russian universities, as well as regulatory documents of universities, which fix the procedure for recording of results of open online courses (we analyzed the provisions on recording of the results of MOOCs in St. Petersburg Polytechnic University, Siberian Federal University, TSU, TPU and HSE, which at that time began to appear in universities). Secondly, the data sources included data on experts' interviews conducted with representatives of online learning centers of selective Russian universities that are members of the national platform "Open Education" (NOEP) (ITMO, Moscow Institute of Physics and Technology, HSE, St. Petersburg Polytechnic University and Ural Federal University). The questions of the guide were aimed at identifying experience and strategies for integrating MOOCs in Russian universities. The analysis of documents and thematic coding of transcripts of experts' interviews were used as a method of analysis.

The results of solving the first task are set out in the article: *Semenova T., Vilkova K. Types of MOOC integration into the educational process of universities // University Management: Practice and Analysis 2017. Vol. 21. № 6. P. 114-126.*

II. To solve the third task of the study – to assess the impact of the formats of using engineering MOOCs on educational outcomes of engineering students – we conducted an experimental study as part of the project "Research of new forms to organize the educational process with using open online courses" (hereinafter

referred to as the data set "RCT with students"). The field stage was held in the fall semester of the 2017-2018 academic year. The study involved 325 students from three regional universities in Russia, the Volga Federal District, which are included in the third quartile of the university enrolment quality rating. The students who agreed to take part in the experiment were sophomore of the bachelor's/specialist's degree majoring in "engineering, technology and technical sciences". In accordance with the research design, students were randomly divided into three groups: in first group, course was given in a traditional format (101 students), in second group, in a blended format (MOOC video lectures and face-to-face seminars) (100 students), and in third group, in online format (MOOC on the national online platform) (124 students). Students of the first group attended face-to-face lectures and seminars, which were conducted by the instructor of the university, and also completed tests and homework assignments. Students of the second group watched video lectures of the online course and attended face-to-face seminars led by the instructor of the university, as well as completed tests and homework assignments. Students of the third group did not attend face-to-face lectures or seminars, instead they watched video lectures and completed MOOC tasks on the platform. Students of all three groups, formed at random, took one of two courses: "Engineering Mechanics" (EM) or "Construction Materials Technology" (CMT). The first course was attended by 238 students of two technical universities, the second course was attended by 87 students of one classical university. The MOOCs created by the Ural Federal University team of authors in accordance with the Federal State Educational Standards (FSES) and launched on NOEP became the equivalent of these courses[5]. All materials of the courses were identical for the students of the three groups to avoid the influence of the course content on the results of the experiment. Curriculums, topics, assignments, as well as a list of references corresponding to the

[5] Both MOOCs were prepared by professors, associate professors of Ural Federal University with an average work experience of 40 years. EM course was recognized as the best in the nomination "Best practice in creating open online courses" at the competition #EdCrunch Award (http://neorusedu.ru/news/mihail-kotyukov-nagradil-avtorov-luchshih-onlayn-kursov).

content of the MOOC were sent to the instructors of the universities participated in the project.

Before the start of the course, students of all three groups took a pre-test that measured their level of preparation for studying EM or CMT, as well as a pre-survey that measured their socio-demographic, psychological characteristics and learning experience. At the end of the course, students passed a post-test in the form of face-to-face testing at the university campuses (the test tasks were identical to the final exams of EM and CMT launched on NOEP[6]), a post-survey that measured their experience of completing the course and the level of satisfaction, as well as participated in the focus group. We also collected administrative data from the statistical databases of universities including scores of the unified state examination (USE) and average academic performance.

To assess the effect of formats with using engineering MOOCs on students' educational outcomes, we constructed two linear regressions (using the least-squares method) with fixed effects for universities with and without covariates. The covariates were variables that had previously shown their relationship with achievement in online courses: socio-demographic characteristics (gender and age), online learning experience, academic motivation, level of self-efficacy and level of interaction with instructors (these variables were measured in the pre-survey). We also added the score for the pre-test, the average score for academic performance (analogous to GPA), USE scores in Russian language, mathematics and physics to this set of covariates (these variables were in administrative data provided by the coordinators of the universities). The score for the post-test was used as a dependent variable, which allowed us to compare the educational outcomes of students from all three groups.

The results of solving the second task are set out in the article: *Chirikov I., Semenova T., Maloshonok N., Bettinger E., Kizilcec R. F. Online education*

[6] The use of tasks developed by the authors of MOOCs for post-test was due to two reasons: 1) use an objective indicator that measures the level of acquired knowledge, which were included in the content of the MOOCs by the authors, 2) a correct ratio between the course materials that students took during the learning process and the post-test tasks.

platforms scale college STEM instruction with equivalent learning outcomes at lower cost // Science advances. 2020. T. 6. №. 15. C. eaay5324

III. To solve the fourth task of the study – to evaluate the relationship between the formats of using engineering MOOCs and the level of satisfaction with the course among engineering students – the same data source was used as for the solution of the third task of the study (data set "RCT with students"). The database included pre-test, pre-survey and post-survey data, as well as administrative data for students who participated in the experiment. We constructed two linear regressions (using the least-squares method) with fixed effects for universities with and without covariates to assess the relationship between the format of using engineering MOOCs and level of satisfaction with the course. The covariates were: socio-demographic characteristics (gender and age), online learning experience, academic motivation, level of self-efficacy, level of interaction with instructors, score for the pre-test, average score for academic performance (analogous to GPA), USE scores in Russian language, mathematics and physics. The dependent variable was the level of satisfaction measured in the post-survey, which allowed us to compare the level of satisfaction with engineering courses among students of traditional (full-time), blended and online groups.

The results of solving the third task are set out in the article: *Chirikov I., Semenova T., Maloshonok N., Bettinger E., Kizilcec R. F. Online education platforms scale college STEM instruction with equivalent learning outcomes at lower cost // Science advances. 2020. T. 6. №. 15. C. eaay5324*

IV. To solve the fifth task of the study – to clarify the theoretical model that describes the mechanism of the influence of learning formats on the educational outcomes and level of satisfaction through meeting the needs of students – we used the data of focus groups conducted as part of the experimental study "Research of new forms to organize the educational process with using open online courses" (hereinafter referred to as the dataset "Focus groups with students"). Face-to-face

focus groups were conducted with students of blended and online groups at each university campus after they passed the post-test and post-survey. We conducted 5 focus groups and one interview: in each university, two focus groups were held separately with students of blended and online groups (the exception was one university, where an interview was conducted with students of a blended format instead of a focus group). Of the 325 participants of the experiment, 57 took part in the focus groups. We used a semi-structured guide to collect data, which included three thematic blocks of questions: (a) course activity, (b) advantages and limitations of online/blended formats, and c) attitudes towards online/blended formats. The transcripts were analyzed using a topic coding approach to highlight the online learning needs and challenges faced by the students, as well as to identify the strategies they were used.

The results of solving the fifth task are set out in the article: *Semenova T.V. "When You Just Sit in Front of a Computer, It Does Not Require Anything from You": Difficulties and Strategies of Students While Completing University-Level MOOCs. Monitoring of Public Opinion: Economic and Social Changes. No. 2. P. 292–316. https://doi.org/10.14515/monitoring.2022.2.1999.*

V. To solve the sixth task of the study – to assess the relationship between student academic motivation and educational outcomes in MOOCs– we used survey data on participants of HSE courses launched on the Coursera online platform (hereinafter referred to as the data set "MOOC participants survey"). The survey was conducted among participants of HSE MOOC on the Coursera platform in 2014-2015. The database included participants of 8 economic courses in Russian: Economics for Non-Economists, Institutional Economics, Econometrics, Financial Markets and Institutions, Fundamentals of Microeconomics, History of Economic Thought, Fundamentals of Corporate Finance and Macroeconomics. The sample consisted of 2392 students from 52 Russian universities, who pursued undergraduate, graduate and postgraduate studies in various majors, out of 10187 participants who filled out the online questionnaire. The questionnaire included

questions about socio-demographic characteristics, education level, online learning experience, level of subject knowledge, and academic motivation. To measure academic motivation, we used a scale based on the model of types of motivation proposed in the self-determination theory by Deci and Ryan (Ryan & Deci, 2000)[7].

To identify the role of types of academic motivation in MOOCs completion for students from Russian universities, we constructed a logistic regression with covariates. The covariates were variables from the survey data that showed their relationship with the successful studying in online environment (gender, age, level of education, online learning experience, level of subject knowledges), as well as streaming data on students' activity (test completion of the first week test and participation in the course forum). Types of academic motivation were an independent variable, and a dichotomous variable, indicating the fact of obtaining a certificate in the course, was a dependent variable.

The results of solving the sixth task are set out in the article: *Semenova T. The role of learners' motivation in MOOC completion // Open Learning: The Journal of Open, Distance and e-Learning. 2020. C. 1-15.*

Limitation of the research

This study has a number of limitations that should be taken into account when evaluating and extrapolating its results.

1. An experimental study was conducted on a sample of undergraduate students majoring in "engineering, technology and technical sciences" at non-selective universities, who took one of engineering courses: "Engineering Mechanics" or "Construction Materials Technology". The conclusions drawn from this study cannot be extended to other

[7] Statements in the motivation scale: "I participate in the course out of curiosity, interest in the subject"; "I participate in the course because it is useful for my university studies/preparation for university studies"; "I participate in the course because it is important to my current job"; "I participate because the course will help me change the type of work"; "I participate because I want to communicate with other students interested in this topic"; "I participate for the company, following the example of friends"; "I participate because I want to receive a verified certificate (Signature Track)"; "I participate because the course is taught by this teacher / the course is organized by this university"; "I'm not going to participate regularly, I would just like to have access to course materials". A 4-point scale from "strongly disagree" to "strongly agree".

majors, other courses, as well as to the entire set of universities that offer engineering educational programs. Despite the fact that only two engineering courses were used in the study, these courses are basic and included in the curriculum of engineering educational programs. In 2018, in 129 state Russian universities, 29 992 students took the discipline "Engineering Mechanics" and 72 516 – the discipline "Technology of Structural Materials" (Chirikov at al., 2020).

2. Two different samples were used to test the effect of the practice of using MOOCs in the educational process and to determine the role of academic motivation in the MOOCs completion for students. In this study, two non-overlapping samples were used to solve research problems. One sample was used in the field experiment to evaluate the possibility of using engineering MOOCs in Russian universities. Sophomore of the bachelor's/specialist's degree majoring in "engineering, technology and technical sciences" from three non-selective Russian universities participated in this RCT. Another sample was used to determine the role of types of academic motivation in MOOCs completion. The sample included students from various Russian universities, from various majors and years of studying, who registered for HSE online courses pursuing different goals (not only to replace the full-time course).
3. Untested tools were used to measure the role of academic motivation in MOOCs completion for students. Resort to untested tools is caused by the use of secondary data for analysis, which were collected by the team of HSE internal monitoring center to measure the characteristics and intentions of participants who registered for HSE courses on Coursera.

MAIN FINDINGS

1. Formats of using MOOCs in the educational process of Russian universities

The result of the solution of the first task was the revealing of three formats for MOOCs integration into the educational process of Russian universities. The first format is the use of MOOCs to organize a blended learning format. In this case, MOOC materials are used to replace some part of the face-to-face course. Typically, MOOC materials are used to replace the lecture part of the face-to-face course while maintaining the face-to-face seminars.

The second format is the use of MOOCs as an alternative to face-to-face courses. In this case, an open online course is used instead of a full-time course, replacing not only the lecture part, but also seminars along with homework and the final exam. The decision to replace a full-time course with a MOOC is made either at the individual level (the student is assigned the right to choose a course), or at the institutional level (the university administration makes adjustments to the curriculum for the entire study group, including MOOCs instead of a full-time course).

The third format is the use of MOOCs as part of online master's programs. In this case, open online courses are used to construct online master's programs that offer a set of MOOCs for a master's degree.

Revealed formats of MOOCs integration into the educational process of Russian universities have also become widespread in foreign universities, where MOOCs are used both for organizing the blended format, online format and online master's programs (Barak et al., 2016; Milligan & Littlejohn, 2017; Swinnerton et al., 2017; Wang, Hall & Wang, 2019; Eradze et al., 2019).

2. The effect of formats of using engineering MOOCs on students' educational outcomes

The formats (blended and online) revealed as the solution of the first task served as a basis for developing the design of the experimental study. Its results show no significant statistical differences in the educational outcomes of students

completed engineering courses in traditional, blended (MOOC video lectures and face-to-face seminars) and online formats (online course on the national online platform) (Table 1, model with and without covariates; data set "RCT with students"). Students who studied the same engineering courses in three different learning formats, on average, got the same post-test scores, which is consistent with the findings of a neutral effect of learning format on students' achievement shown in meta-analyses studies that compared formats without the use of MOOCs (Shachar & Neumann, 2003; Burns & Ungerleider, 2003), as well as with the findings of several quasi-experiments assessing the effect of MOOC integration (Najafi, Evans & Federico, 2014; Griffiths et al., 2015) . Thus, the first research hypothesis about the negative impact of the online format with the use of engineering MOOCs on the educational outcomes of engineering students is not confirmed.

In addition, the study showed that the online format has a neutral effect on the educational outcomes for engineering students with different levels of academic achievement and self-efficacy (Table A of the appendix, data set "RCT with students"). Thus, students with low levels of academic achievement and self-efficacy are not at risk when studying engineering MOOCs.

Table 1 – The results of the regression analysis of the causal relationship between the learning formats and educational outcomes of engineering students; data set "RCT with students"

	Unadjusted	Covariate-adjusted
Online format	0.589 (2.21)	1.442 (2.28)
Blended format	-1.081 (2.31)	-0.791 (2.35)
Intercept	52.089*** (2.26)	53.074*** (2.41)
University fixed effect	+	+
Covariates	-	+
R^2	14.0%	18.4%

Note:
base group: traditional format; SEs in parentheses; ***p < 0.01, **p < 0.05, *p < 0.1

3. Relationship between formats of using engineering MOOCs and students' satisfaction with the courses

As a result of solving the fourth problem, the following conclusions were drawn. There are no significant statistical differences in the level of satisfaction with the course among students who completed engineering courses in traditional, blended and online formats (Table 2, model with covariates; data set "RCT with students"). However, when comparing shares, there are differences in the level of satisfaction with engineering courses between students of the online format and students of the traditional format. If in the online format, the share of those who were rather and completely satisfied with their learning in engineering courses was 48%, then in the traditional format this share reached 62%. Significant statistical differences are confirmed in the regression model without covariates (Table 2, model without covariates; data set "RCT with students"). Thus, students of the online format (an online course on the national online platform) were slightly less satisfied with their learning experience in engineering courses compared to students of the traditional format. The results are partly consistent with the findings of a meta-analysis that compared learning formats in terms of student satisfaction (Allen et al., 2002).

The second research hypothesis about the negative relationship between the online format with the use of MOOCs and the level of satisfaction with engineering courses is partially confirmed.

Table 2 – The results of the regression analysis of the relationship between learning formats and the level of satisfaction with engineering courses among students; data set "RCT with students"

	Unadjusted	Covariate-adjusted
Online format	-5.01** (2.54)	-5.05* (2.69)
Blended format	-2.03 (2.69)	-2.48 (2.71)
Intercept	64.12*** (2.55)	63.02*** (2.67)
University fixed effect		
Covariates		
R^2	19.9%	29.5%
Note: base group: traditional format; SEs in parentheses; *** p < 0.01, **p < 0.05, *p < 0.1		

4. Fulfilling the need for autonomy and relatedness in an online format with using a MOOC

As our study showed, students of the online format that was based on engineering MOOC were slightly less satisfied with their learning experience. Based on the theoretical model proposed in this dissertation research, we will explain the results through the fulfilling the needs for autonomy and relatedness. The need for autonomy among students of the online format was satisfied, however, in their opinion, it made excessive demands for self-organization. Students of this format were faced with the fact that they had to spend subjectively more effort on self-control over their learning activity. Thus, the flexibility of the online environment is, on the one hand, one of its advantages, providing students with greater autonomy in the learning process (Johnson, Stewart & Bachman, 2015; Vanslambrouck et al., 2018), and on the other hand, a disadvantage, challenges students to exercise a high level of self-control.

The need for relatedness among engineering students of online format was not satisfied due to the absence of an instructor and the possibility of interaction with him, which the MOOC forum cannot fulfill. The students did not use the forum because of its specificity: it does not provide instant meaningful answers to questions. It is no coincidence that studies have shown that only a small proportion

of MOOC participants turn to the forum (Onah, Sinclair & Boyatt, 2014; Rose & Siemens, 2014), and the students of blended format prefer to ask a seminar instructor a question rather than on a forum (Bruff et al., 2013). The absence of an instructor in an online format, according to the students' perception, leads to the fact that they lose the feeling of learning, they begin to perceive the study of engineering courses as a one-way process in which they need to teach themself. Students are ready for such forced independence to study courses that are perceived as simple and unimportant for the profession, because they believe that simply reading the material and watching video lectures will be enough. The humanitarian and socio-economic disciplines were referred to such courses. Courses that are perceived as difficult and important, students are ready to master in a blended format, because it provides an opportunity to interact with the instructor, who can not only immediately give a meaningful answer to the question, but also adapt to the abilities of students, explaining the material from different angles. In turn, MOOCs are perceived as a rigid environment that cannot adapt to the abilities of engineering students, providing course material from only one "recorded" side.

Thus, when completing engineering courses in an online format, students are faced with the need for self-organization for successful studying, which is referred to the fulfilling the need for autonomy, and with the lack of direct interaction with the instructor to get answers to their questions, which is referred to dissatisfaction of the need for relatedness.

5. Learning strategies in the online format with using MOOCs

Despite the dissatisfaction with the need for relatedness and the high demands for self-organization faced by engineering students who completed engineering courses in online format (MOOC on the national online platform), they managed to adapt to the new learning environment, because they got, on average, the same post-test score compared to students of the traditional and blended formats. Using the theoretical model developed in this study, we explain the results through the academic motivation of students.

As the study showed, two learning strategies can be revealed among students of the online format, related not only to academic motivation, but also to confidence in their abilities (data set "Focus groups with students"). The first strategy is to complete engineering courses on your own without looking for workarounds to do the MOOC assignments. This strategy was followed by students with academic motivation and confidence in their ability to cope with the course materials on their own. The second strategy is to complete engineering courses by using workarounds to do MOOC assignments. This strategy was pursued by students who were either initially unmotivated and unconfident in their abilities, or when motivation and confidence disappeared due to problems with competing engineering courses online. The main aim of such a strategy was to find a way to pass the course, which would allow you to get a non-negative grade. The workarounds were to search for solutions of identical problems on the Internet or use several browser tabs to find and substitute the correct answer in tests. Previous research have shown that a lack of intrinsic motivation and the fear of failing online course materials leads to take a superficial approach for learning (Marton & Säljö, 2005; You, 2019), which in turn allows them to complete the courses.

6. The role of types of academic motivation in MOOCs completion

The online format with using engineering MOOCs has proven to be just as effective in terms of student educational outcomes as the traditional (face-to-face) format. However, students of the online format were slightly less satisfied with their learning compared to students of the other two formats due the dissatisfaction with the need for relatedness and the excessive demands for self-organization due to the fulfillment of the need for autonomy. According to the theoretical model, proposed in this research, as well as the results of the choice of learning strategies in the online environment, academic motivation can become one of the important incentives for successful completion of MOOCs, facilitating self-study of the material without looking for workarounds to obtain a satisfactory grade. We test the relationship

between the types of academic motivation and the educational outcomes of students who completed the MOOCs.

The results of the study showed a significant role of academic motivation in obtaining a MOOC certificate while controlling the socio-demographic characteristics of students, their experience, as well as the level of engagement, which is one of the main predictors of success in MOOCs (Crossley et al., 2016) (Table 3, data set "MOOC participants survey"). The chances of successfully completing an open online course were higher for students who take the course out of curiosity and interest in the subject (i.e. due to an intrinsic type of motivation). It is believed that intrinsically motivated students are able to choose more successful learning strategies, cope with difficulties, and demonstrate positive self-perception (Yang, 2014; Littlejohn et al., 2016; Magen-Nagar & Cohen, 2017). In addition, students who aim to get a MOOC certificate (ie, participate due to an external type of motivation) have higher chances of successfully completing a MOOC. This type of motivation shows a negative relationship with students' educational outcomes in face-to-face format (Mitchell, 1992; Vallerand & Bissonnette, 1992; Goldberg & Cornell, 1998). However, in an online environment, due to the lack of external regulators, it can become an additional external incentive pushing students to complete the course. In turn, if students are not motivated to participate in MOOCs (they have amotivation) it significantly reduces their chances to successfully complete the course. This outcome is consistent with the results of previous studies for the entire population of open online courses participants (Khalil & Ebner, 2017). Participants with amotivation may experience a lack of persistence, which is necessary for learning in an online environment (Hart, 2012; Vanthournout et al., 2012).

Table 3 – The results of the regression analysis of the relationship between the types of academic motivation and obtaining a MOOC certificate for students from Russian universities; data set "MOOC participants survey"

Academic motivation	Model for students
Intrinsic motivation	1.38*** (0.165)
External motivation	1.20*** (0.074)
Amotivation	0.75*** (0.066)
Other types of motivation	+
Covariates: the level of engagement	+
Covariates: social-demographic characteristics and learning experience	+
LR chi^2	567.24
Pseudo R^2	0.25
AIC	1698.82
BIC	1797.08

Note:
base groups: lack of these types of motivation; the value of odds ratios are given; SEs in parentheses; *** p<0.01, ** p<0.05, * p<0.1;

Thesis statements

1. MOOCs are used in the educational process of Russian universities in three formats: a) the use of MOOCs in a blended format to replace part of the full-time course; b) the use of MOOCs in an online format to completely replace the full-time course(s); c) the use of MOOCs in an online master's program to hold courses outlined in the curriculum.
2. The impact of learning formats on the educational outcomes and the level of satisfaction can be explained by a theoretical framework based on the postulates of R.J. Vallerand hierarchical theory of self-determination and Giddens' structuration theory. The proposed model allows us to show and explain the effect of learning formats on the educational outcomes and level of satisfaction with the course through satisfaction of the needs for autonomy, relatedness, and academic motivation.
3. The use of engineering MOOCs in blended and online formats does not lead to a significant decrease or increase in the educational outcomes of

undergraduate students majoring in the engineering, technology and technical sciences.

4. The practice of using engineering MOOCs in the educational process has a neutral or negative effect on the level of satisfaction with engineering courses. Delivering engineering courses in online format results in slightly less students' learning satisfaction compared to delivering engineering courses in face-to-face format.
5. When completing engineering courses in online format with using MOOCs, engineering students do not satisfy the need for relatedness, and there are excessive demands for greater independence related to the fulfillment of the need for autonomy. Students perceive online learning as a one-way process, where it becomes necessary to teach oneself in a rigid environment which is unable to adapt to their abilities.
6. Strategies for completing engineering courses in online format are determined by academic motivation and the confidence in the abilities, the absence of which leads engineering students to find workarounds to get a non-negative grade in the course.
7. Academic motivation plays a significant role in the successful completion of MOOCs for students. Intrinsic motivation and an external type of extrinsic motivation significantly increase the chances to successfully complete an online course.

SCIENTIFIC VALUE OF RESEARCH RESULTS

This research is the first experimental study to determine the possibility of using engineering MOOCs in the educational process of Russian universities. It makes a theoretical and methodological contribution by offering an approach to the conceptualization of the learning format based on the postulates of two theories: the hierarchical theory of self-determination by R.J. Vallerand (Vallerand, 1997) and Giddens' structuration theory (Giddens, 2005). The proposed theoretical model allows us to see the key differences between traditional, blended and online formats

and, to show and explain the mechanism of the influence of learning formats on cognitive (educational outcomes) and affective (level of satisfaction) consequences through satisfaction of the needs for autonomy and relatedness, and academic motivation.

CONCLUSIONS FOR EDUCATIONAL POLICY

The research contributes to the development of the practice of engineering MOOCs integration into the educational process, since its results can be used in making managerial decisions regarding options for integrating open online courses into universities. The use of engineering MOOCs complied with the FSES in the RCT allows us to show the possibility of scaling up such studying without making significant changes in the structure of courses, as well as to draw conclusions about the format used in mass practice.

This study showed that, firstly, the use of engineering MOOCs in blended and online formats does not lead to a statistically significant decrease or increase in educational outcomes of undergraduate students majoring in engineering. Therefore, Russian universities can integrate both their own and “foreign” engineering MOOCs developed by third-party organizations into curricula to partially or completely replace face-to-face courses. Thus, universities can remove resource and financial issues related to the development of educational programs for the preparation of qualified engineers by turning to engineering MOOCs launched on national platforms, for example, NOEP, where online courses complying with FSES are posted. In particular, this approach will benefit non-selective universities that are struggling to recruit and retain qualified engineering faculty in the face of a funding gap.

However, when integrating MOOCs in the educational process, it is worth considering their characteristics and pedagogical design, because it can affect the educational outcomes. This study tested the effect of engineering courses created by professors and associate professors of a selective Russian university, one of which got an award in the "Best practice in creating open online courses" nomination.

Therefore, using courses with design and characteristics that differ from those used in the study may lead to different results.

Secondly, when including engineering MOOCs in the curriculum, it is worth focusing not only on the educational outcomes of students, but also on the level of satisfaction, because low satisfaction with a course can lead to finding workarounds to complete it (McCabe, Butterfield, & Trevino, 2012; Costley, 2017). Blended format should be used for courses for specialized occupations, the knowledge of which will allow students to master their future profession. In this situation, it is imperative to maintain the possibility for direct interaction with the instructor, who will answer students' questions and adapt to their abilities while explaining the material, thereby removing the problems of the rigidity of the online environment. In turn, online format should be used for general courses, which students can master on their own without asking questions to the instructor. For engineering students, such courses include disciplines of the humanitarian and socio-economic block.

Thirdly, the integration of MOOC in online format should be done on an individual level in order to leave students the right to choose a course based on their interest in the subject, ease of learning and importance for the profession. This will increase the chances for successful completion of the MOOC. If the flexibility of the environment becomes the main reason for choosing an online course, then students will consider it as a secondary discipline and will prefer to fulfill other obligations that are more important to them, which can lead to the use of a superficial approach for learning (McPartlan et al., 2021). In addition, in order to increase the chances for successful completion of the MOOC, students should focus on obtaining a certificate, so the university should work out the procedure for enrolling in a course with the possibility of mastering it for free.

In case MOOCs are being integrated into the educational process at the institutional level, then before taking an online course, students should form an understanding of its importance for mastering their future profession. This understanding can be developed, among other things, via interventions introduced at the start of the course, when students reflect on the personal value of the course.

Such interventions can address the issue with poorly motivated and unmotivated students who are more at risk of failure when learning online.

DIRECTIONS FOR FURTHER RESEARCH

Further research should be devoted to several topics. Firstly, it is necessary to determine the cognitive and affective consequences of MOOCs completion, which completely or partially replace full-time courses, for students of other majors. The answer to this question will allow us to define courses that can be taught online for students studying on other educational programs. Secondly, it is worth examining the effect of using MOOCs with different pedagogical designs to assess how course characteristics might affect educational outcomes. Thirdly, it is worth assessing the prevalence rate of perceived difficulties related to studying in MOOCs among students, as well as exploring the relationship between learning strategies on MOOCs, self-confidence, and successful completion of online courses. This will test a model which describes a possible relationship between learning strategies, students' psychological characteristics, and MOOC completion. Finally, it is necessary to identify and test the effectiveness of interventions that could remove the difficulties of online learning associated with the absence of instructor and greater self-control for learning activities. The answer to this question will make online learning more effective by turning MOOCs and the online environment to the needs and abilities of learners, including the needs of students with special educational opportunities.

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APPENDIX

Abbreviations used in the paper:

1. MOOC is a massive open online course launched on international or national online platforms, which can be enrolled by any Internet user, regardless of the level of education, experience, gender, age, and social status.
2. NOEP is the National Open Education Platform, which hosts MOOCs of selective Russian universities for various majors.
3. EM is the MOOC "Engineering Mechanics" launched on NOEP. The course workload is 5 credit units. The course program includes sections such as statics, kinematics and dynamics.
4. CMT is a MOOC "Construction Materials Technology" launched on NOEP. The course workload is 4 credit units. Its program includes such sections as iron metallurgy, metal forming and cutting, foundry, welding.

Table A – The results of the regression analysis with interaction effect of learning formats, students achievement and the level of self-efficacy on educational outcomes in engineering disciplines; data set "RCT with students"

	Model with interaction effect for the level of achievement	Model with interaction effect for the level of self-efficacy
Online format*achievement	-0.024 (0.022)	-
Blended format*achievement	-0.018 (0.022)	-
Online format*self-efficacy	-	0.007 (0.018)
Blended format*self-efficacy	-	-0.001 (0.018)
University fixed effect	+	+
Intercept	+	+
Note: base group: traditional format; SEs in parentheses; *** p < 0.01, **p < 0.05, *p < 0.1		