Multimedia Educational Technologies for Teaching Students with Autism

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Abstract. Visualization of educational materials in the education of students with autism is a useful and convenient learning tool. At the same time, choosing the most useful and effective multimedia educational technology to support such learning is a problem, as there is a wide range of developed technologies, and each participant in the process of education of children with autism assesses such technologies subjectively. Each participant of IT-support of education of students with autism, i.e. inclusive school teacher, psychologist, parents, IT specialist has its own criteria how to assess such multimedia technology, and development of objective criteria for evaluating such technologies will become the basis for developing an appropriate system that will form a complex information technology of education of a student with autism in an inclusive classroom. Applying the analytic hierarchy process, allows to make reasoned decisions.

Keywords: Multimedia Educational Technologies, Teaching Students with Autism, Information Technology, Analytic Hierarchy Process

1. Introduction

Combining different forms of information provision in educational content is an integral characteristic of modern educational technologies. The use of audio, graphical and video signals is of particular importance for the teaching of students with autism. Moreover, the theory and practice of teaching students with autism is developing through the ability to use multimedia educational technologies.

The use of visual tools in teaching such students has proven effective [1, 2]. The reason for this is the peculiarities of the autism spectrum disorders, often students with such nosology have communication difficulties, it is problematic for them to establish social bonds [3]. Developed information technologies to support the learning of students with autism, in addition to the presentation of academic knowledge, should be able to improve social and communication skills.

In Ukraine, one of the regional training and rehabilitation centers for children with autism uses augmented and virtual reality (AR and VR) ICTs to study specific topics in the training course. For example, the *Social and everyday orientation* course is

supported with augmented reality technology (fig. 1a, 1b shows the *road crossing with a traffic signal* scenario, 1c, 1d shows the *computer class behavior* scenario).

a)  b) 

c)  d) 

Fig. 1a-1b. A fragment of a *Road crossing with a traffic signal* scenario, 1c, 1d. A fragment of a *Computer class behavior* scenario

Such visualization of the processes of daily activity enables students with autism to learn and improve social skills in safe situation, providing the necessary number of repetitions of such activities for better memorization.

Modern, actual ICTs for students with autism are developed using virtual, augmented and mixed reality technologies [1, 4, 5] (Fig. 2). Such technologies are very useful to improve the social and communication skills of students with autism.

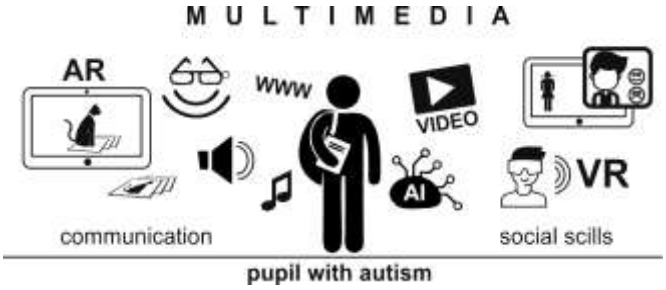

Fig. 2. Types of educational information technologies for education of students with autism

Modern professionals, who work with students with autism have access to a wide range of multimedia educational technologies. A large amount of such ICTs is publicly available. At the same time, such multimedia educational technologies developed by enthusiasts (inclusive teachers, psychologists, parents, and IT professionals) are disparate, mutually unrelated technologies, and are used to teach a specific topic or a special, personalized social or communication skill. Therefore, the use of such

multimedia educational technology by a third-party paraprofessional is almost impossible. The selection of appropriate information technology could be remedied by the existence of a common pool of accessible multimedia technologies that could be used by inclusive education professionals. But even then, the search for the right ICT that would meet the requirements of the specialist, and also take into account the characteristics and abilities of the student with autism, involves a complete search of such information technologies. It will be a complete waste of time. In other hand, if such technologies were characterized, it would save time for teachers. Currently, various paraprofessionals publish reviews of available ICTs and evaluate them for certain subjective characteristics [7].

The standard ISO / IEC40500: 2012, created by World Wide Web Consortium (W3C) is an objective tool for assessing the IT-support of autistic student education [8]. This standard recommends that the developers of ICTs for persons with disabilities should take into account the responsiveness, efficiency, comprehensibility and reliability of the created software [9]. One can check automatically the level of website compliant to such demands by using the *Achecker* service [10]. The *Achecker* detects various types of errors, and for the average standard compliance level (AA level) there are 61 types of such errors.

The Fig. 3 shows a snippet of the *Achecker*, displaying the results of a review of the *Inclusive Education* website (https://education-inclusive.com/), created by by the All-Ukrainian public association *The National Assembly of People with Disabilities of Ukraine*. Six errors of two types were identified, these were related to distinction (to facilitate the visual and auditory perception of information by users, including distinguishing of the front and back of the site), as well as sufficient time to read and use the content. For comparison, the site of the All-Ukrainian public association *National Assembly of People with Disabilities of Ukraine* (https://naiu.org.ua/) has 48 errors of five types (related to non-text elements of the site, adaptability of its content, the distinguishability of the content, site navigation, assistance with data entry). The website of the *National Committee for Sport of Disabled People of Ukraine* (https://new.paralympic.org.ua/, version for the visually impaired), has 29 errors of five types.

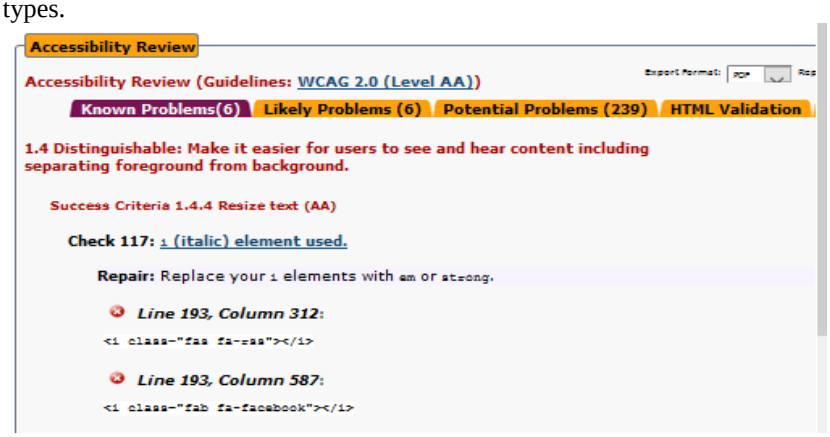

Fig. 3. Fragment of *Achecker* application window with web site analysis results

The *Achecker* application has proven to be a useful tool for analyzing the websites of regional psychological, medical, and pedagogical institutions of Ukraine [9], the websites of regional libraries [1], etc. However, this application is only useful for website analysis, it cannot be used to test for compliance with the ISO requirements of other types of ICTs. The variety of multimedia educational technologies available to students with autism does not systematically support the learning of such students. According to the authors, it is advisable to develop a recommendation system that would allow the design of information technology for the training of a student with autism, taking into account his or hers abilities, as well as the psychophysical characteristics of such a student, his educational characteristics. And of course, we need to consider the available hardware, i.e. computers, VR-glasses, video projector, etc.

The development of such a recommendation system involves evaluating the available multimedia education technologies for students with autism on a variety of dimensions. The characteristics of assessing of educational multimedia for students with autism will allow not only to comprehensively select and combine existing educational technologies, but also to develop appropriate ICTs that would meet the needs of all participants in the educational process of students with autism.

As it was mentioned above, the modern process of education of students with autism involved psychologists, inclusive education teachers, parents of students with autism, IT specialists [7]. According to the Ministry of science and education of Ukrainian, in the Letter *Regarding the duties of a teaching assistant* [11], the teaching assistant teacher in the inclusive classroom must perform a number of functions. Multimedia educational technologies can help such a specialist to perform these functions. Therefore, the criteria for evaluating such technologies for a assisting teacher are the ability to use such technologies to assist in the fulfillment of their functions in an inclusive classroom. For example, to support organizational function, the assisting teacher may use multimedia educational technologies to organize the educational process, to monitor the child in order to study his individual characteristics, inclinations, interests and needs, etc. (appropriate criterion for evaluating educational we call *organizational*).

To support the educational and development function, multimedia educational technologies are used to provide educational services, to promote the development of children with special educational needs, to improve their psychological and emotional state, to stimulate the development of their social activity, to facilitate the identification and disclosure of their abilities, talents, and gifts (*training* criterion). The diagnostic function is to participate in the development of an individual curriculum, evaluation of students' educational achievements, etc. (*diagnostic* criterion). The prognostic function is to create an individual development program based on an analysis of the actual and potential development of the child (*prognostic* criterion). And finally, the counseling function involves, among other things, constant communication with parents and informing them and the class teacher about the student's achievements (*consultation* criterion).

The criteria of educational multimedia, relevant to each participant of the educational process of a student with autism, are presented at Fig. 4 [8, 9, 11, 12].

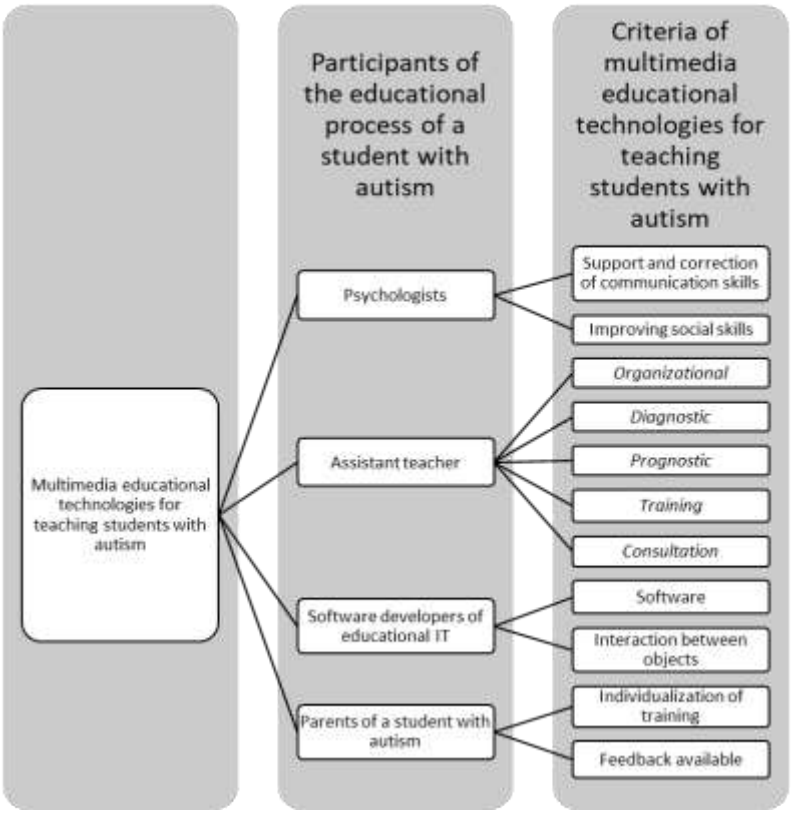

Fig. 4. Relevant criteria of educational multimedia for students with autism

To support the decision about the components of such complex information technology, various methods can be used. For example, a analytic hierarchy process can be implemented.

2. An Analytic Hierarchy Process for Choosing Multimedia Educational Technology

Decision-making problems are constantly emerging and solved in biological, ecological, social, and economic systems, various processes and phenomena. The decision is a reasonable set of actions by the decision maker aimed at the object or control system, which gives the opportunity to bring the object or system to the desired state or to achieve its goal. Decision making is the process of choosing the most preferential decision from the set of valid decisions or ordering the set of decisions. Decision-making is possible on the basis of knowledge about the object of management, the processes that take place in it and can happen over time, as well as in the presence of many indicators that characterize the effectiveness and quality of the decision.

Any decision-making process is carried out in several basic stages.

Stage of the problem statement. It consists of phases of analysis and diagnosis of the problem and determination of the goals of the solution.

Stage of decision making. It consists of the phases of formulating constraints and decision-making criteria and identifying alternatives to the decision.

Stage of decision selection. It consists of phases of evaluation of alternatives and final decision selection. At this final stage, the options from the set of feasible alternatives are evaluated according to the criteria chosen and the final decision is made.

The analytic hierarchy process (AHP), proposed by the T. Saati [13] is one of the well-known approaches for determining the optimal solution in multicriteria conditions. This method has several advantages over other methods as it allows to take fully into account all the criteria offered to select the best multimedia educational technology for teaching students with autism.

To implement the method of analytic hierarchy process it is necessary to create a hierarchical three-level structure. The goal is the upper level and the decision is taken about this goal, the second level is the set of criteria by which alternative multimedia educational technologies for training students with autism are selected. Next, the alternatives form the third level of the hierarchy. Decision-making is about choosing one of the possible alternatives based on a set of priorities. We shall illustrate the method of analytic hierarchy for choosing a multimedia educational technologies for teaching students with autism – from the point of view of an assistant teacher (the criteria and attributes are above). A diagram illustrating from the perspective of an inclusive classroom assisting teacher is shown in Fig. 5.

Matrixes of judgments are constructed based on the results of pairwise comparison. Each matrix defines a priority vector that reflects the weights of the criteria and alternatives. The alternative with the greatest global weight is considered to be the choice of multimedia educational technology.

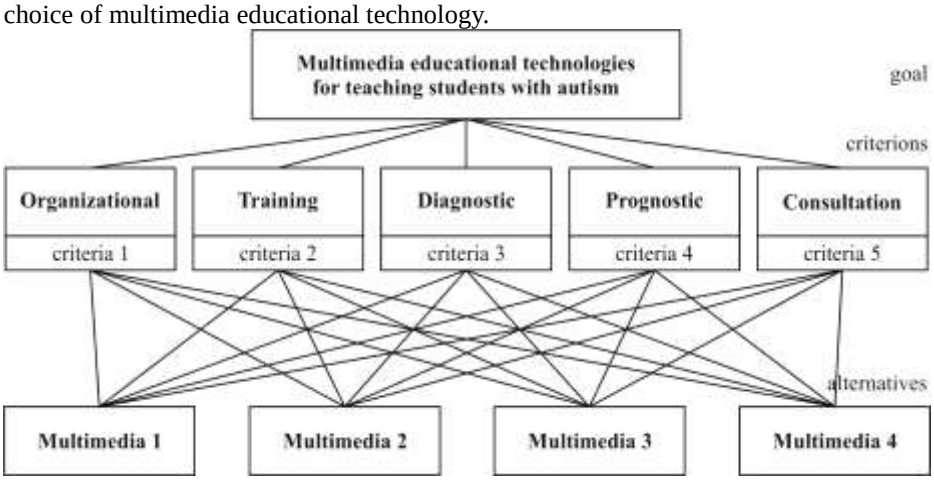

Fig. 5. Scheme of the AHP method for selecting multimedia educational technologies for teaching students with autism from the perspective of an inclusive classroom assisting teacher

The AHP method uses an expert rating scale of paired comparisons of one object over another, with values from 1 to 9. The general content of these estimates is given in Table 1 [15].

Table 1. The importance scale for pairwise comparison matrices

Importance scale	Value
Equal	1
Weak	3
Strong	5
Very strong	7
Absolute	9
Intermediate value	2, 4, 6, 8

Let us consider the features of using the AHP to determine the best multimedia educational technology for teaching students with autism, which should be used by assistant teacher. As mentioned above, such technologies can be used by the teacher in terms of being able to assist in the performance of his functions. For each such criterion (*organizational, diagnostic, prognostic, training, and consultation*), we set a scale of importance for the four multimedia technologies, find the weight of the respective alternatives.

The matrix of pairwise comparisons of the alternative multimedia according to the *diagnostic* criterion is given in table 2.

Table 2. The matrix of pairwise comparisons for the *diagnostic* criterion

Alternatives	M1	M2	M3	M4
M1	1,00	3,00	5	9,00
M2	0,33	1,00	3	7,00
M3	0,20	0,33	1	3,00
M4	0,11	0,14	0,33	1,00
Sum	1,64	4,47	9,33	20

The results of the calculation of the weights of alternatives by the *diagnostic* criterion are given in Table. 3. The calculation was performed according to method 3 (see [14]), after which each column was normalized, and then priority column vector found.

Table 3. Weight of alternatives by the *diagnostic* criterion

Alternatives	M1	M2	M3	M4	Sum	Weight of alternative
M1	0,60	0,70	0,50	0,50	2,26	0,56
M2	0,20	1,20	0,30	0,40	1,09	0,27
M3	0,10	0,10	0,10	0,20	0,45	0,11
M4	0,10	0,0	0,0	0,10	0,18	0,46

We calculate the priority vector as an estimate of the principal eigenvector of the pairwise comparison matrix. The elements of this vector are the weights of alternatives, which are calculated as the algebraic sum of the elements of the corresponding row of the table 3, divided by the total number of alternatives.

Therefore, by *diagnostic* criterion, Multimedia 1 is the best alternative because it has the highest weight value of 0,56.

For pairwise comparison matrix for the *diagnostic* criterion, the following parameters were calculated:

- the estimation of the largest eigenvalue, which is calculated by the formula $\lambda_{\max} = \sum_{i=1}^{n} w_i s_i$, where w_i is a weight of the alternative with number i, s_i is a sum of elements of column number i from pairwise estimation matrix, n is the number of alternatives;
- consistency index $CI = \frac{\lambda_{\max} - n}{n-1}$;
- index of ratios sequence $CR = \frac{CI}{RI}$.

Here and after, RI = 0,9 an index for n = 4 alternatives.

After calculating for the pairwise comparison matrix constructed by the *diagnostic* criterion, these parameters take the following values:

$\lambda_{\max}$ = 1,64·0,56 + 4,47·0,27 + 9,33·0,11 + 20·0,46 = 4,142;

– consistency index $CI = \frac{\lambda_{\max} - n}{n-1}$ = (4,142-4)/4-1 = 0,047;

– index of ratios sequence $CR = \frac{CI}{RI}$ = 0,047/0,9 = 0,053.

Because the CR = 5,30% < 10%, then we consider the matrix of pairwise comparisons for the *diagnostic* criterion as agreed.

Similar calculations are made for the other criteria (organizational, diagnostic, prognostic, training, consultation). The calculated weights of the alternatives are given in Table 4.

Table 4. Weights of alternatives

Organizational	Diagnostic	Prongostic	Training	Consultation
0,566009	0,504974	0,411548	0,634582	0,54394568
0,274384	0,320422	0,41774	0,17624	0,20693193
0,113308	0,133113	0,110652	0,117988	0,18572699
0,046299	0,041492	0,060061	0,07119	0,0633954

Diagram of the distribution of weight coefficients presented at in Fig. 6.

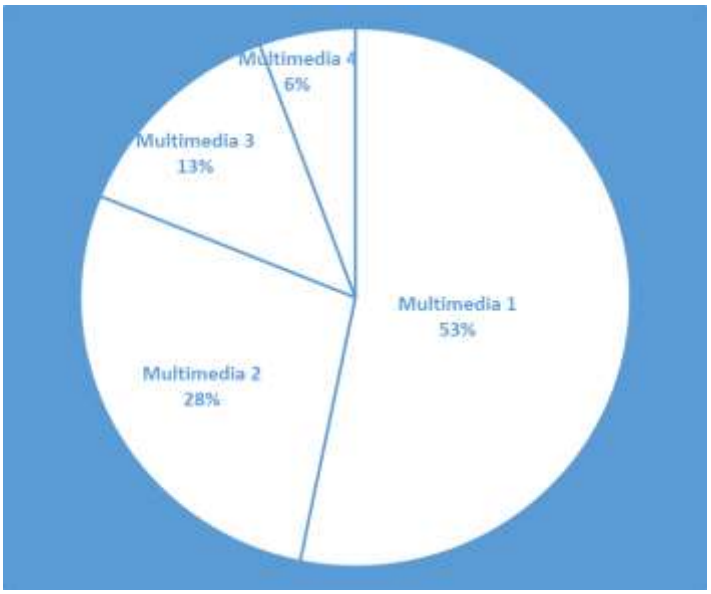

Fig 6. The scales of alternative multimedia educational technologies for students with autism

According to the results, Multimedia 1 is the best alternative for assisting teacher in fulfilling his demands to help in an inclusive class. The AHP can be a helpful tool in educational decision making. To make the method more accurate, we shall detail the assessment of each of criteria by specifying its attributes.

The criterion *Support and correction of communication skills* can be evaluated by such attributes:

- Types of educational influences,
- The degree of interactivity of the training environment,
- Need for communication,
- Variation of types and forms of dialogue,
- Types of interaction,
- Formation of skills of correct dialogue.

The criterion *Improving social skills* can be evaluated by such attributes:

- Taking into account the individual abilities and characteristics of the student with ASD,
- Individualization of training,
- New types of educational activity,
- Organizational forms of the lesson,
- Design of educational material.

The criterion *Organizational* can be evaluated by such attributes:

- Monitor changes in a student's psychological and emotional state of a student with ASD,
- Multilevel training material,

- Academic mobility,
- Organizational forms of the lesson,
- The structure of the learning algorithm,
- The degree of interactivity of the learning environment.

The criterion *Diagnostic* can be evaluated by such attributes:

- Educational success,
- Taking into account the initial level of student`s skills.

The criterion *Prognostic* can be evaluated by such attributes:

- Consideration of individual abilities and characteristics of the student with ASD,
- Individualization of education.

The criterion *Consultation* can be evaluated by such attributes:

- Academic mobility,
- Informing students about their achievements.

The criterion *Training* can be evaluated by such attributes:

- Individualization of learning,
- Capability development,
- Structure of educational goals,
- Quality of educational material,
- Design of educational material,
- Performance of the educational task,
- Types of educational influences,
- The degree of interactivity of the learning environment,
- Development of professional independence,
- New types of educational activity,
- Type of dialogue.

The criterion *Software* can be evaluated by such attributes:

- Software quality,
- Methods and means of access to educational material,
- Additivity,
- Availability of multimedia,
- Type of environment management,
- Programming technologies used.

The criterion *Interaction between objects* can be evaluated by such attributes:

- The degree of interactivity of the learning environment,
- Compliance with the requirements of universal design,
- Compliance with ISO requirements,
- Overall composition of the website,
- A harmonious combination of color schemes,
- Feedback.

The criterion *Individualization of training* can be evaluated by such attributes:

- Taking into account the individual abilities and characteristics of the student with ASD,
- Capabilities development,

- Monitoring changes in the psycho-emotional state of a student with ASD.

The criterion *Feedback available* can be evaluated by such attributes:

- Type of environment management,
- Learning success.

The proposed attributes of each criterion will form the basis of a complex multi-criteria assessment of multimedia educational technologies for children with autism. After assessment of each attribute, the final assessment of the criterion will be calculated, and only then the AHP will be conducted. Adding attributes assessment into the AHP will enable more specific, personalized evaluation of each criterion.

3. Conclusions

The multimedia educational technologies are of great support in training students with autism. It is difficult to choose an appropriate media from the existing, each teacher, psychologist or parent of such a student is doing this on his own. The system of decision support might help to choose the best alternative multimedia, but that requires the existence of a range of characteristics, that might be assessed for each multimedia. The difficulty is that such set of characteristics should take into account needs of all the participants of education of students with autism. Authors proposed such set of characteristics and showed how decision can be taken using the analytic hierarchy process. To enable taking into account more detailed assessment of multimedia educational technology, we suggested a set of attributes as a specification of each attribute. In the future researches, we shall develop a system, that will evaluate the effects of multimedia implementation into educational process of a student with autism.

References

1. Andrunyk, V., Shestakevych, T., Pasichnyk, V.: The technology of augmented and virtual reality in teaching children with ASD. Econtechmod. Vol. 7 (4), 59-64 (2018).
2. Drigas, A., Vlachou, J.: Information and Communication Technologies (ICTs) and Autistic Spectrum Disorders (ASD). International Journal of Recent Contributions from Engineering, Science & IT (iJES). 3 (2016).
3. Tsiopela, D., Jimoyiannis, A.: Pre-vocational Skills Laboratory: Development and Investigation of a Web-based Environment for Students with Autism. Procedia Computer Science. Vol. 27, pp. 207–217. (2014).
4. Lytvyn, V., Vysotska, V., Mykhailyshyn, V., Rzheuskyi, A., Semianchuk, S.: System Development for Video Stream Data Analyzing. In: Lytvynenko V., Babichev S., Wójcik W., Vynokurova O., Vyshemyrskaya S., Radetskaya S. (eds) Lecture Notes in Computational Intelligence and Decision Making. ISDMCI 2019. Advances in Intelligent Systems and Computing, vol 1020, pp. 315-331. Springer, Cham (2020).
5. Zdebskyi, P., Vysotska, V., Peleshchak, R., Peleshchak, I., Demchuk, A., Krylyshyn, M.: An Application Development for Recognizing of View in Order to Control the Mouse Pointer. In: Modern Machine Learning Technologies and Data Science, Vol. 2386, pp. 55-74 (2019).

6. Pasichnyk, V., Shestakevych, T., Kunanets, N., Rzheuskyi, A., Andrunyk, V.: Accessibility Analysis of Scientific Libraries Web Resources. Econtechmod. Vol. 8(2), pp 9-16 (2019).
7. Andrunyk, V., Shestakevych, T., Pasichnyk, V., Kunanets, N.: Information Technologies for Teaching Children with ASD. In: Hu Z., Petoukhov S., Dychka I., He M. (eds) Advances in Computer Science for Engineering and Education II. ICCSEEA 2019. Advances in Intelligent Systems and Computing, vol 938. Springer, Cham (2020).
8. ISO Homepage. Available online: https://www.iso.org/standard/58625.html, last accessed 2019/10/09.
9. Pasichnyk, V., Shestakevych, T., Kunanets, N., Andrunyk, V.: Analysis of completeness, diversity and ergonomics of information online resources of diagnostic and correction facilities in Ukraine. In: 14th International Conference on ICT in Education, Research and Industrial Applications. Integration, Harmonization and Knowledge Transfer (ICTERI), vol. I, pp. 193-208 (2018.)
10. Youngblood, S., Youngblood, N.: Usability, content, and connections: how county-level Alabama emergency management agencies communicate with their online public. Government Information Quarterly, vol. 35, iss. 1, pp. 50-60 (2018).
11. Regarding the duties of a teaching assistant, https://zakon.rada.gov.ua/rada/show/v-675736-12, last accessed 2019/10/21.
12. Hrytsiuk, Yu., Andrushakevych, O.: A tool for determining the quality of software by metric analysis methods. Scientific bulletin NLTU of Ukraine. Vol. 28 (6), pp. 159-171 (2018).
13. Saaty, Thomas L.: Mathematical Principles of Decision Making (Principia Mathematica Decernendi) Pittsburgh: RWS. (2009).
14. Kolyada, M., Bugayeva, T.: Making pedagogical decisions based on the analysis of hierarchies by the Saati method. Educational technologists and society. No. 2(18) (2015). http://ifets.ieee.org/russian/periodical/V_182_2015EE.html, last accessed 2019/11/01.