DEVELOPMENT OF METHODOLOGY
FOR ASSESSING DIGITAL COMPETENCE LEVELS IN PERSONNEL TRAINING

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The developing digital economy alters the labor market demand both qualitatively and quantitatively, thus shaping a new paradigm for specialist training. In the RF regions professional education is meant to be significant in supplying economy with human resources. There must be competent trainers to enable trainees' digital skills development. Research in determining levels of trainers' digital literacy is one of the stages aimed at professional education improvement to procure digital economy with specialists. Issues of theoretical modelling of digital competences structure as well as methodological support of competences diagnosis are the key ones. This research is devoted to the development of methods for diagnosing levels of mastering digital competences in training. An overview of literature embracing such concepts as «digital literacy», «digital competences» is introduced. Basic features of currently available digital competences models are being described. Based on the investigations held by colleagues and with account of activities specifity of higher educational structures a new competence model including such major digital competences groups as «Digital office», «Net technologies use», «Digital security in professional activity», «Software and applications installation» has been developed. A description of the toolkit for diagnosing digital competence levels in training is given. Automatic data processing algorithm has been developed to enhance interpretation of digital competences levels. Diagnosis method to determine the level of digital competences proficiency was tried out in 2018 at the Ryazan Region Department of Education and youth policy. The research results may be used by public authorities in the decision-making procedures. Study materials may be applied in the process of further investigations of research and practice issues dealing with specialists training fit for digital economy. The toolset of field research including the method for trainers' digital competences level testing may be replicated and used in both public administration and entrepreneurship activities.

Keywords: digital economy, professional education, digital literacy, digital competences proficiency level diagnosis

РАЗРАБОТКА МЕТОДИКИ ОЦЕНКИ УРОВНЕЙ ЦИФРОВЫХ КОМПЕТЕНЦИЙ ПРИ ПОДГОТОВКЕ КАДРОВ

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Развитие цифровой экономики качественно и количественно изменяет потребности рынка труда в человеческих ресурсах, что определяет новую парадигму подготовки кадров. В субъектах РФ система профессионального образования играет значительную роль в обес-

печении экономики человеческими ресурсами. Одним из обязательных условий развития у обучающихся навыков в сфере информационно-коммуникационных технологий является наличие компетентных преподавателей. Исследование уровня цифровой грамотности педагогов — один из этапов совершенствование системы профессионального образования, которая должна обеспечивать цифровую экономику кадрами. Становятся актуальными вопросы теоретического моделирования структуры цифровых компетенций и методологического обеспечения их диагностики. Данное исследование посвящено разработке методики диагностики уровней освоения цифровых компетенций при подготовке кадров. Приводится обзор работ, посвященных рассмотрению сущности понятий «цифровая грамотность» и «цифровые компетенции». Описываются основные характеристики существующих моделей цифровых компетенций. На основе рассмотренных исследований коллег и с учетом специфики деятельности преподавателей образовательных учреждений профессионального образования разработана модель компетенций, включающая следующие укрупненные группы цифровых компетенций: «Цифровой офис», «Использование сетевых технологий», «Цифровая безопасность в профессиональной деятельности», «Инсталляция программного обеспечения и приложений, в том числе мобильных». Приводится описание инструментария диагностики уровней цифровых компетенций при подготовке кадров. Разработан и описан алгоритм автоматизации обработки данных для интерпретаций уровней освоения цифровых компетенций. Методика диагностики уровней освоения цифровых компетенций апробирована в 2018 г. на базе Министерства образования и молодежной политики Рязанской области. Результаты исследования могут быть использованы при принятии решений органами государственной власти. Материалы исследования могут быть применены в процессе дальнейших исследований научно-практических проблем подготовки кадров для цифровой экономики. Инструментарий полевых исследований, в том числе методика тестирования у преподавателей уровня сформированности компетенций в сфере информационно-коммуникационных технологий, может быть тиражирован и использован как в сфере государственного управления, так и в сфере предпринимательской деятельности. Исследование выполнено при финансовой поддержке РФФИ и Правительства Рязанской области в рамках научного проекта № 18-410-620002.

Ключевые слова: цифровая экономика, система профессионального образования, цифровая грамотность, диагностика уровней освоения цифровых компетенций

Introduction. Transition to digital economy sees the growing importance of human resources for the competitiveness of enterprises, regions and the country. New opportunities for doing business come along with new challenges for economy and society. The development of digital economy is connected with more effective use of intellectual capital [1]. Education plays a major role in this. The educational system is the most important factor stipulating the opportunities for the development of any economic system. Russia is currently facing the problem of modernizing education in accordance with the demands of the labor market [2].

In the past decade, the composition of the leading companies has changed. IT companies and those working in the field of information and communications technologies have taken the upper hand: Apple, Microsoft, Amazon, Google, Facebook, Alibaba, Tencent [3]. Companies and organizations are have a demand for digitally competent specialists. Consequently, the structure of employment changes as economy is getting more and more intellectual. There is a growth in demand for qualified ICT specialists in all sectors of economy. Digital skills are required for almost all working places. Traditional ways of teaching are also changing [4].

Introducing digital technologies causes significant transformative influence on the type of skills required in the economy. That is why modern education targets knowledge globalization, life-long learning. The aim of education is to train specialists capable of working in new places in current and future working environments [5].

The program «Digital economy of the Russian Federation» pays special attention to availability of human resources and improving the system of professional education. The goals of improving federal educational standards of professional education in accordance with the demands of digital economy are set in the «Human Resources and Education» activity plan of the «Digital economy of the Russian Federation» program. By 2024, it is planned to annually train up to 120,000 higher education students in the field of information and telecommunication technologies. The number of graduates of higher and secondary professional education with digital competences is supposed to reach 800,000 people per year [6]. The issues of theoretical modelling of digital competences and methodological support of their diagnostics are becoming essential.

Availability of competent teachers is considered to be a prerequisite for the students to be able to make progress in the field of information and communication technologies. One of the stages of improving professional education with the view to supply human resources for the digital economy is studying the trainers' digital literacy. This paper introduces a methodology for diagnosing the development level of digital competences.

Statement and description of the problem. The issues of digital transformation in the Russian Federation are vital both on federal and regional levels. The Ryazan Region carries out the measures set out in the activity plan of the program «Digital economy of the Russian Federation»: updating the regulatory base, building the IT infrastructure, training qualified specialists, implementing applied solutions to use information and communication technologies in state government and municipal administration, education, healthcare and other branches. Integration into cyberspace is supposed to let the region step into a new level of social and economic development.

The major long-term strategic provisions determining the Ryazan Region's socio-economic development are defined in the regional act «Long-term strategy for socio-economic development of Ryazan Region up to 2030» of December 25, 2018. Human capital is declared to be the priority trend laying the groundwork for citizens' life-long education in the evolving educational cyberspace. The human capital trend assumes organizing advanced training for teachers engaged in the system of professional education, setting up a regional training center focused on the issues of professional competences [7].

The project is aimed at developing the methodology for assessing the level of digital competences to be applied by the teachers engaged in the regional system of professional education.

The project set the following tasks:
— analysis of theoretical and methodological approaches used to diagnose digital competences: the concepts of digital literacy and digital competences, analysis of existing models for digital competences;
— developing and testing a procedure for diagnosing the competence levels;
— developing an algorithm for automatic data processing to interpret digital competence levels.

Theoretical and methodological approaches used to diagnose digital competences. Many papers explore the concept of literacy, the issue of its transformation. Earlier, literacy was seen as an ability to read, to write and to count. Now advances in science and technology have increased the number of «partial literacies». Thus, with personal computers widely used in professional activities, the concept of computer literacy emerges [8]. The concept of internet literacy appears with the spread of World Wide Web [9]. There are also other similar concepts: media literacy and information literacy.

Investigating the nature of digital literacy is a multidisciplinary endeavor rapidly evolving at international scale. Tab. 1 offers an overview of approaches to define the concept of digital literacy.

Table 1

Overview of approaches to defining digital literacy

Source	Definition
World Economic Forum in cooperation with The Boston Consulting Group [10]	Ability to use and create content on the basis of digital technologies including search and swap of information, questions and answers session, interaction with other people and computer programming
цифроваяграмотность.рф	Set of knowledge and abilities necessary for secure and effective use of digital technologies and internet resources. It includes digital consumption, digital competences and digital security
Aviram & Eshet-Alkalai [11]	Digital literacy comprises five types of literacy: Photo-visual literacy (ability to read and recognize necessary information from visuals); Reproduction literacy (ability to use digital technology in order to independently create new objects required); Branching literacy (ability to successfully handle objects in non-linear cyberspace); Information literacy (ability to search and critically assess information on the Internet); Socio-emotional literacy (social and emotional aspects of staying online: ability to cooperate, to use socialization tools and simply consume)
Hinrichsen J. & Coombs A. [12]	Ability to interact with mass media, correlate digital content with the events of one's own life by means of four models of interaction with digital environments: text participation, code-breaking, text analysis and text use
American Library Association, USA [13]	Ability to apply information and communication technologies for searching, understanding, assessing, creating and transferring digital information
The Royal Society, United Kingdom [14]	Ability to competently, securely and effectively use computers. It also includes: ability to use office software such as text processors, email and presentations software packages; ability to generate and edit pictures/audio/video; ability to use web browsers and internet search systems
International Telecommunication Union (ITU) [15]	Ability to process data, transform them into information, knowledge and decisions. This requires skills of searching and assessing information, information culture and its ethical aspects and also methodological and ethical aspects necessary to communicate in the world of digital technologies
European Union Commission, Europe (Eurostat) [16]	Competent and critical use of information and communication technologies for work, leisure, studies and communication. It should be backed by basic technical computer and Internet skills

Along with digital literacy, researchers also investigate the issues of describing digital competences. The competence-based approach is put into national educational standards in major European countries including Russia. In Russia, further development and indicators of economic growth are limited by the population's level of knowledge, abilities and skills in using new technologies. Consequently, the level of these competences has to be assessed throughout the country. It is important to compare the data obtained from different regions of Russia [17]. Let us consider the existing digital competences models.

Ershova and Zieva, researchers from the National Center of Digital Economy of the Lomonosov Moscow State University, identified the following trends in determining cross-cutting digital competences:

— computer literacy;
— communication and cooperation;
— digital content generation;
— security;
— problem-solving;
— competences related to career [18].

From Sharikov's point of view, literacy in the modern sense includes components of technological and information and communication content. The scientist comes up with a four-component model of digital literacy in a semantic environment of two constructs: technical and technological/socio-humanitarian and opportunities/threats. The four

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components related to digital literacy are identified: technical and pragmatic opportunities, communication content opportunities, technical and technological threats and socio-psychological threats [19].

Since 2015, the Internet Technologies Center, a regional non-governmental organization, has been carrying out, together with Higher School of Economics National Research University, the Digital Literacy Index project aimed at comparative assessment of the digital literacy level throughout Russian regions [20]. The structure of the index is a three–level model consisting of subindices for digital consumption, digital competences and digital security. The following parameters are taken for the index of digital competences:

— competence in information search on the Internet;
— competence in using mobile means of communication;
— competence in using social networks;
— competence in making on-line financial transactions;
— competences in consumption of goods and services via the Internet;
— critically evaluating information and verifying it;
— competence in generating multimedia content for the Internet [21].

Prokofeva, Levina and Zagrebina developed an algorithm for diagnosing professional and cultural competences in the system of higher education. Taking the materials for testing and assessment as a basis for diagnostics, the authors suggested forming professional profiles for university students, including integrated assessment of their competences [22].

A universal method for diagnosing professional competences and soft skills is currently under development (a research group is working in that direction) [23]. Modern mathematical methods are applied for developing a methodology aimed at diagnosing competences and professional soft skills.

The models of digital competences and methods for assessing competences given above are informative, diverse and, doubtlessly, have scientific and practical value. At the same time, developing an instrument for operational diagnostics of the level of digital competences taking into account the professional specifics of the employees is seen as a priority task.

In addition to the above, the instrument to be developed should offer an opportunity to automate the processes of competence assessment, to consolidate information and to analytically handle data, serving to reduce the time spent and obtain not only individual assessments but aggregated results for the entire organization.

Research methodology and results. To construct a valid competence profile, professional activity-related factors should be taken into account, i.e., the functions that the employee is responsible for.

Based on the above-mentioned research and with view to the specifics of the university teachers' professional activities, the following large groups of digital competences have been defined for the purposes of our study:

— Digital Office;
— Using Internet technologies;
— Digital security in professional activity;
— Installing software and applications [24].

Testing was chosen as an instrument for assessing independent competences. The test consists of 40 questions, 10 questions to assess each competence. For each competence there is a selection of random, mixed-level questions.

Knowledge and skills of office packages are assessed in the «Digital Office» competence group. Examples of the test questions include:

Which kind of diagrams can be constructed in EXCEL?
— bar graph
— circle diagram
— high-low chart
— radial chart
— Gaussian

Knowledge and skills of Internet technologies are assessed in the «Using Internet technologies» competence group. Examples of the test questions include:

Which tool could be used by several users to simultaneously edit e-documents?
— Google Documents
— Яндекс.Disk
— Mail.Ru Cloud
— MS-Word 2010
— This is not possible

or

What is the quickest way to deliver the task written on the board to the students missing the class?

– Take a smartphone photo and post it in a WhatsApp group

– Take a smartphone photo and post it in a VKontakte conference

– Reprint the task and send it by email

– Reprint the task and post the file in an electronic educational environment

Knowledge of information and computer security is assessed in the «Digital security in professional activity» competence group. Examples of the test questions include:

If there is a reason to suspect a phishing attack, you should... (choose the appropriate actions):

– Change the password of the resources containing personal data

– Notify the administrator of the original site

– Reply expressing your suspicions

or

What is an electronic digital signature?

– Signature scan

– Facsimile

– Cryptographic sequence used for signing remote documents

– No correct answer

Knowledge, abilities and skills of installing software on computers and/or mobile devices are assessed in the «Installing software and applications» competence group. Both test questions and practical tasks asking to install professionally useful applications on a smartphone are offered.

A comprehensive test on Digital Competences Assessment is hosted at the Ryazan State Radio Engineering University in the system of distance learning based on the Moodle platform. A Moodle-based system of distance learning allows to test a large number of respondents and to automatically assess the tasks fulfilled. Each competence has its own question bank made in advance. The individual test consisting of 40 questions (10 questions for assessing each competence) is generated for each respondent by random selection from the bank. The test includes questions with varying difficulty levels taken into account in assessing the answers. Different types of questions are used: multiple choice with a single answer or several correct answers, matching questions, questions with short answer.

The order in which questions and answer options in multiple choice questions were offered was changed when a new (individual) test was generated. One attempt was given for testing. The time limit set was 90 minutes.

Algorithm for automatically processing data and interpreting digital competence levels. After testing, a table showing the test results was generated. It contains 45 columns and 200 lines. Each table line represents a finished test attempt.

The table for processing the results contains the following columns:

User (user identifier);

Test is started (test start time);

Finished (test finish time);

Time spent (execution time);

Final mark (test result);

Question 1 (competence 1), ..., Question 10 (competence 1);

Question 11 (competence 2), ..., Question 20 (competence 2);

Question 21 (competence 3), ..., Question 30 (competence 3);

Question 31 (competence 4) ...., Question 40 (competence 4).

Thus, the resulting table represents an array consisting of 9000 cells. To automatically process the results in accordance with the developed algorithm, it is necessary to develop a program for calculating the results.

The summary results of the testing (Tab. 2) are input data. Processing complexity and, as a result, the necessity for automation are due to the fact that the test bank contains questions with varying difficulty levels.

Mathematical model for interpreting the test results uses fuzzy logic and soft computing methods.

The output data should be organized, for example, as in the following table (Tab. 3).

It is known that the test bank contains m_1^{kj} questions for each jth competence, which score 1 point. There are also m_2^{kj} questions which score 2 points and there are m_3^{kj} questions which score 3 points.

Summary testing results

	competence 1 «Digital office» k_1	competence 2 «Using Internet technologies» k_2	competence 3 «Digital security in professional activity» k_3	competence 4 «Installing software and applications» k_4
User₁	$L_{1,1}$	$L_{1,2}$	$L_{1,3}$	$L_{1,4}$
User₂	$L_{2,1}$	$L_{2,2}$	$L_{2,3}$	$L_{2,4}$
....	....	....	....	....
Userₙ	$L_{n,1}$	$L_{n,2}$	$L_{n,3}$	$L_{n,4}$

Output data for interpreting results

User	competence 1 «Digital office» k_1	competence 2 «Using Internet technologies» k_2	competence 3 «Digital security in professional activity» k_3	competence 4 «Installing software and applications» k_4
User₁	Advanced Level	Threshold level	Below critical level	Critical level
User₂	Critical level	Below critical level	Advanced Level	Threshold level
....	...	...	...	...
Userₙ	Threshold level	Advanced Level	Threshold level	Critical level

Step 1. Determining the upper interval boundary balanced by probability of getting questions with higher or lower difficulty:

$$\forall k_j \quad (j = \overline{1,4}), \qquad m_3^{kj} \qquad \tilde{D}_{k_j} = n(1m_1^{kj} + 2m_2^{kj} + 3m_3^{kj}) / (m_1^{kj} + m_2^{kj} + m_3^{kj}),$$ where n is the amount of generated questions from the test bank.

Step 2. Determining the measure of membership in a given competence for each fuzzy set forming the linguistic variable L (Level of competence proficiency) for each respondent User$_i$ $x^i_{k_j} = \sum_{q=1}^{n}(B_{user_i} / \tilde{D}_{k_j})$, where B_{user_i} is the point for a correct test answer of an ith respondent.

Step 3. Adjusting the values of membership measures: if $x^i_{k_j} > 1$, then set $x^i_{k_j} = 1$.

Step 4. Generating a fuzzy set

$\forall$ User$_i$, $(i = \overline{1,N})$, $\forall k_j$ $(j = \overline{1,4})$, where N is the number of respondents, to generate a fuzzy set $L_{User_i} = \{(x^i_{k_j}, k_j)\}$.

Step 5. Interpreting the results

$$\forall k_j \quad (j = \overline{1,4})$$

if $x^i_{k_j} \geqslant 0,75$, then print message «advanced level of proficiency for competence k_j», otherwise,

if $(x^i_{k_j} \geq 0,5) \& (x^i_{k_j} \leq 0,75)$, then print message «threshold level of proficiency for competence k_j», otherwise,

if $(x^i_{k_j} \geq 0,25) \& (x^i_{k_j} \leq 0,49)$, then print message «critical level of proficiency for competence k_j», otherwise, print message «level of proficiency for competence k_j is below critical».

Step 6. End of algorithm.

Enlarged flowchart for the algorithm is shown in Fig. 1.

It should be noted that the developed algorithm allows to obtain a fuzzy set which reflects the level of proficiency in digital competences for four established groups («Digital Office», «Using Internet technologies», «Digital security in professional activity», «Installing software and applications, including mobile». We should stress that a procedure of ranging (applied to each specified competence) appears to be useful for further analysis of the results obtained. Existing algorithms (for example, Shell sort algorithm) may be applied for data sorting. It is obvious that data processing in parallel mode is appropriate in that case [25].
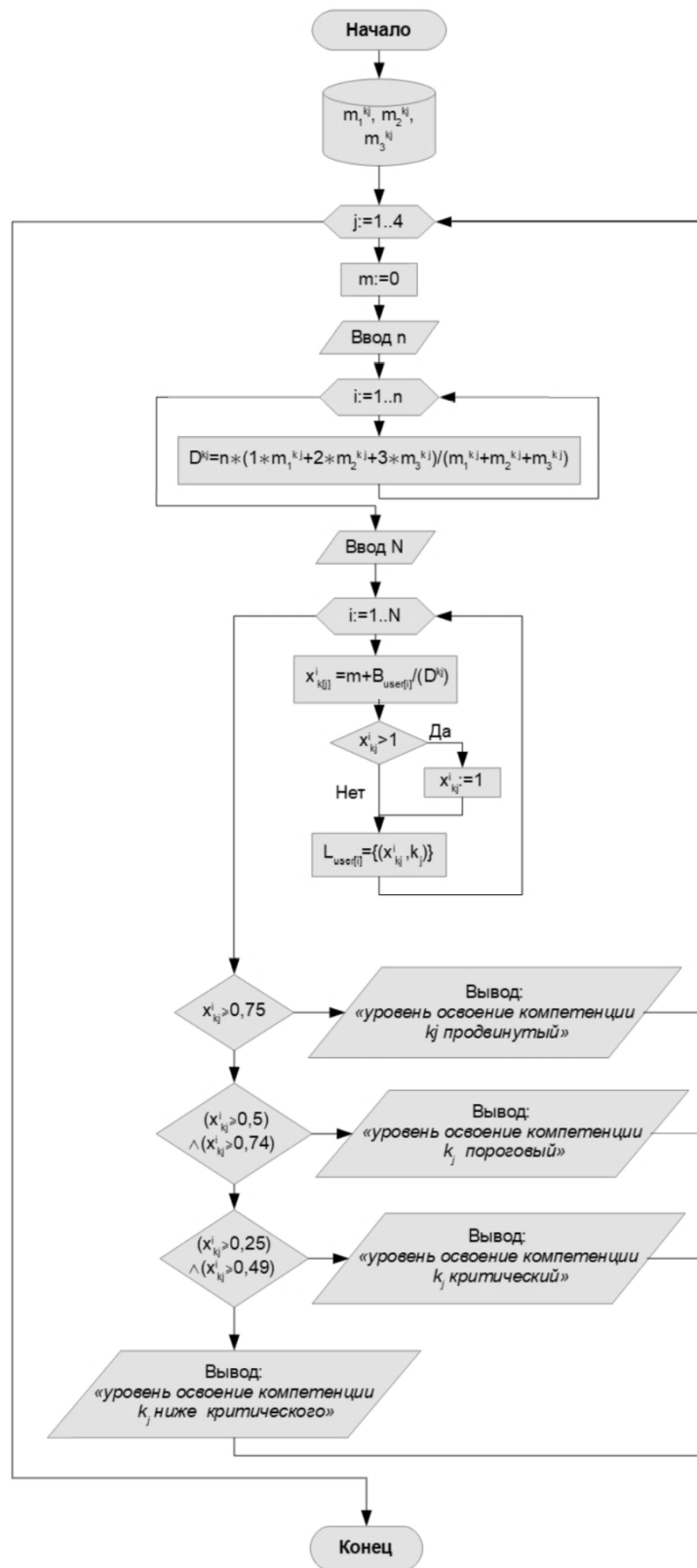
Fig. 1. Algorithm flowchart

In case of a large number of respondents and, consequently, a large data array, it is advisable to interpret the results using the criteria of maximum and minimum. That should allow to calculate the analyzed factors for different combinations of large groups [26]. The results obtained for the teachers' digital competences may be used by the Regional Ministry of Education and Youth Policy for making managerial decisions.

Conclusions and suggestions. The evolving digital economy both quantitavely and qualitively alters the demand of the labor market in human resources, shaping a new regional paradigm for training specialists. A system of professional education provides input resource flows and, thus, fulfills its major task of supplying regional economy with human resources.

Improving the regional system of professional education to ensure the development of digital economy should be started with diagnostics of the system's current state.

A methodology for assessing the level of digital competences in teachers (of professional education) has been developed.

The developed toolset for field studies was registered in as electronic resources. They meet the requirements of novelty and priority. In 2018, we obtained registration certificates no. 23944

«Questionnaire bank for Regional Digital economy» from the Institute of education management of Russian academy of education and no. 23945 «Test system for Digital Competences Assessment» from the Science and Education Joint Fund of E-resources.

The results of the study may be used by representatives of the government and municipal regulatory agencies in order to develop and implement a comprehensive set of measures targeting the support of different educational establishments of the region.

The developed algorithms allow to automate the process of interpreting the results. Fuzzy logic methods were employed to serve as a mathematical model, allowing to transform a quantitative indicator of test results into a qualitative characteristic describing the level of competence proficiency.

The assessment tools are recommended for use in other regions. The described method can be used not only in the system of professional education but it can also have wide applications in the sphere of state administration, in state and municipal organizations, and in entrepreneurial activity.

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