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ORIGINAL RESEARCH ARTICLE

The impact of online learning technology on self-regulation and student success

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The research purpose is to analyse the self-regulation of students who use the massive open online course (MOOC) technology to learn the exact sciences. The sample included 252 students: females were 47%, and males were 53%. The average age of students was 20.08 ± 0.72. The students were divided into two groups: group 1 consisted of students who learnt the Digital singular (nano) optics course online using the MicrosoftTeams platform with teacher's support; group 2 consisted of students who learnt the MOOC course individually. The relationships between self-regulation and academic success were also analysed. The research found that the overall level of self-regulation of students using MOOCs was 40% higher. In students who learnt online using the MicrosoftTeams, the level of self-regulation was average and amounted to 24.96 ± 1.32. In students who learnt the course based on the MOOC technology, the level of self-regulation was high and amounted to 35.02 ± 1.44 ($p < 0.05$). The research of self-regulation shows higher results among the students who learnt using MOOCs platforms: flexibility – 46%, planning – 23% and results assessment – 15%; modelling and programming were no different. The average success score of students after learning the course on the MicrosoftTeams platform was 3.83 ± 0.36, and in the MOOC group, it was 4.43 ± 1.89.

Keywords: availability; education; e-learning; massive open online courses; personalisation; self-regulation

Introduction

In the context of distance learning, it is important to maintain a sufficient level of self-regulation of students and adhere to their success in learning. Digital technologies create favourable conditions for developing an interactive learning environment. They ensure information exchange, improve non-verbal communication and positive perception of information by students as well as benefit learning effectiveness (Lim *et al*. 2021). The use of online educational platforms to optimise the learning process and its full implementation is characterised by relevance (Chen, Xia, and Jia 2020).

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Modern education makes use of different approaches (offline, online and mixed) and tools to transfer theoretical knowledge and practical skills to students (distance, electronic, digital and mobile learning) (Khutorskoy 2019). However, the approach implying the use of massive open online courses (MOOCs) is becoming popular in higher education (Allen and Seaman 2016). The ultra-modern MOOC technology makes it possible to develop an adaptive e-learning environment, supplement the available educational material, use a hybrid (mixed) form of education, increase the number of out of classroom hours, develop discipline flexibility and increase student satisfaction. What is more, MOOCs make learning assessable for all learners through open access to educational resources (Beloglazov and Beloglazova 2018). The use of MOOCs provides an opportunity to increase the level of self-regulation of students, as the curriculum can be designed according to the level of knowledge of students, and tasks for classes are selected according to their interests, skills and abilities, which will contribute to the independent formation of workloads, greater involvement in education and, as a consequence, will lead to higher student success rates (Giasiranis and Sofos 2020).

In modern higher education, MOOCs are used for different purposes. They help educators improve the educational process by ensuring high academic achievements with minimal time and resources spent by both educators and students. Using this technology, students acquire new knowledge and practice their skills with pleasure.

Currently, MOOCs are rolled in the universities of the US and Europe and are considered trendsetters among educational changers and e-learning providers (Monakhov 2019). The active integration of MOOCs is heated by the popularisation of technology available for educational services as well as the autonomy, flexibility and personalisation issues. MOOCs are nowadays on the rise, which is proved by the availability of plenty of materials and papers indexed in the international bibliographic databases such as Web of Science and Scopus (Monakhov 2019).

The main advantages of the modern education system are an integrated approach that includes personalisation (Konobeev *et al*., 2020), customisation of education (Antonenko *et al*. 2020) and the use of smart technologies (Baeva, Khrapov, and Azhmukhamedov 2021). E-learning based on the MOOC is an innovative and progressive learning approach that has an inevitable impact on student learning (Duan 2022). The introduction of MOOCs ensures objectivity, democracy, feedback, digital credentials and the high quality of diverse learning content (Kusov 2019). MOOCs are now widely integrated into modern higher education and considered a part of the classical curricula. They are embedded into blended learning, replace some offline courses and provide e-learning for Master's students. No less often, MOOCs are perceived as an essential element of training, for example, in the case of IT specialities. This strategy is highly valued in such establishments as the University of Minnesota Duluth or Cambridge University (Sundukova and Vanykina 2018).

MOOCs help educators to introduce innovative methods in pedagogy and ensure the quality of education, the quality of information shared with students, the quality of services, the quality of the course material, increase the number of students, and improve the attitude and satisfaction of all participants (Albelbisi 2020). The ground for developing a MOOC is represented by the microlecture learning format, a modern teaching technology that helps educators influence student behaviour, allows modelling and predicting high learning outcomes and has proven its effectiveness, simplicity and the possibility to make students feel satisfied (Wang, Zhu, and Tondeur 2021).

Being an innovative learning means, MOOCs allow thousands of students to study online simultaneously, communicate with each other, work with all course materials,

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and manage their personal autonomy and mobility, which, thus, has a positive effect on the level of self-regulation of students. Insofar, as MOOCs provide free education, they are accessible to a wide student audience, including international students, individuals of different age groups, characteristics and study paces (Zakharova and Tanasenko 2019).

In modern education, the innovative MOOC method requires the participant to have a high level of self-regulation, motivation, computer literacy and other learning-related skills. Self-regulation is an important skill for learning. It exerts a positive impact on students' academic achievements and abilities (the ability to prioritise, make decisions and work as a team member) (Albelbisi, Al-Adwan, and Habibi 2021). The MOOCs platform allows students to maintain the required level of self-regulation, as students can allocate time to complete tasks presented in one place on the online platform, which saves them a lot of time, as they do not need to search for additional materials, and students can track their own academic success through the platform (Reparaz *et al*. 2020).

The MOOC environment exhibits high flexibility that helps people of different ages, qualifications and experiences to manage their studies and use metacognition, motivation and strategic thinking (together with planning, monitoring and assessment) in learning. The evidence from practice shows that independent study, understanding, self-efficacy and Internet navigation skills are interrelated. Moreover, there are close links between motivation to learn and reflection, the desire to learn and the need for reflection, navigation through information, self-management and mobile Internet skills as well as between self-control and self-efficacy (Agonács *et al*. 2020). This research is concentrated on the analysis of self-regulation while turning to MOOCs while studying the exact sciences. Its novelty is explained by the appeal to the current problem of e-learning and the use of innovative technologies in the educational process.

Literature review

In modern higher education, online courses are widely used for different purposes. MOOCs help educators to improve the educational process: MOOCs ensure high academic achievements with minimal time and resources spent by both teachers and students. Using this technology, students acquire new knowledge and practice their practical skills with pleasure.

The perception of MOOCs by learners was examined by Chinese researchers (Wu 2021). The integration of modern digital technologies and MOOCs is possible taking into account the needs of students, their self-motivation, self-regulation and choice of learning. Efficiency depends on the basic psychological needs: autonomy, flexibility, significance and ability. The progress of MOOC learning is positively influenced by discussion forum posts, online text reviews, number of followers, online ratings, online review sentiments, discussion forum posts and likes. The length of the online reviews of MOOC has a negative impact on the number of online views (Wu 2021).

Types of MOOCs such as cMOOCs (based on online courses that are interconnected) and xMOOCs (based on teaching materials provided by universities and other educational institutions) are popular in modern education (Fidalgo-Blanco, Sein-Echaluce, and García-Peñalvo 2016).

The influence of social factors and self-regulation to improve high academic results using MOOCs was analysed by French scientists (Chaker and Impedovo

2021). MOOC has a wide discussion space, allowing participants to interact and share experiences, such as collaborative and self-regulated learning that leads to high academic achievements. Social platforms Twitter and Facebook were used for MOOCs. For the effective use of MOOCs, student autonomy and self-regulation of learning are important tools that help to develop transversal competence. The use of Twitter and Facebook is not effective to drive self-regulated learning and achievements using MOOCs (Chaker and Impedovo 2021).

The analysis of the deconstruction in self-regulated learning using MOOCs was carried out by scientists from Russia (Vilkova and Shcheglova 2021). The researchers describe self-regulated learning as a basic skill for successful education. The research on self-regulation can be analysed using the online Self-Regulated Learning Questionnaire. The main elements of MOOC include the purpose, educational environment, tasks, time management, support and self-assessment. The help function is not provided in the MOOC environment (Vilkova and Shcheglova 2021).

Self-regulation in MOOC learning was examined by scientists from Russia (Shilko and Egorov 2021). Today, Internet technologies, global communications and MOOCs have transformed education into a new environment and promoted metacognition, self-directed learning, self-organised learning, personalised learning, self-regulated learning and personalised learning. Levels of self-regulation differ in high- and low-achieving students. The elements of self-regulation are student interest, learning schedule, self-efficacy and goal orientation. Successful results are influenced by the presence of several of these factors (Shilko and Egorov 2021).

A team of scholars from Morocco (El Kabtane *et al*. 2020) examined how virtual and augmented reality increased MOOCs interactivity. Online and distance learning using the Internet has some limitations such as the lack of interactivity of participants working on the platform and dropouts. A more active position of students is required to solve these problems as well as the desire to understand the learning process. The scholars propose virtual manipulations model (virtual simulations and practical exercises) based on augmented or virtual reality technologies with a large set of manipulations online or offline. This form of training is highly effective and helps to strengthen the practical competences of students (El Kabtane *et al*. 2020).

The implementation of MOOCs in the education of the Gulf countries was analysed by researchers from Kuwait (Mutawa 2017). The annual growth of MOOC applications forced many educational institutions (Stanford University, Massachusetts Institute of Technology, Rice University, Kuwait University) to reconsider their educational approaches and introduce MOOCs into their educational environment. Many elite universities have started using MOOC providers such as Edraak.org, Nadrus.com and Rwaq.org. All MOOC providers have huge bandwidth and have been adapted to meet the needs of students in the Gulf region. The most popular provider was Edraak.org. It was used by 22.8% of users. MOOC has been integrated into traditional education, and students have the opportunity to get quality education at elite Arab universities from home. Today, MOOCs are recognised as an effective online learning tool used by all universities in the Persian Gulf (Mutawa 2017).

The impact of self-regulation on digital literacy was analysed by researchers from Korea (Lim and Newby 2021). The Web 2.0 tool was used to examine the personal learning environment based on instrumental literacy, metacognition self-regulation, planning and time management (a key role). All of these factors have a predictive effect on students (Lim and Newby 2021).

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The influence of self-regulation on university students was researched by Spanish scientists (De la Fuente *et al*. 2018). Among students, the low, medium or high level of self-regulation and improvements in self-regulation lead to positive decisions (positive reassessment, self-talk and help). Negative feelings (a sense that something bad is going to happen, the ability to accept things as they are and personal observation) cause a decrease in self-regulation. Self-regulation is influenced by attentiveness and time (De la Fuente *et al*. 2018).

In Spain, the scholars provide the analysis of self-regulation in education (De la Fuente-Arias 2017). For training, it is recommended to introduce a cyclical model of external and individual self-regulation. The phase of self-regulation depends on self-esteem (positive, neutral and negative reaction to oneself) and causality. Self-regulation of students is facilitated by academic curriculum and disciplines students admire. Self-regulation evokes positive emotions (De la Fuente-Arias 2017).

Spanish scientists (Ion, Cano, and Cabrera 2016) investigated the factors influencing the competences development in students and the innovative assessment procedures in higher education. The satisfaction level of all participants influences improvements in learning, acquisition of competences, awareness and self-regulation. Digital tools influence the competences development but require a certain level of self-regulation (Ion, Cano, and Cabrera 2016).

The role of self-regulation in digital learning was investigated by researchers from Germany (Steffens and Underwood 2008). Self-regulation influences active participation in the learning process and interaction with trainers and consultants. In virtual and asynchronous environments, the phases of planning, monitoring and assessment as well as emotional, individual and social aspects of learning play a pivotal role. The personalisation of learning is effectively applied to vertical and horizontal alignment in education.

Personalisation of learning is flexible and easily integrates with the individual needs of students, their interests, motivation and choice of the way of learning. It helps educators to create and strengthen the interaction among the teacher, the student and the learning process (Steffens and Underwood 2008). At the same time, the research that examines the introduction of online MOOC courses into the Russian higher education system deepens the preliminary research on this issue.

Setting goals

The introduction of MOOCs into higher education ensures the continuity of learning and effectiveness. Students acquire professional theoretical knowledge and practical skills and competences (the ability to think abstractly; analytical skills; the ability to manage the flow of scientific and technical information; physical phenomena modelling; organisation and assessment of experimental research). Moreover, students should understand physical phenomena and their descriptors, perform calculations for the mass, temperature, density, viscosity, current–voltage, frequency, illumination, radiation dose, etc., measure kinematic quantities of motion and perform other functions.

Effective integration of MOOCs into the educational process helps educators to optimise learning and achieve high academic results. Students' self-regulation and understanding play an important role in the integration of MOOCs. Technical education adopts MOOC technology to develop and improve professional knowledge and competences in students.

The research investigates the important issues related to the online courses introduced in Russian higher education. The present research analyses characteristics of

self-regulation in students of Tula State University, I.M. Sechenov First Moscow State Medical University (Sechenov University) and Kazan Federal University using the modern MOOC technology. The research goals were the following: (1) analyse the self-regulation of students; (2) evaluate the relationship between self-regulation and student learning success using the MOOC technology.

The research is important for the scientific community because it examines the relationship between self-regulation and the academic success of students using the MOOC technology. MOOC technology provides the flexibility and accessibility of higher education and ensures its effectiveness. The ultra-modern student is developing in a multi-vector direction and requires modern content from teachers, interesting lessons and time-saving strategies provided by the MOOC technology.

Methods and materials

Study design and sample

The research was conducted at Tula State University, I.M. Sechenov First Moscow State Medical University (Sechenov University) and Kazan Federal University. The design and methodology were developed by a team of authors. The sample consisted of 252 second-year full-time students (females were 47%, and males were 53%, average age – 20.08 ± 0.72).

The Academic Council of the University approved the course *Digital Singular (Nano) Optics*, its Work Programme and Syllabus as relevant for the research. The learning course consisted of 60 h (two European Credit Transfer and Accumulation System (ECTS) credits), including 10 h of lectures, 20 h of practical training and 30 h of independent work of students. At the end of the course, the controlled assessment was performed.

Research tools

The research took place at the Department of Mathematics and Natural Sciences. The sample consisted of two groups of second-year students. The first group (138 students) included students who studied this course distantly using the Microsoft Teams platform. Students had joined lessons conducted by a teacher three times a week for 5 weeks. All students joined the licensed Microsoft Teams platform from different devices (phones, tablets and computers). All lessons were conducted by the department teachers online. The structure of tutor-led MS Teams sessions was represented by online classes conducted by teachers, and students had the opportunity to communicate with teachers, ask questions, etc. Lectures and seminars were key elements of the curriculum. At the same time, the curriculum was developed by teachers using traditional teaching methods, and students did not have the opportunity to choose topics but instead had to attend all classes. The second group (114 students) included students who studied the course using MOOC. Students had access to educational and methodological materials of the course and learnt all the materials independently. Educational and methodological materials included lectures in Microsoft PowerPoint format with audio and up-to-date video content, as well as written assignments from the student to the teacher. The structure of the program, built on the basis of MOOC, provided training through online courses, which students could choose independently according to their level of success, interests and requirements of the educational process. The key elements of the MOOC curriculum were video and audio materials, as well as an interactive forum where students

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had the opportunity to share their knowledge and skills. However, this training did not involve online classes for teachers. The purpose of choosing two groups was to compare self-regulation and the academic success of students using different teaching methods. Accordingly, the difference between these two modes of delivery used in this research was the way information was presented: students who studied with the help of MOOC could independently manage the learning process, choose online courses, did not have seminars and communicate with teachers; students who studied through MS Teams sessions were required to attend lectures and seminars developed by teachers.

The level of self-regulation in students was analysed using Morosanova's psychological questionnaire, which consisted of 46 questions and examined the planning, modelling, programming, assessment of results, flexibility and independence in students (see Appendix) (Morosanova 2004).

The survey was conducted by the authors using Google Forms. The link to the online questionnaire was available from any device for 1 month (from February to March 2021). The questions were closed, accurate and proposed students to choose the correct answer (*True, Probably True, Probably False* and *False*). The respondents read the questions and marked the correct answers (see Appendix). The results were as follows: <23 – the low overall level of self-regulation, 24–32 – the medium level of self-regulation and ≥33 – the high level of self-regulation. The students' learning based on the MOOC technology was based on the five-point scale, where *1* means the student performed poorly; *2* – mediocre; *3* – sufficient; *4* – good; *5* – excellent.

Statistical data analysis

The statistical analysis of the results was performed using the Microsoft Office Excel programme of Microsoft Office. The quantitative data were calculated according to the following formula ($x \pm m$), where x is the arithmetic mean and m is the error of the mean. The results were considered statistically significant at 0.05.

The results analysis aims to identify the relationship between self-regulation and the academic success of students. The following actions were undertaken:

(1) for the *correlation analysis* to analyse the existence and closeness of relationships between the parameters, the Pearson coefficient (r) was used; its values (a module) up to 0.2 mean that the correlation is very weak, the value up to 0.5 means weak correlation, the value up to 0.7 means medium correlation, the value up to 0.9 means high correlation and the value over 0.9 means very high correlation;

(2) the multiple regression analysis means the closeness of the relationship in the experimental data.

Study limitations

The research did not include students of the Faculty of International Relations, psychology and education, socio-philosophical sciences and mass communications, management, economics and finance because the standardised educational programmes have the other academic disciplines, work programmes and syllabuses.

Ethical issues

This non-therapeutic research met the Declaration of Helsinki: Ethical Principles for Medical Research Involving Human Subjects. The participants were informed about

Table 1. The self-regulation level of students.

No	Self-regulation scales	1 group 138 students Microsoft Teams+ Support by a teacher	2 group 114 students MOOK+ Individual learning
1	Planning**	4.98 ± 0.86	6.11 ± 0.98
2	Modelling*	4.63 ± 0.32	5.02 ± 0.44
3	Programming*	6.81 ± 0.54	6.97 ± 0.17
4	Results assessment**	6.11 ± 0.74	7.03 ± 0.34
5	Flexibility**	6.11 ± 0.71	8.93 ± 1.02
6	Overall level of self-regulation**	24.96 ± 1.32	35.02 ± 1.44
Self-regulation level		Average	High

*$p > 0.05$, not significantly different; **$p < 0.05$, significantly different.

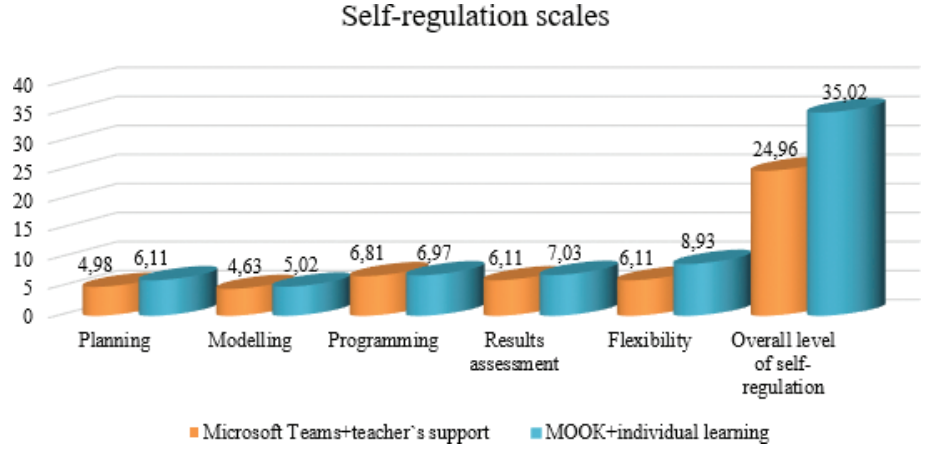

Figure 1. The scales of self-regulation of students.

the aims and methods of scientific work. The participants signed written informed consent and agreed to participate in the research. The participants' anonymity was protected. There was no conflict of interest. The University Bioethics Committee permitted to conduct the research in the 2020/2021 academic year.

Results and discussion

The results revealed that the overall level of self-regulation of students in group 1 (Microsoft Teams + teacher's support) was average and amounted to 24.96 ± 1.32, and in group 2 (MOOC + independent learning), the level of self-regulation was high and amounted to 35.02 ± 1.44 ($p < 0.05$). The analysis of the level of self-regulation shows that the modelling and programming do not differ in the two groups. The other scales show significantly higher values in group 2 (MOOC): flexibility – by 46%, planning – by 23% and results from assessment – by 15% (Table 1).

The results of the analysis show that the overall level of self-regulation was higher by 40% in group 2 (MOOC) students (Figure 1).

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After the course completion of *Digital Singular (Nano) Optics*, the training was assessed. The average success score in group 1 was 3.83 ± 0.36, and in group 2 – 4.43 ± 1.89 (significantly higher by 15.7% in group 2). The duration of the course for students in group 1 was 5 weeks, for group 2, the duration was 4 weeks (in 20% less than in the first group).

Using the research data, a multiple correlation-regression analysis was performed. As a performance indicator (Y), the average score of students' success was calculated. The indicators of planning (X1), modelling (X2), programming (X3), assessment of results (X4), flexibility (X5) and the overall level of self-regulation (X6) were considered as factors that potentially affect the academic success. Assessing the relationship, correlations on the Chaddock scale X1, X4, X5 and X6 were selected for further regression analysis. These associations were positive and significant. The coefficient of determination was 0.862, that was, 86.2% of the value of success indicators. It means the dependence of planning, results assessment, flexibility and the overall level of self-regulation. The Y-intersection coefficient was 2.4100824. It means that if all parameters are equal to 0, then Y will be 2.4100824, that is, other factors not described in this model also affect the success. The results of the variance analysis show the significance of the Fisher's test (p). The value equals 0.021547941, and it means that independent variables have an impact on the dependent variable, and the coefficient must be taken into account. The model is significant because the significance level of the Fisher's test is less than 0.05. The research found that there was an average positive relationship between the success of students and their ability to plan, evaluate results, be flexible and meet overall self-regulation functions: the higher the scale of self-regulation, the higher the academic success of students. MOOC can significantly increase the overall level of students' self-regulation as well as students can study individually, choose online study courses, track their progress and choose a convenient time to study.

A team of scientists from Chile, the USA and Spain (Guerrero, Heaton, and Urbano 2021) investigated the possibilities of developing universities using MOOCs technology. The research examines the relationship between traditional education (the quality of teaching, the quality of research and the quality of administration) and the possibilities of the university's entrepreneurial strategy (focus on innovative MOOC methods). MOOCs had a positive impact on learning outcomes in business, humanities and science. The present research revealed a positive impact on the proposed strategy on the exact sciences (physics) (Guerrero, Heaton, and Urbano 2021).

The impact of MOOCs on learning outcomes was analysed by US scientists (Janelli and Lipnevich 2020). Four groups of students took part in the research: students of the first group did not receive feedback from instructors, students of the second group received basic correct or incorrect feedback, students of the third group received detailed feedback and the fourth group was the control group. The results showed that feedback did not influence student learning outcomes, and students who completed MOOCs had positive learning outcomes (Janelli and Lipnevich 2020). The same conclusions were made by the present research. Moreover, the increase in learning outcomes by 15.7% was identified.

The acquired benefit (functional value) for students who learnt using MOOCs was examined by Brazilian scientists (Feitosa de Moura *et al*. 2020). MOOCs are actively used as an alternative learning model for integration into blended learning. At the Brazilian University, the following aspects were investigated: pedagogical and rationale approaches; instructional design for integrating; perceived quality and value by the students. The research describes that MOOCs help educators to replace some

face-to-face lessons, increase the number of students per teacher and make the academic discipline more attractive to students. The results also show that the functional value and perception of this learning model by students lead to an average score in the training of 4.53 (the 7-point scale) and an average score of 4.43 ± 1.89 (the 5-point scale). The Brazilian research unveils that MOOCs have a positive impact on the pedagogical approaches, reduce costs, and improve the quality and results of the disciplines learnt by students (Feitosa de Moura *et al*. 2020).

Student satisfaction and intention to use MOOCs were analysed by researchers in Spain (Pozón-López *et al*. 2021). The research highlights that students' choice of a particular course depends on its simplicity, content diversity, interactivity, motivation, entertainment, quality, usefulness, emotion and satisfaction. The results show that the strongest predictors to use MOOCs are the pleasure and autonomy (flexibility) of the student (Pozón-López *et al*. 2021). In the present research, planning and flexibility are the elements of learning that help student to develop a high (35.02 ± 1.44) level of self-regulation.

The impact of self-regulation on a MOOC environment and student achievement has been discussed by Greek scholars (Giasiranis and Sofos 2020). In modern education, MOOCs help universities to improve the educational services and open assess to education to a large number of students. The research examined the extent to which self-regulation affects academic performance. The research consisted of two groups: control and experimental groups. It was found that 80.2% of students completed MOOCs achieving high learning outcomes. In the present research, academic performance in the experimental group that used MOOCs was significantly higher than in the other group. The authors of the experiment in Greece suggest that self-regulation is not the only factor influencing successful knowledge acquisition (Giasiranis and Sofos 2020). The results of the current research confirm this issue. The value of success rates (86.2%) depends on the overall level of self-regulation, and other independent variables also affect academic performance.

A team of scholars in Spain analysed self-regulation in MOOCs (Charo, Maite, and Guillermo 2020). The authors examined self-regulating learning strategies and other variables: effectiveness, interaction, motivation and sociodemographic characteristics. In the research, the authors used an adapted self-regulation questionnaire. The present research used a questionnaire as a research tool. Students who used MOOCs completed their training successfully and had a higher level of self-regulation. Their effectiveness of training was also higher (Charo, Maite, and Guillermo 2020). The current research identified the same trend: students who used MOOCs have 40% higher levels of self-regulation and 15.7% higher academic success.

Self-regulated learning in MOOCs was analysed by a team of scientists from Spain, Chile, Ecuador and France (Alonso-Mencía *et al*. 2019). They suggest that an important factor for MOOC students is the autonomy of learning and the level of self-regulation. Students with low levels of self-regulation have non-specific goals and often feel frustrated. Students with a high level of self-regulation perceive MOOCs as a non-standard learning environment, have specific learning goals and have high self-satisfaction. Students with a low level of self-regulation are less flexible in education than students with a high level of self-regulation (Alonso-Mencía *et al*. 2019). The present research revealed the same: the flexibility of students with an average level of self-regulation was 6.11 ± 0.71, and with a high level of self-regulation, it was 8.93 ± 1.02 (significantly higher).

Russian scholars focus on the relationship between self-regulation and the professional perspective of students (Zavodchikov and Manyakova 2018). The introduction of digital technologies and changes in professions require the individual approach to each student

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and self-regulation skills. The research used the *Styles of self-regulation of behaviour* questionnaire by Morosanova. The same methodology was used for the present research. The correlation analysis revealed the relationship between self-regulation and professional orientation: the lower the level of self-regulation, the lower the level of planning. The authors of the current research came to the same conclusions and stated that the lower the planning, the lower the self-regulation. Factors such as planning, modelling, programming, assessment results and flexibility of the overall self-realisation: the lower their values, the lower the level of overall self-realisation (Zavodchikov and Manyakova 2018).

The Russian scientist (Nartov 2017) researched the self-regulation of students. Self-regulation of students is considered important for the academic success of students by which individuals control and reflect on their learning. The research analysed the core factors and described differential-psychological aspects of self-regulation. The scholar discussed that self-regulation maintained a positive relationship between volitional regulation of emotions and the level of meaningfulness of life, as well as self-control and academic success among students. The present research proved the relationships (correlation) between self-regulation and learning success. The Russian scholar claims that self-regulation depends on life perception, the importance of the learning course for the student, the learning direction and gender (Nartov 2017).

Conclusions

Today, modern digital technologies and MOOCs are a part of global higher education. MOOCs make it possible to use interactive tools and modern content in learning and make the student an active participant in the learning process. It allows students to acquire and improve practical competences and develop professional skills.

The sample consisted of two groups of second-year students: one group included the students who learnt the course *Digital singular (nano) optics* online on the Microsoft Teams platform with the teacher's support. The course lasted for 5 weeks. Group 2 consisted of students who learnt the course based on MOOC technologies and provided educational and methodological materials to students. The students learnt all the materials independently. The research examined the levels of self-regulation following the Morosanova method and assessed the academic success of students after the course. Moreover, the research examined the relationship (correlation) between self-regulation and the academic success of students.

The research highlighted that the overall level of self-regulation of students was 40%, and it was significantly higher in group 2 (MOOC). In group 1 (Microsoft Teams and support by a teacher), it was average and amounted to 24.96 ± 1.32, in group 2 (MOOC + independent learning), the results were high and amounted to 35.02 ± 1.44 ($p < 0.05$). The results of the level of self-regulation of students revealed that the values in group 2 (MOOC) were significantly higher: flexibility was higher by 46%, planning was higher by 23% and results assessment were higher by 15%; the processes of modelling and programming in groups did not differ. The average success score of students after the course *Digital singular (nano) optics* in group 1 was 3.83 ± 0.36, and in group 2 – 4.43 ± 1.89 (15.7% significantly higher in group 2). The duration of the course for students in group 1 was 5 weeks, while in group 2, it was 4 weeks (20% less).

The results of multiple correlation-regression analysis showed that there was an average positive relationship between the success of students and their self-regulation: the higher the self-regulation, the higher the academic success of students. MOOC technology can significantly increase the overall level of students' self-regulation.

The research rationalises the learning process in technical educational institutions and introduces new MOOCs to learn technical disciplines. The scholars offer recommendations on how to improve the learning process and replace face-to-face courses with MOOCs. They suppose that MOOCs will increase the number of students per teacher and ensure students' academic achievements. The proposed approach helps students acquire knowledge and develop professional competences and practical skills. Future research is needed to investigate the drivers for increasing students' self-regulation and motivation. The research recommends changes to the Work Programmes and Syllabuses of technical disciplines to foster the development of technical knowledge and skills in students.

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Conflict of interests

Authors declare that they have no conflict of interests.

Data availability

Data will be available on request.

Authors' contributions

All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by KM and NK. The first draft of the manuscript was written by VS. All authors read and approved the final manuscript.

Ethics approval

This non-therapeutic research met the Declaration of Helsinki: Ethical Principles for Medical Research Involving Human Subjects. The participants were informed about the aims and methods of scientific work. The participants signed written informed consent and agreed to participate in the research. The participants' anonymity was protected. There was no conflict of interest. The University Bioethics Committee permitted to conduct the research in the 2020/2021 academic year.

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Appendix

Dear respondent!

We ask you to participate in the scientific research supported by the Department of Physics of the Kazan Federal University.

Please mark the answer with a tick or another symbol that is convenient for you.

#	Question	Answer			
		True	Probably true	Probably false	False
1	I like to develop my future plans in details.				
2	I love adventures, I can take risks.				
3	I always try to arrive on time, but I am often late.				
4	I adhere to the motto: Listen to advice, but follow your heart.				
5	I often rely on my skills to respond to the situation and do not forecast actions or the unseen future.				
6	Individuals around me admit that I am not critical enough of myself and my actions, but I do not always notice this.				
7	Before tests or exams, I usually feel that I need 1–2 more days to prepare.				
8	To feel confident, you need to know where you are going.				
9	It is difficult for me to force myself to redo something, even if the quality does not meet my expectations.				
10	I do not always notice my mistakes, individuals around me do it.				
11	The transition to a new system of work does not cause me any inconvenience.				
12	It is difficult to change my decision, even if my close friends ask me for that.				
13	I do not consider myself a person whose life moto is: measure seven times, cut once.				
14	I cannot stand it if others take care of me and decide something for me.				
15	I do not like thinking too much about my future.				
16	I feel uncomfortable in new clothes.				
17	I always plan my expenses in advance, I do not like to make unplanned purchases.				
18	I avoid risk, I do not cope well with unexpected situations.				
19	My attitude to the future often changes: sometimes I make bright plans, sometimes the future seems gloomy to me.				

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#	Question	Answer			
		True	Probably true	Probably false	False
20	I always try to think how to achieve a goal before I take actions.				
21	I prefer to preserve independence even from close individuals.				
22	My future plans are realistic and I do not like to change them.				
23	In the first days of vacation (holidays), when you change your lifestyle, you always feel discomfort.				
24	With a large amount of work, the results quality inevitably suffers.				
25	I love life changes, change of surrounding and lifestyle.				
26	I do not always notice changes in circumstances and suffer because of this.				
27	It happens that I insist on my decision, even when I am not sure it is correct.				
28	I like to follow a plan for the day.				
29	Before sorting-out the relationship, I try to develop several approaches to solve a conflict.				
30	In case of failure, I always look for what was done wrong.				
31	I do not like to tell anybody about my plans, I rarely follow advice.				
32	I consider the principle reasonable: you need to get involved in the battle, and then look for means to win.				
33	I like to dream about the future, but this is more fantasy than reality.				
34	I always take into account the opinion of my colleagues about myself and my work.				
35	If I work on something important for myself, I can work in any environment.				
36	To anticipate important events, I try to foresee the consequences of my actions in a particular situation.				
37	Before starting to work on a particular issue, I need information on its implementation and circumstances.				
38	I rarely quit my job that I have started.				
39	I may fulfil my obligations carelessly in case of fatigue and poor health.				

#	Question	Answer			
		True	Probably true	Probably false	False
40	If I believe that I am right, then I care little about the opinions of others.				
41	They say that I scatter, I cannot differentiate the important and non-important information.				
42	I do not know how to plan my budget in advance.				
43	If it was not possible to meet the quality, I strive to redo the work, even if others do not care.				
44	After resolving a conflict situation, I return to it, double-check the actions and the results.				
45	I feel easy with new people and interested in new acquaintances.				
46	Usually, I react negatively to any objections and I try to think and do everything on my own.				

Thank you for participating in the research!

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