THE COMPLEX OF QUALITY MANAGEMENT MODELS FOR ONLINE EDUCATIONAL COURSES

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Yatsenko R. M., Yakovliev A. A. The Complex of Quality Management Models for Online Educational Courses

Due to the COVID-19 pandemic spread over the world and military operations in Ukraine, the issue of the importance of quality control of online courses has moved from the category of «moderately necessary» to the category of «necessary here and now». Online learning is a very large topic that just cannot be covered by one single paper or study, considering the nature of educational services, their stretching in time and huge variability, combined with the factor of the unique approach of individual teachers to the presentation of the material. Hence, the study designates online courses as one of the measurable entities of online learning, both in terms of statistical information that can be collected from the electronic implementation of online courses on the relevant platform, and owing to the short life cycle of a single online course, allowing for more feedback and the impact adjusted in order to improve. The study presents a complex of mathematical models that provides both a numerical characteristic of the quality of an online course and an algorithm for choosing options for improving the quality of the course, which will reduce the labor intensity of developing and maintaining online courses and increase their attractiveness both in the commercial environment and in the environment of non-profit education. Should commercial use be the case, the proposed set of models can be based on indicators that are important for maximizing profits and minimizing costs, pushing technical quality indicators aside, or vice versa: it would be more necessary to assess quality at all possible levels for courses that are not aimed at direct profit. Thus, the proposed complex of models can become a tool that will help improve the quality of online courses, based on objective indicators; allocate the most ineffective courses; adjust the attention of course developers depending on the purpose when creating a course.

Keywords: online courses, quality of online courses, online learning, mathematical models, complex of quality management models.

Fig.: 1. Bibl.: 14.

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Яценко Р. М., Яковлєв А. А. Комплекс моделей управління якістю освітніх онлайн-курсів

У зв'язку з пандемією коронавірусу у світі та військовими діями в Україні питання важливості контролю якості онлайн-курсів перейшло з розряду помірно необхідного в розряд необхідного тут і зараз. Онлайн-навчання – дуже велика тема, яку просто неможливо охопити однією статтею або дослідженням через природу освітніх послуг, їхню розтягнутість у часі та величезну варіативність у поєднанні з фактором унікальності підходу окремих викладачів до подачі матеріалу. Тому в даному дослідженні будуть розглядатися лише онлайн-курси як одна з вимірних сутностей онлайн-навчання як з точки зору статистичної інформації, яку можна зібрати з електронного втілення онлайн-курсів на відповідній платформі, так і в силу короткого життєвого циклу одиничного онлайн-курсу, що дозволить частіше отримувати зворотний зв'язок і коригувати його вплив з метою поліпшення. У дослідженні представлений комплекс математичних моделей, що дозволяє як чисельну характеристику якості онлайн-курсу, так і алгоритм вибору варіантів поліпшення якості курсу, що дозволить знизити трудомісткість розробки та підтримки онлайн-курсів та підвищити їхню привабливість як у комерційному середовищі, так і в середовищі некомерційної освіти. У разі комерційного використання запропонований комплекс моделей може спиратися на показники, важливі саме для максимізації прибутку та мінімізації витрат, відсуваючи показники технічної якості вбік, або ж навпаки, – курси, що не націлені на пряме отримання прибутку, будуть більше зацікавлені в оцінці саме якості на всіх можливих рівнях. Таким чином, запропонований комплекс моделей може стати інструментом, який допоможе поліпшити якість онлайн-курсів, спираючись на об'єктивні показники; виділити найбільш неефективні курси; скоригувати увагу розробників курсу залежно від мети при створенні курсу.

Ключові слова: онлайн-курси, якість онлайн-курсів, онлайн-навчання, математичні моделі, комплекс моделей управління якістю.

Рис.: 1. Бібл.: 14.

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ЕКОНОМІКА ОСВІТА І НАУКА

With the start of the coronavirus pandemic in 2020, distance education began to actively gain weight in the global education market. Both private and public educational institutions began to use distance education technologies widely, while the number of available mass online educational courses (Massive open online courses, MOOC) continues to grow.

According to Class Central, in 2020, the number of mass education online courses' students exceeded 180 million, and in 2021, the number of MOOCs' students increased to 220 million, which indicates a direct need for online education in general and online courses in particular in today's environment [1].

Moreover, the growth of investments in online education did not stop with the end of the quarantine, as could be assumed at the beginning of the pandemic. Global trends show the continued growth of the online education market, for example, ReportLinker researchers in their report "Worldwide Digital Education Sector Analysis" for 2023 say "The global market for E-Learning estimated at US$332.6 Billion in the year 2022, is projected to reach a revised size of US$686.9 Billion by 2030, growing at aCAGR of 9.5%" [2].

The indicators above clearly show the prospects for the online education market development. But it is necessary to consider the phenomenon of online education in parts, due to the fact that the issue is complex, and it is impossible to cover it in one study, since in recent years the tools used in online learning are dynamically developing, which positively affects distance education, new approaches are emerging and basic methods of using online education are being formed. Therefore, this study will consider the quality management processes of online educational courses as independent resources of distance education.

If we consider the importance of online educational courses, the following aspects can be highlighted (based on statistical data collected by "markinstyle.co" [3]):

✦ 43% of students use online learning platforms while studying which positively reflects on their grades;
✦ 81% of students say online learning has helped them improve their grades;
✦ 65% of investigated universities support and encourage additional online learning.

On the "devlinpeck.com" portal, you can find the following statistical information on online courses for 2024:

✦ worldwide, 49% of students have completed some sort of online learning;
✦ online learning is the fastest-growing market in the education industry – it has grown 900% since its creation in 2000;

✦ 70% of students say online learning is better than traditional classroom learning;
✦ the number of online learning users is expected to increase to 57 million by 2027;
✦ 80% of businesses now offer online learning or training solutions;
✦ online learning can increase student and employee retention to as much as 50%;
✦ online learning can reduce the time needed to learn a subject by 40% to 60%;
✦ the online learning industry is projected to be worth more than $370 billion by 2026;
✦ online learning and training can improve employee performance by 15% to 25% [4].

In these statistics, online courses are considered as a supplement to basic education, but in the case of Ukraine, where military operations are taking place, online educational courses become one of the main tools to support the educational process.

Unfortunately, both in the world and in Ukraine, established approaches to quality management of online educational courses have not yet been formed due to the complexity of this phenomenon. Considering the global trends in the use of online education in general and the urgent need of Ukraine in particular, such a system or a mechanism that allows to standardize the evaluation of the course's quality and help to improve its quality will positively affect both the education system as a whole and its individual educational resources in particular.

There can be many solutions to such a problem, and the task of this article is to propose one of them, namely a complex of quality management models for online educational courses, which is based on the use of feedback as a source of subjective perception of the online course, and on the use of statistical indicators as a source of the objective state of the online course. The proposed complex of models will use both system modeling approaches in general and specific methods and models of economic-mathematical modeling, the description of which is given below.

Literary review

The issue of the online courses' quality was relevant throughout the development of the information technologies field. Considering the experience of foreign researchers in the direction of the quality of both online education and online educational courses, one noticeable and important trend can be noted. In order to reveal the essence of this trend, scientific works will be given below. This question was studied by Judy Foster Davis, Matthew H. Sauber, Elizabeth A. Edwards (2011) [5], that successfully applied the SERVQUAL model to the University of Michigan. Silvia P., Samuel O. I.,

Georgeta-Madalina Meghisan-Toma, Roxana Maria Bădîrcea (2023) [6], that proposed an interesting model for evaluating the quality of online courses, based on the Romanian experience. Richard Watermeyer, Tom Crick, Cathryn Knight, Janet Goodall (2021) [7], dealing with UK cases. Rizky Firmansyah, Dhika Maha Putri, Mochammad Galih Wicaksono, Sheila Febriani Putri, Ahmad Arif Widianto (2020) [8], who talked about the Indonesian experience.

Considering studies that have appeared as a result of the challenges thrown at the world by the COVID-19 pandemic, we can see a tendency to consider the readiness of the education system to go online within the borders of a certain country, and this selectivity is understandable if we start from the fact that countries have different:

✦ access to technical support;
✦ traditions and requirements for the educational process;
✦ social norms.

In this work, it was also not possible to abstract the national nature of distance online education (this issue is particularly acute in the modern realities of Ukraine), because with the onset of the pandemic, when state educational institutions began an active transition to distance education technologies, the Ministry of Education and Science of Ukraine allowed educational institutions to independently design distance education, educational courses and evaluate their quality [9].

Complex of mathematical models

Considering the inexperience and weak preparation of both teachers and students for the distance education process, the quality of the developed courses was heterogeneous, and in connection with the popularization of distance education and the military conflict, which does not allow to restore stable classroom classes, the importance of distance education for Ukraine is difficult to overestimate.

This article will propose a complex of models that should evaluate the online educational course's quality and offer the course developer possible solutions for its improvement based on statistical data and expert evaluations. The proposed ideas and models will if possible be freed from the influence of national factors in order to make this work suitable for any region.

The models that proposed below can be used both to improve the quality and competitiveness of educational courses on commercial online educational platforms and for online resources embodied in online courses used by public educational institutions.

When analyzing the models, there will be no emphasis on a separate component in the form of eco-nomic efficiency when used for commercial educational platforms, but these qualifiers will only be used when they appear for the first time.

Description of the complex of models

The proposed set of quality management models for online educational courses (shown in *Fig. 1*) can be divided into 3 stages, the actions of which are combined in the diagram into logical blocks:

✦ *classification stage* – is the first stage where we need to divide courses into clusters on statistical indicators of online educational courses (such indicators as the number of course registrations, the percentage of course completion, the time spent on the course, etc.). This allows to highlight both potentially successful courses, the structure and content of which can be called effective, and potentially problematic courses that need more attention;

✦ *analysis stage* – on the second stage we need to conduct a statistical analysis of separate courses. This analysis will use both an expert assessment of the course's quality, namely feedback questionnaires for evaluating the quality of the course by its users as well as statistical information within the course, for example, the time spent interacting with different elements of the course, the frequency of visits to individual elements or completion of tasks on time. After analyzing the statistical data, the results will be transferred to the control unit;

✦ *management stage* – on this stage we need to analyze both statistical data from the second stage and the results from the cluster division on the first stage. Using the obtained data the online course developer will receive recommendations for improving the online course. The system itself will not have a direct impact on the online course and the results of its work are of a recommendatory nature.

Description of the first stage

The first stage should prepare the ground for research and divide the courses into initial clusters based on factors common to all online courses. Depending on the selected criteria, the clustering result can be interpreted appropriately.

For example, when choosing the following criteria: the number of registrations, the number of course completions, the average/mode/median of course users' ratings and the number of hours spent on the course - the formed clusters will be able to preliminarily talk about both the retention of users by the course and the potential financial payback of the courses.
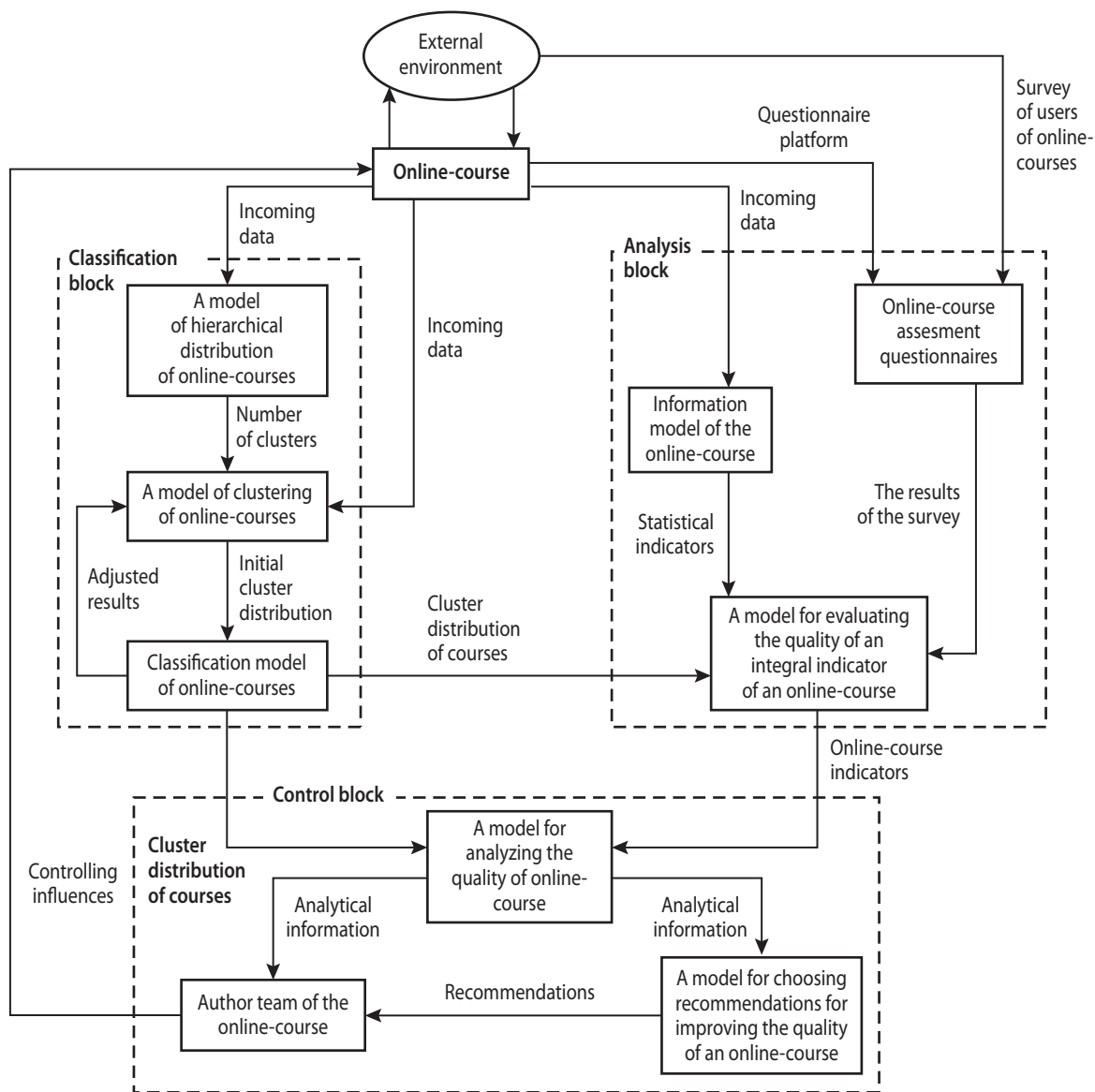
Fig. 1. A complex of models for online courses quality management

Another example of a set of criteria can be the parameters of the load on the platform on which the course is hosted, such as: the memory required for the course, the number of simultaneous connections to the course, the degree of use of all elements of the course and the average activity of students when using the course – according to these parameters clusters will divide courses by the level of usage activity despite financial benefit or user retention.

In this complex of models, the assessment of the usage activity is part of the second stage. At the first stage, clusters will be distinguished based on economic efficiency. This is due to the importance of identifying potentially problematic courses, recommendations for improvement of which should be given first.

Clustering and classification tasks can be solved by a huge number of math modeling methods, but in this study the choice was made in favor of:

✦ *fuzzy k-means method* [10] – modification of the classical k-means method, the main difference of which is not the unambiguous assignment of the object to one of the clusters, but the probability that the object belongs to the specified cluster. This method is most suitable for research in connection with the complexity of unambiguous judgment in conditions of similarity of data;

✦ *hierarchical clustering method* [11] – is the basis for the fuzzy k-means method and is necessary for the initial determination of the number of clusters;

✦ *decision tree* [12] – a classification model that will allow assigning new courses to existing clusters based on their statistical data.

If you change the set of characteristics proposed at the beginning of the stage, then it will be possible

to obtain clustering according to other important parameters (at the beginning an example of assessing the technical condition of courses was also given), the first stage is the most important from the assessing economic efficiency point of view, it is at this stage that you need to evaluate which courses it is necessary to develop and which should be removed.

Depending on the ultimate goal of the platform with educational online courses (whether it is a commercial or non-profit institution) and the technical capabilities for collecting information, you can build clusters that display both economic and technical efficiency and, based on the analysis, identify courses that should get attention first. The obtained clusters can be interpreted from different points of view and levels of management of the learning platform (the set of criteria given at the beginning will be used as an example):

+ if we take the level of the course development team, then, using this analysis, we can glean information about which courses of a similar or related focus are more interesting for users, which allows us to analyze and formulate possible ways for further development of the course;
+ considering the level of platform managers, then, from cluster analysis it is possible to determine the most popular areas for online education, identify both leaders and outsiders in their educational areas and optimize the costs for developing online courses based on the data obtained;
+ another option could be a platform owner's level where the owner provides the technical part for the functioning of the courses and this analysis will allow him to optimize the costs and resources allocated to the support for the functioning of online courses.

But the main problem of this stage is the high individualization of each course. This is due to the fact that the course developer has his own quality criteria that he applies to the developed course, therefore a conditionally high-quality course with high revenues and time spent on the course may actually be overloaded and users will be forced to spend time solving technical problems.

In this regard, each chosen course should be spent time on for a more thorough analysis of its strengths and weaknesses.

Description of the second stage

The strengths and weaknesses of the course can be evaluated from several points of view: expert assessment of teachers, expert assessment of course users, labor costs during course development and expected benefit from the course, statistical information about the course.

When the quality of the course as a separate educational unit will be evaluated at the second stage, the evaluation of the quality of the course will be carried out from the following points of view:

+ expert assessment of course users;
+ statistical information about the course.

The first point of view is necessary because the long-term satisfaction of the course user's needs is one of the main quality criteria of the educational service, the material implementation of which is the online course.

Speaking about receiving information from course users, the most effective form of feedback is questionnaires, which users can fill out, expressing their opinion on various elements of the course, but when compiling feedback questionnaires we should take into account that the user may start answering averaged options if the questionnaire is too detailed or give questionable assessments in case of too complex questions.

In order to avoid such a situation, it is suggested to develop several questionnaires that will be responsible for different aspects of the online course. In this way the questionnaires will not be oversupplied with details and the user of the course will be able to choose the most relevant aspect of the course and devote more time to it.

In this way the evaluation of the course by its user will be the most complete and meaningful, which will allow to conduct an analysis from the course user's satisfaction point of view. But this is not enough for an objective assessment because users of the course have their own preferences in the learning style, design and sometimes the technical component (although the most general problems of the course will be easier to detect, because they will disturb many of its participants). In addition, all users of the course will have the opportunity to take a survey, even those who took the course irresponsibly and carelessly, which will also affect the grades.

In order to be able to get a more objective assessment, it is also necessary to take into account factors that are not influenced by subjective preferences and prejudiced attitude. Such factors can be statistical indicators of online courses, which reflect both the activity of individual users and course elements, and describe the course in general.

This analysis will be useful for the course developer to determine the topics and aspects that are most interesting to users (for example, course users actively interact with materials on neural networks) or, on the contrary, the most problematic to understand and

work with (for example, users of the course have problems configuring the software and spend much more time on the instructions than in other courses).

Such information can also show both sharp differences between the planned complexity and the actual one (for example, the planned test execution time is 20 minutes but users complete it in 7), and low activity when interacting with certain tasks (for example users do not use methodological recommendations to complete the task), which will allow the course developer to correct such problems.

Using the statistical indicators of the educational online course, the following features of the considered course can be identified:

+ *points of attraction for course users* – the most actively used interactive tasks, educational materials and links to external sources. Such information allows you to determine successful decisions made during the development of the course, or on the contrary to highlight points that cause problems for users of the educational online course;

+ *point of repulsion for course users* – in analogy with the previous point, points of repulsion are the least actively used materials in an online educational course. This may be the result of some "detachment" of educational and methodical materials from the general topic of the course, low flexibility of interactive tasks, or an unsuccessful choice/complete absence of materials for self-education;

+ *the dynamics of attendance and active interaction with the educational online course elements* – this statistical indicator is applicable both to the activity of the course as a whole and to individual users. According to the obtained data, it is possible to understand how successful the distribution of the load on the educational online course is and whether it is necessary to review the distribution of activity. Activity indicators for individual users of the course are needed to control the quality of feedback on the questionnaires, which were discussed earlier – if the activity distribution peaks before the course closes, and prior to that the activity rates were lower than the average for the duration of the course, then the course developer can reduce the impact of feedback from the course user in that particular case.

The statistics themselves may reflect the main trends, but they do not reflect the success of the course in performing its functions. Most educational online courses have a plan according to which they are built – the number of ECTS credits, distribution of tasks by academic weeks and distribution of points for tasks, distribution of different types of work. These parameters are an excellent basis for the statistics that are collected, and a comparison of the planned indicators with the actual ones can show how well the course fulfills the stated technical requirements.

After processing statistical indicators, all data, evaluations of feedback questionnaires and processed statistical indicators are collected into a single integrated indicator that reflects the current assessment of course quality. In the future, the quality of the online course evaluated using an integral indicator and the data obtained in the first two stages will be sent to the control unit in the third stage.

Description of the third stage

At the third stage, the obtained data are evaluated dynamically, if there are data for previous time periods, and the selection of the most relevant actions to improve the course is carried out using decision-making methods.

The first step is to use the online educational course evaluation quality model. If at the first stage the courses were considered as separate clusters, and at the second – separate courses, then the models of the third stage should take into account both the results of the general clustering with the risk groups highlighted there, and correct and expand the results with the information obtained at the second stage (it may happen that the integrated indicator may include the cluster to which the course is assigned, or it may not. It depends both on the platform and on the goals of using the complex of models, so the third stage will in any case take into account the results of both previous stages).

At the same time, a conflict may arise between the stages due to the fact that the global and local assessment of the course parts may differ. In such a situation, it is important to understand what course the model works with.

In the case of a course primarily created for the purpose of its monetization, priority should be given to improving the indicators of the first stage, focusing on increasing recognition and awareness among users of online educational courses, thus increasing the cost-effectiveness of the course.

If the course was created primarily as a learning tool and not a product for profit (for example, online courses on platforms in state educational institutions), then priority should be given to the results of the second step of research when improving the course.

Instead, to achieve a high quality online educational course, quality must be maintained at both the course level and the information level. The above only indicates the prioritization of the aim of improving the quality of the online course, but does not call for

neglecting non-prioritized aspects. On the contrary, in order to achieve a high quality online educational course, it is necessary to maintain quality both at the course level and at the information level.

Based on the priorities in course development, the course quality assessment model should provide an overall course assessment, after which this information, together with all statistical data, is transferred to the next model – the online course quality analysis model, which will select the most important factors from the analyzed and transfer the information as models for selecting recommendations for improving the quality of an online course to the course developer.

In connection with the fact that the number of possible actions in any online course is limited, but at the same time the developers of online courses strive to adjust the process of interaction with the online course to the usual process of interaction between the teacher and students, there is a problem with the non-obvious use of the same elements of an online educational course in order to achieve different results, for example, teachers may use an element that is responsible for tests for a five-minute test on every lecture, a semester test, a practice test before an exam, self-testing of knowledge, etc. This creates the problem that the same type of elements should be perceived by models in different ways, which further complicates the evaluation and management of course quality.

Unfortunately, at this level of technology development, no model will be able to understand the thoughts of a living person, only trying to find the relationship between input and output data. In connection with the described situation, the model for choosing recommendations for improving the online course's quality should not just issue recommendations, but also a justification – why such a recommendation was proposed and on the basis of which statistical factors it was proposed, and the course developer will already decide whether the recommendation is relevant for him or not.

The choice of recommendations should be based on both economic indicators and quality indicators of the online educational course. The following are indicators that can be used to make decisions on managing the quality of an online course. The following economic indicators were selected:
- ✦ development costs;
- ✦ current expenses;
- ✦ investments per student;
- ✦ income from education;
- ✦ net profit;
- ✦ return on investment [13].

This set of indicators will allow you to evaluate an online course for an educational platform, only building on the interests of the platform itself. However, if course developers or platform holders are interested in their educational courses being useful to entrepreneurs, then employers' feedback becomes useful. Receiving such feedback, online course developers will be able to adjust the course program in order to more effectively interact with their stakeholders. It is important for public institutions of higher education since the latter actively engage potential employers of their students, adjusting work programs and adapting to the current labor market.

If we consider the indicators that reflect the quality of the online course, then the criteria for decision-making will be the following indicators:
- ✦ course completion rate;
- ✦ students' satisfaction;
- ✦ evaluation of learning outcomes;
- ✦ content quality;
- ✦ teaching quality;
- ✦ course design;
- ✦ accessibility [14].

Some of these metrics are already covered in the first and second stage models, but tracking them is critical to assessing the effectiveness of online course management.

All recommendations that will be given to the team of the online course's authors will have to be based on these indicators (obviously, the authors will not need all the indicators; the list of analyzed indicators will be formed depending on the main purpose of the course), however, for assessing control actions, the provided indicators are just as important.

After completing the full training cycle on the course, you will need to re-evaluate the selected indicators and, if there is a noticeable improvement in the indicators, then we can assume that the model of control actions has confirmed its effectiveness. If there are no changes in the indicators, or they are barely noticeable, then it is worth reviewing the indicators, making sure that the recommendations are suitable for the course, and making sure that the team of authors received the recommendations and took them into account.

The proposed model, which will be used to select the most appropriate recommendations, will be built on the basis of the decision tree method. The use of decision trees is caused by both a clear division of statistical parameters and the limitation of possible actions based on statistical parameters (read, possible actions), as well as a theoretical justification of branching in decision-making.

After the completion of both models of the third stage work, the course developer will receive detailed information about the results of the model's activity – both statistical reports and possible solutions for im-

proving the course, after which he will be able to make an informed decision about improving the quality of the educational online course.

The proposed complex of models will not be able to solve all problems with the design and quality control of educational online courses, but it will be an effective tool for course developers in improving and updating the course.

CONCLUSIONS

In this study, a complex of quality management models for online educational courses was proposed. The proposed complex is a fairly flexible tool for collecting and processing information with interim summaries for each individual course both outside the ecosystem of the online educational platform and inside it.

The complex of models is aimed at both qualitative and quantitative evaluation of the online course's quality, so the evaluation is based on both the opinion of the course users and their activity indicators on the course. This will allow to evaluate the adequacy of the received expert evaluations (users act as experts), and to evaluate the importance of certain methodical and technical elements of the course.

It is important to understand that at this point in time, no tool will be able to do the work of developing a course instead of a person, so models are a tool for working with statistical indicators and a system with the generation of recommendations for the online course improvement.

If we consider the shortcomings and weaknesses of the proposed set of models, the following can be noted:

✦ high dependence on the conscientiousness of the course users' answers to the questionnaires provided to them. If the answers will be inaccurate, but they will be able to pass the consistency check (for example, university students have a habit of overestimating the points of the passed course due to indifference), but will not have practical value. It is best to get answers from people who are interested in the course, and such are those who have paid for the access to the course on private educational platforms and it is important for him to get the maximum benefit for the money they paid;

✦ the indirect impact of a complex of models on an educational online course. As mentioned above, no tool can replace a person, because the proposed models are a tool that facilitates the evaluation of the course and offers possible ways for the course improvement. The model "does not see the whole picture" and relies only on the data it knows, so decisions about any changes in the course are made by its deve-

loper, whose vision may not correspond to the ideas embedded in the model.

Summing up, we can say that the proposed complex of models was a conceived tool that does not depend on regional factors. The models are designed to rely on statistical data that can be analyzed and checked for quality. But it is impossible to completely get rid of the influence of national characteristics in such a socialized process as education (even in a separate part of it, such as online courses), so the proposed models can be used as an additional tool for a more comprehensive assessment of educational online courses.

If we consider the economic aspect of the study, we can highlight the following results: the proposed set of models fulfills the goal of dynamic adaptive management of an online course quality. Effective management of educational courses will allow us to reduce the cost of maintaining online courses by reducing the time spent by a team of authors on evaluating, analyzing and developing possible ways to improve online educational courses.

Quality control of online courses allows educational platforms to maintain competitiveness in the distance education market. The performance and economic efficiency of the proposed set of models can be assessed over time, relying on feedback indicators received from course users and assessments of the degree of implementation of recommendations provided to the team of course authors.

To summarize, we can say that the proposed set of models can be effective both for improving courses in universities and on commercial platforms. The key goal of the developed models is to manage the quality of online courses, which affects courses both as an educational service and as an economic commercial product in the form of an educational service. ∎

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