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Oksana M. Melnyk
post-graduate student
Institute of Information Technologies and Learning Tools of NAES of Ukraine, Kyiv, Ukraine
ok_melnyk@ukr.net

THE FACTOR-CRITERIA MODEL OF ASSESSMENT OF ELECTRONIC EDUCATIONAL GAME RESOURCES IN MATHEMATICS FOR PRIMARY SCHOOL STUDENTS

Abstract. This article proves the need for a comprehensive assessment of electronic educational game resources in mathematics for the primary school students; gives the definition of "the factor-criteria model of the electronic educational game resources (EEGR)". It also describes the created model, which consists of requirements for the content, methodological and program parts of the electronic resources for primary school; identifies the factors and the criteria to each of them. It was proposed to assess the ratios within the group of factors and each group of criteria according to the arithmetic progression. The presented model can be a convenient tool both for primary school teachers and EEGR developers. It can also be a basis for a unified state comprehensive system of assessment of the EEGR.

Keywords: electronic educational resources (EER); electronic educational game resources (EEGR); factor-criteria model of assessment of EEGR; ranking factor's coefficient; ranking criterion's coefficient.

1. INTRODUCTION

It is impossible to imagine modern education without the formation and use of innovative educational environment which is based on the balanced use of a wide range of forms, methods and new learning tools. Due to more frequently use of information and communication technologies (ICT), including electronic educational resources (EER) in the educational process of primary schools, many researchers and practitioners are interested how to measure the effectiveness of such innovation and face the problem of objective assessment of EER.

Problem statement. The efficiency of any tools depends on their quality and the way how they are used. Therefore, a quality of EER is one of the essential requirements for the effectiveness of new technologies implementation in educational process, which is especially important for sensitive primary schools students. The study of scientific and pedagogical sources of information, pedagogical experience of primary teachers shows the widespread use of EER in practice, including EEGR. Taken from the Internet or developed by teachers themselves they are not always of high quality because they are made without taking into account all necessary requirements and criteria [6].

There were adopted a number of important documents in Ukraine in the past few years to ensure scientific and methodological support of educational process with innovative tools. They are such as the Action Plan for the development and implementation of e-learning content (order of the Ministry of Education, Science, Youth and Sports of Ukraine of 01.04.2011 №302), Regulation of electronic educational resources (order of the Ministry of Education, Science, Youth and Sports of Ukraine of 01.10.2012 №1060), etc. But at present there is no common system of assessment of EER adopted at the state level in Ukraine, which leads to misunderstanding among software engineers and teachers in the process of creation of high-quality EER.

Analysis of recent research and publications. The study of the problem reveals that some aspects of determination of necessary quality criteria of EER, including such tools for primary school, are represented in the scientific works of G. Lavrentieva, V. Lapinskyi, S. Lytvynova, N.

Olefirenko, O. Spivakovskyi, etc. Thus, H. Lavrentieva examines of psychological and pedagogical requirements for computer games, ergonomic requirements for educational software and also health care requirements for electronic learning tools [5]. The requirements for electronics educational resources for primary schools are the subject of investigation of N. Olefirenko [7]. The collective work [1] presents a system of psychological and pedagogical requirements for the tools of information and communication technologies for educational purposes, in particular the scientist V. Lapinskyi analyzes the technical and technological, ergonomic and health care requirements for educational software for primary school pupils; the researcher S. Lytvynova reveals the features of the development of criteria for assessment of the quality of EER; the scholar O. Spivakovskyi clarifies the parameterization of the indicators and methods of evaluation of EER. But, despite the fact that the questions of determination of the quality criteria of EER have been investigated by a number of scientists and researchers, as well as the fact that Ukraine has made some steps towards the information society and education in particular, including the development of legal support, our modern teaching practice is still not equipped with a unified system of the quality assessment of the EEGR in mathematics for primary school. This situation leads to certain difficulties among developers of electronic resources and primary school teachers in a selection and development of their own high-quality electronic resources. The unified system of assessment of EEGR in mathematics for primary school students will help to determine some common requirements for developers of these resources and to have a unified system of their implementation in the future.

The purpose of the article is to identify the main factors and quality criteria of EEGR in mathematics for 6-7-year-old **s**tudents; to present and justify the comprehensive approach to assessment of EEGR quality; to determine the method of getting the ranking factors' and criteria's coefficients.

2. THE RESEARCH METHODS

To achieve the purpose of the research we used a set of general theoretical and empirical methods.

Theoretical methods:

- method of direct structural analysis;
- method of simply theoretical analysis;
- structural synthesis method.

Empirical method:

- simulation method.

3. THE RESEARCH RESULTS

Any process or implementation requires an objective assessment. Therefore, as the researcher V. Hrygorash says, nowadays the strict criteria's assessment and subjective experts' opinions (inspectors, headmasters, etc.) are being replaced by flexible, focused on objectivity, regulatory, quantitative assessment of educational process with the help of factor-criteria models [2, p. 140]. The problem of improving the system of assessment of secondary schools' activities was researched by the scientist H. Yelnikova [9]. A lot of researchers have built some factor-criteria models to assess the efficiency of learning process or certain personality traits' formation, specifically for the assessment of the effectiveness of computer-based learning environment of an institution of postgraduate education (K. Kolos [3]); the medical college students' autonomy levels (O. Kovalenko [4]); the level of students' responsibility (R. Zelenskyi [10]), etc.

On the basis of the classical methods, mentioned above, we developed the factor-criteria

model of quality assessment of EEGR in mathematics for primary school students. Under *the factor- criteria model for assessment of EEGR* in mathematics for the 1-st grade students (FCM EEGR) we understand *the complex system of quantitative and qualitative assessment of factors and criteria which determines the degree of conformity of the mentioned learning tools with the stated objectives, standards and norms*.

In general, the quality of any product depends on the quality of each of its components. Based on the structure of EER, presented by S. Lytvynova [8, p. 87], we defined semantic, methodological and software components of the EEGR, mentioned above. We constructed the FCM EEGR in mathematics for primary school, identifying the factors and the criteria of each of them. They are presented in table 1.

Table 1

The factor-criteria model of assessment of EEGR in mathematics for 6-7-year-old students

Factor	Ranking factor's coefficient	Criterion	Ranking criterion's coefficient
1	2	3	4
I. Content (common)	K_1	1.1 conformity with accepted mathematics curriculum	$k_{1.1}$
		1.2 integrity and systematization	$k_{1.2}$
		1.3 succession and sequence	$k_{1.3}$
		1.4 simplicity of presenting	$k_{1.4}$
		1.5 opportunity of problem-based and practice learning	$k_{1.5}$
		1.6 tasks conformity with requirements for abilities and skills to be formed	$k_{1.6}$
		1.7 a balance of the theoretical and practical parts	$k_{1.7}$
II. Content (specific)	K_2	2.1. availability of game element	$k_{2.1}$
		2.2. possibility of formative assessment	$k_{2.2}$
		2.3. possibility of summative assessment	$k_{2.3}$
		2.4. scoring of theoretical part	$k_{2.4}$
		2.5. scoring of practical part	$k_{2.5}$
		2.6. logical and precise system of encouraging students	$k_{2.6}$
		2.7. understandable assistance system	$k_{2.7}$
		2.8. availability of practical differentiating assignments	$k_{2.8}$
		2.9. possibility of multiple performance of assignments with their further complication	$k_{2.9}$
		2.10. connection of educational material with the life of primary schoolchildren	$k_{2.10}$
		2.11. use of characters and heroes of children stories	$k_{2.11}$
		2.12. positive emotional environment of	$k_{2.12}$

		assignments	
III. Methodical	K_3	3.1. availability, structure and content of methodical guidelines on the use of EEGR for teachers	$k_{3.1}$
		3.2. availability, structure and content of methodical guidelines on the use of EEGR for students	$k_{3.2}$
IV. Ergonomic design	K_4	4.1. interface understandable for a user	$k_{4.1}$
		4.2. ease of navigation	$k_{4.2}$
		4.3. feasibility of visual aids and their conformity to the content	$k_{4.3}$
		4.4. non-aggressive sound and colour design	$k_{4.4}$
		4.5. intelligibility and meaningfulness of sound guidelines and tips for students	$k_{4.5}$
		4.6. possibility of changing the font size	$k_{4.6}$
		4.7. possibility of changing musical support	$k_{4.7}$
V. Technical and technological	K_5	5.1. possibility to monitor students' work in the network both individually and the whole class	$k_{5.1}$
		5.2. operating systems' compatibility	$k_{5.2}$
		5.3. local mode operation	$k_{5.3}$
		5.4. network mode operation	$k_{5.4}$
		5.5. long-term smooth operation	$k_{5.5}$
		5.6. convenience and ease of installation and software update	$k_{5.6}$

Then we are examining the factors and criteria presented in the model, mentioned above, in details. The content of the EEGR requires the adherence to certain general demands mostly the same as to printed and electronic publications, as well as specific, caused by age, psychological characteristics of primary school students and some peculiarities of electronic resources. The first of these groups is based on the well-known didactic principles.

One of the common requirements for the content is the conformity of learning material of the EEGR with a current curriculum in mathematics (probably, its topic, a part, etc.), approved by the Ministry of Education and Science (MES) of Ukraine. Since the main purpose of the mentioned EEGR is assistance in studying mathematics by elementary school students, the theme or themes of the electronic resource have to be the same as the recommended ones by the MES of Ukraine for students of this age group.

The integrity and systematization of learning material is the next important criterion during studying mathematics, including primary school. This material has to form a single training cycle and cover all issues of the curriculum for the first grade students completely. In addition, its content should have an internal unity that is subordinated to a certain system of teaching mathematics taking into consideration all special features of elementary school students.

Another quality criterion for the EEGR, mentioned above, is succession and sequence of presenting learning material on mathematics. The content of each lesson should be connected with previous one and gradually become more complicated according to the curriculum during both a lesson and a whole topic.

A simplicity of presenting of educational material implements one of the common didactic principles. Taking into consideration that the resource is designed for 6-7-year-old students, developers should be especially careful about the level of complexity of educational

material, tasks formulation, their compliance with the age and individual needs of students of this age.

An important requirement of the present time is providing an opportunity of problem-based and practice learning. A selection of tasks which contribute to the formation of students' creative thinking, learning through practice is a necessary condition for training a competitive active personality in the future.

One of the common didactic requirements includes the conformity of task requirements with the knowledge and skills that have to be performed. In other words, all EEGR assignments have to meet stated purposes to get profound theoretical knowledge and practical skills.

A balance of the theoretical and practical parts is also, in our opinion, a criterion of quality of the educational content of the EEGR. There is a need to balance the theoretical material with a certain number of practical tasks for each theme. It depends on material's complexity but needs to be sufficient for its understanding by students. On the other hand, theoretical and practical parts should not cause students' fatigue.

As for the specific didactic requirements, they are connected with the physiological, psychological, individual special features of 6-7-year-old students and some peculiarities of this type of electronic resources.

Since the resources that we are examining surely include a game component that is one of the most important requirements for students of primary school age, we have identified its existence as a separate specific requirement for the content part.

Despite the fact that the level of the 1-st grade students' knowledge is not marked according to the Ukrainian law (it can be done only verbally), we consider the possibility of formative and summative assessments of students' knowledge in the EEGR very important and reasonable. Such assessment should be provided in a comprehensible form for 6-7-year-old students (not in marks). This will help to support their desire to learn, identify and will contribute to further revisal of any problem and increase of students' learning motivation.

A specific requirement for the content part of the EEGR is a scoring of theoretical part in mathematics so far as some students of such age cannot read yet.

It is also necessary for students of mentioned age to have a scoring of practical tasks because they are only learning to read. The specific features of such age should be taken into account: the speed of perception, concentration and so on.

To the following specific requirements for the content we refer a logical and precise system of encouraging students. The system should be presented in a way which is interesting and understandable to the students of such age and should not cause any negative emotions. The assistance should also be clear, precise and easy to receive, without any difficulties for primary school children.

We consider that another specific requirement for the resources mentioned above is availability of differential practical assignments in mathematics. The EEGR should enclose tasks of different complexity that will enable individual approach to students, help to build an individual learning path of each student, starting from the 1-st grade.

A possibility of multiple performances of the assignments with their further complication is a necessary condition for the developing education. The implementation of this requirement will allow each student to master theoretical knowledge and gain practical skills according to their personal abilities.

Psychological features of primary school age require a connection of educational material with the life of schoolchildren. The students of this age perceive and understand the course material more easily if it operates familiar objects to them and is connected with their lives.

The use of characters and heroes of children stories in the EEGR is extremely important

for 6-7-year-old students because it increases learning motivation, creates friendly and more relaxed environment.

A positive emotional background of the tasks given in the EEGR is also necessary for primary schools. It affects and helps to create a friendly learning environment, motivate students to study.

The specified resource should be accompanied by the methodical guidelines on the use of the EEGR by teachers. The appropriate structure and content of the mentioned guidelines are very important for the effective implementation of the EEGR in training. Such guidelines ought to include some organizational and methodological aspects of its use. They should also explain how, on what stage of a lesson the electronic resource can be implemented more effectively, contain time standards, compliance with medical rules and norms as well as all possible ways and forms of working with it.

Another requirement for the methodological part of the EEGR is an availability of guidance for students. Software should clearly warn about a mistake, offer help if it is necessary and support a transition to another level of complexity. The structure and content of the guidance for students are also important. The recommendations should be understandable for 6-7-year-old students and can be presented in an audio format or by means of animation, or even as a short clear text which can be announced by a teacher.

The requirements for the program part of electronic resources are divided into two groups: ergonomic design, technical and technological, which are presented and detailed below.

An ergonomic design factor consists of the following criteria. The first of them is an interface understandable for a user. All students' actions in a user environment of EEGR occur with the help of the interface, which includes components of management, tools of the EEGR reaction to users' actions, information display format. The interface of the mentioned EEGR should be developed taking into account a possible level of the students' ICT skills.

The ease of navigation is another requirement. Database of the EEGR, software modules and data display tools should be designed in such a way that the navigation system will follow the shortest path and will be understandable for the 1-st grade students.

A feasibility of visual aids and their conformity with the content of the EEGR are another significant quality requirement for the EEGR, especially for primary school students. Visual aids increase students' interest, keep their attention within a required period of time but they should not cause any fatigue or negative emotions. And since primary school age is very sensitive, the developers of EEGR need to be especially careful in a choice and amount of visual aids in the new electronic resources.

All 6-7-year-old children have specific psychological features; they are very emotional and conducive to external factors, including sounds and colours. Therefore, sound and colour design of EEGR should be non-aggressive. Sounds should be soft, melodious, based on children's songs. And mostly soft, pastel colours ought to be chosen.

An intelligibility and meaningfulness of sound guidelines and tips for the students in the EEGR are very important. All audio instructions should be recorded with a calm, friendly voice (male and female), clear and accurate.

Every child has the peculiarities of eyesight and visual perception. An uncomfortable font can cause fatigue. Therefore, it is necessary to provide the EEGR with a possibility to change the font size easily if it is necessary.

Monotonous music can annoy the students and cause their negative reactions. This fact should be taken into account by the EEGR developers providing it with a possibility to turn a tune off or to change it. That is very important for creating positive emotional environment.

The technical and technological factor of the EEGR consists of several criteria, presented below.

One of these criteria is a possibility to monitor students' work in the network both individually and the whole class**.** A teacher should constantly monitor each student's and a whole class progress via his electronic device (local network server) during a lesson. It is important because any student can have some problems or difficulties during the lesson. The possibility to monitor learning progress both of each student individually and the whole class gives the teacher an opportunity to react and help any student immediately.

An EEGR compatibility with different operating systems is another important criterion. Any software, including the EEGR, should run regardless of a type of an operating system or electronic device. Otherwise, some inconvenience and difficulties for the students and teachers may arise.

A local mode of the EEGR is necessary both for an individual student's work and for teachers' preparing for the lessons. It allows working in groups or with the whole class without provider's service (for example, by the Bluetooth).

A network mode of the mentioned above resources is required for cooperation of students in a group or the whole class. In addition, the teacher's server should have an access to the Internet to get new database and update the EEGR.

Another criterion for the EEGR is a long-term smooth operation. All users expect that the software, installed on their devices, will run reliably for a long period, at least during 6 months. Software glitches are unacceptable because they can stop or make an uninterrupted educational process impossible.

A software installation process should not take much time or cause any difficulties for teachers. It saves teacher's time and does not lead to a delay of the educational process via EEGR or negative attitude towards the resource.

The ranking factor's and criterion's coefficients are determined in an expert manner (for example, with the help of ranking their magnitude by the primary school teachers, who use the EEGR almost every day). They should take into account the fact that the cumulative sum of all the factors is 1:

$K1 + K2 + K3 + K4 + K5 = 1,$

so the cumulative sum of all the criteria within each of the five groups is:

$k_{1.1} + k_{1.2} + k_{1.3} + k_{1.4} + k_{1.5} + k_{1.6} + k_{1.7} = 1;$

$k_{2.1} + k_{2.2} + k_{2.3} + k_{2.4} + k_{2.5} + k_{2.6} + k_{2.7} + k_{2.8} + k_{2.9} + k_{2.10} + k_{2.11} + k_{2.12} = 1;$

$k_{3.1} + k_{3.2} + k_{3.3} + k_{3.4} = 1;$

$k_{4.1} + k_{4.2} + k_{4.3} + k_{4.4} + k_{4.5} + k_{4.6} + k_{4.7} = 1;$

$k_{5.1} + k_{5.2} + k_{5.3} + k_{5.4} + k_{5.5} + k_{5.6} = 1.$

We propose to assess the ranking criterion's coefficient within each of the groups according to the law of the arithmetic progression.

The summative assessment of the EEGR (SA_{EEGR}) is calculated as the sum of scores of each of the five factors O_1, O_2, O_3, O_4, O_5 as follows:

$SA_{EEGR} = O_1 + O_2 + O_3 + O_4 + O_5,$

according to the table 1:

$O_1 = K_1 (k_{1.1} * O_{1.1} + k_{1.2} * O_{1.2} + k_{1.3} * O_{1.3} + k_{1.4} * O_{1.4} + k_{1.5} * O_{1.5} + k_{1.6} * O_{1.6} + k_{1.7} * O_{1.7});$

$O_2 = K_2 (k_{2.1} * O_{2.1} + k_{2.2} * O_{2.2} + k_{2.3} * O_{2.3} + k_{2.4} * O_{2.4} + k_{2.5} * O_{2.5} + k_{2.6} * O_{2.6} + k_{2.7} * O_{2.7} + k_{2.8} * O_{2.8} + k_{2.8} * O_{2.8} + k_{2.9} * O_{2.9} + k_{2.10} * O_{2.10} + k_{2.11} * O_{2.11} + k_{2.12} * O_{2.12});$

$O_3 = K_3 (k_{3.1} * O_{3.1} + k_{3.2} * O_{3.2} + k_{3.3} * O_{3.3} + k_{3.4} * O_{3.4});$

$O_4 = K_4 (k_{4.1} * O_{4.1} + k_{4.2} * O_{4.2} + k_{4.3} * O_{4.3} + k_{4.4} * O_{4.4} + k_{4.5} * O_{4.5} + k_{4.6} * O_{4.6} + k_{4.7} * O_{4.7});$

$O_5 = K_5 (k_{5.1} * O_{5.1} + k_{5.2} * O_{5.2} + k_{5.3} * O_{5.3} + k_{5.4} * O_{5.4} + k_{5.5} * O_{5.5} + k_{5.6} * O_{5.6}).$

Using this technique of EEGR assessment, the resource is considered to have sufficient quality to be used in primary schools if it gets 75% or more of the highest possible score. If

the EEGR gets 65-74% of the highest score, the quality of the EEGR is not high enough and it should be updated, followed by reassessment. In the case of less than 64%, the EEGR requires thorough review and improvement.

4. CONCLUSION AND PROSPECTS FOR FURTHER RESEARCH

Thus, the determination of the key factors and quality criteria of the EEGR in mathematics for primary school children and taking them into consideration helped us to develop the relevant factor- criteria model for their quality assessment. The direct proportionality of the ranking coefficients according to their importance encouraged the technique of obtaining the ratios of the factors and criteria. This model seems to be a convenient tool for an objective assessment of the EEGR that will be useful both for primary school teachers and developers of electronic educational resources. Such method of the EEGR assessment with the further selection and use of high-quality electronic resources in the educational process will help to increase the efficiency of education in primary school. This model can also be used as the basis for a creation of a unified state comprehensive system of EEGR assessment.

There is a logical necessity in identification of the primary school teachers' opinions about the importance of all factors and criteria to determine their ranking coefficients and the highest score of the EEGR that requires the further research.

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ФАКТОРНО-КРИТЕРІАЛЬНА МОДЕЛЬ ОЦІНЮВАННЯ ЕЛЕКТРОННИХ ОСВІТНІХ ІГРОВИХ РЕСУРСІВ З МАТЕМАТИКИ ДЛЯ УЧНІВ ПОЧАТКОВИХ КЛАСІВ

Мельник Оксана Миколаївна
аспірант
Інститут інформаційних технологій і засобів навчання НАПН України, м. Київ, Україна
ok_melnyk@ukr.net

Анотація. У статті обґрунтовано необхідність комплексного оцінювання електронних освітніх ігрових ресурсів з математики для учнів початкових класів (ЕОІР); дано визначення поняття «факторно-критеріальна модель оцінювання ЕОІР»; описано створену модель для оцінювання ЕОІР, яка складається з певних вимог до змістової, методичної та програмної частин; виявлено фактори та критерії кожної з них. Було запропоновано оцінювати вагові коефіцієнти факторів та критеріїв в межах кожної з груп за допомогою арифметичної прогресії. Представлена модель може бути зручним інструментом для об'єктивної оцінки ЕОІР, що є корисним як для вчителів початкової школи, так і для розробників електронних ресурсів. Вона також може бути взята за основу при створенні єдиної державної комплексної системи оцінювання ЕОІР.

Ключові слова: електронні освітні ресурси (ЕОР); електронні освітні ігрові ресурси (ЕОІР); факторно-критеріальна модель оцінювання ЕОІР; ваговий коефіцієнт фактору; ваговий коефіцієнт критерію.

ФАКТОРНО-КРИТЕРИАЛЬНАЯ МОДЕЛЬ ОЦЕНИВАНИЯ ЭЛЕКТРОННЫХ ОБРАЗОВАТЕЛЬНЫХ ИГРОВЫХ РЕСУРСОВ ПО МАТЕМАТИКЕ ДЛЯ УЧАЩИХСЯ НАЧАЛЬНЫХ КЛАССОВ

Мельник Оксана Николаевна
аспирант
Институт информационных технологий и средств обучения НАПН Украины, г. Киев, Украина
ok_melnyk@ukr.net

Аннотация. В статье обоснованы необходимость комплексного оценивания электронных образовательных игровых ресурсов по математике для учеников начальной школы (ЕОИР); дано определение понятия «факторно-критериальная модель оценивания ЕОИР»; описано разработанную модель, которая состоит из определенных требований к содержательной, методической и программной частей; определены факторы и критерии каждой из них. Было предложено оценивать весовые коэффициенты факторов и критерий в пределах каждой из групп с помощью арифметической прогрессии. Представленная модель может стать удобным инструментом для объективной оценки ЕОИР, что может быть полезным как для учителей начальной школы, так и для разработчиков электронных ресурсов. Она также может послужить основой для создания единой комплексной системы оценивания ЕОИР, принятой на государственном уровне.

Ключевые слова: электронные образовательные ресурсы (ЭОР); электронные образовательные игровые ресурсы (ЕОИР); факторно-критериальная модель оценивания ЕОИР; весовой коэффициент фактора; весовой коэффициент критерия.

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