Journal of Theoretical and Applied Information Technology
31st October 2022. Vol.100. No 20

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

INFORMATION TECHNOLOGIES FOR VISUALIZATION OF DIAGNOSTIC RESULTS OF FUTURE ENGINEERS COMPETENCES IN MULTIDIMENSIONAL NON-METRIC SPACES

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ABSTRACT

The problem of using information technologies to visualize the results of diagnostics of professional competences development on the example of students of engineering specialties is topical. The purpose of the manuscript is to identify the possibilities of information technologies for data visualization in multidimensional non-metric spaces using the example of identifying the level of formation of individual competencies of future electrical engineers. Methods for achieving the stated purpose were the following: theoretical (analysis and synthesis) ones facilitated the development of the "Chernoff face" designer program based on the MATLAB software package; empirical (expert assessment and surveying) ones helped to identify criteria and means of diagnosing the formation of professional competencies and create the most optimal image of the "Chernoff faces". The results revealed that in educational process visualization is capable of ensuring emotionality, ease and speed of perception of the necessary information by students; structuring data into a coherent image; analysing the visualized information according to specific criteria and indicators; demonstrating the relationships between the various analysed indicators; preventing information overload; supporting attention, activating thinking and memory. Moreover, various methods of visualizing the level of competence formation increase the effectiveness of the perception of diagnostic results and the possibility of adjusting educational and methodical trajectories. The authors have developed a designer program and have proposed fragments of the program code for creating "Chernoff faces" based on the MATLAB software package, which allow students to visualize the level of formation of professional competences and provide the possibility of developing a strategy for their improvement.

Keywords: *Visualization information technologies, Professional competences, Multidimensional non-metric space, Professional training of engineers*

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

1. INTRODUCTION

Based on the use of information technology visualization resources, a program for creating "Chernoff faces" has been developed. It allows us to visually present the data of the multidimensional non-metric space.

With the development of information technologies, a significant volume of special programs for visualization of data arrays has been developed. The Microsoft Office suite installed in each PC allows users to visually present data in the form of graphs and charts of various types. There are a large number of various software tools for data visualization that are in cloud services and are interactively changed. Depending on the task, you can find a comprehensive solution for building diagrams, presentations, dashboards, etc. Software capable of implementing this includes not only Microsoft Office, but also Plotly, DataHero, Dygraphs, ZingChart, Visual.ly, FusionCharts, Aristochart, Graph, Chartbuilder, RAW and others [1]. Mathematical programs, packages of application programs with a graphical interface contain visualization tools. Even if calculations are performed from the "command line", they are activated in the form of especially built-in functions. The following programs are widely known to researchers: FEMM that is software tool for 2D modelling and visualization of magnetic fields; Ansys Maxwell is a leading software product for 2D and 3D modelling of electromagnetic fields used in the design of electric motors, sensors, transformers and other electrical and electromechanical devices; MATLAB is the most powerful set of package solutions aimed at fast and high-quality data processing, covers all areas of mathematics, three-dimensional graphics and animated videos; Mathcad is a computer algebra system from the class of automated design systems, focused on the preparation of interactive documents with calculations and visual support. This list can be expanded.

The means of visualization of information (presented in Figure 1) have both advantages (they provide a discrete distribution of frequencies, allow consumers to see the dynamics of the formation of one or another quality, compare the results of diagnostics, etc.), and disadvantages: template, allows users to graphically display the general trend, but complicates criterion analysis.

Thus, in the modern world the need for visualization of information with educational purposes is especially significant [2]. At the same time professional training of engineers who have extensive knowledge of the problems of modern engineering and innovative technologies, have the skills to apply fundamental knowledge to solve the scientific and practical tasks of managing energy-efficient types of equipment, ensuring the quality of electrical energy in power networks, optimizing operation modes of electric power, electrotechnical and electromechanical systems and can be useful in various structures and branches of enterprises, is becoming more urgent.

Figure 1: Types of charts, presentations, dashboards, etc., offered by modern data visualization software

This requires the training of a specialist who, from the first days of work at the factory, possesses a number of professional competencies and does not require a long process of adaptation to work there. Therefore, the efforts of teachers of modern higher education institutions should be aimed at creating conditions for ensuring the procedural and result-oriented component of education, the basis of which is the formation of professional competences. The active use of ICT in the educational process, especially in the modern conditions, creates prerequisites for changing all links of education in higher schools [3], which is manifested in the diversification of teaching methods, didactic techniques, and means of organizing the educational process in higher education.

The team of authors is of the position that identifying the level of competence formation is a time-consuming process that is not limited to conducting a final diagnosis, but requires the development of innovative forms and methods of training that can bring the educational process as close as possible to the conditions of modern production and provide professionally oriented training of specialists and, of course, objective diagnosis of the development of one or another competence during training.

The training of a specialist should be checked in relation to his achievement of the appropriate level of professional competence

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

development. Therefore, in the course of the study, the authors hypothesized that the use of visualization information technologies ("Chernoff face") in the process of assessing professional competences allows teachers to quickly and effectively diagnose the level of their formation in future specialists in electrical engineering.

2. LITERATURE REVIEW

Diagnostics of professional competencies is a relatively new task for professional pedagogy and at the same time extremely relevant, because the quality of professional training in higher education institutions today must be determined by a number of formed general and professional competencies and their level [4]. The issue of diagnosing students' professional abilities and skills using ICT was considered in the works of Klimova & Hubackova [5], George et al. [6], Bykov [7], Zahirnyak [8], Trifonov [9], Petkov [10], Chornyi [11], and others. Vorotnikov [12], Holubnycha & Baibekova [13] investigated the possibilities of ICT in monitoring educational achievements during e-learning.

However, the analysis of the works of modern researchers did not allow us to identify a well-founded method of systemic diagnosis of the professional competencies of a future engineer in a higher educational institution.

The existing generally recognized methods of diagnosing educational achievements are aimed at evaluating the learner's knowledge in a separate discipline and differ from each other only by points on one or another scale. The transition from the assessment of the acquirer's knowledge of individual disciplines to the assessment of the formation of a certain competence causes an avalanche-like complication of the assessment process and criteria. After all, competence is formed under the influence of a group of disciplines, the teaching of which may not coincide in time. The average value of grades for disciplines forming competence cannot be an indisputable indicator of its formation either, since the question of the importance of individual discipline influence on this process has not been resolved.

Similar problems arise at the final stage of evaluating the quality of specialist training based on hypothetically obtained assessments of the formation of individual competencies. Since their real level in the practice of modern higher education institutions is not revealed. In technology, a similar rapid increase in the complexity of a system consisting of individual simple components due to their combination and the creation of various ways of their interaction leads to the formation of so-called "complex" systems that have properties that are not inherent to any of the constituent elements.

The presence of numerical characteristics of the formation of individual competencies does not eliminate the problem of assessing the quality of specialist training as a whole. From a purely mathematical point of view, this leads to the need to consider sets with vaguely defined values of individual components and weakly determined metrics, or even to consider multidimensional nonmetric sets.

So, **the purpose** of the article is to identify the possibilities of information technologies for data visualization in multidimensional non-metric spaces using the example of identifying the level of formation of individual competencies of future electrical engineers.

3. METHODS AND MATERIALS

In the work, the authors were based on the following scientific approaches:

1) *competence*, which determined the use of the proposed methods of visualization to check the formation of professional competences of electrical engineering specialists;

2) *design and research*, which provided the opportunity to implement the author's ideas, such as: the development of software for data visualization in multidimensional non-metric spaces on the example of the formation of individual competencies of future electrical engineers.

The following methods were used to achieve the specified purpose:

1) theoretical, namely *analysis and synthesis* of research related to pedagogical diagnostics, the use of ICT in conducting diagnostic activities, as well as works devoted to the analysis of information visualization methods and design for the development of the "Chernoff face" designer program based on the MATLAB software package;

2) empirical such as: *expert assessment* to identify criteria and means of diagnosing the formation of professional competencies common among teachers; *surveying* students to create the most optimal image of the "Chernoff faces".

4. RESULTS

The initial data was obtained as a result of research carried out at Kremenchuk Mykhailo Ostrohradskyi National University. Based on the expert evaluation of 132 teachers of higher technical education, two main criteria for diagnosing professional competences were

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

determined. They were the following: 1) cognitive (knowledge of fundamental and professional disciplines); 2) operational (testing of abilities and skills necessary for work in real production conditions).

The proposed diagnostic tools are determined on the basis of the work experience of the academic staff of the Institute of Education and Science in Electrical Engineering and Information Technologies of Kremenchuk Mykhailo Ostrohradskyi National University.

The use of test materials for evaluating the effectiveness of the quality of student training at various stages of education is the subject of numerous studies [10], [14-17]. The knowledge test allows academic staff to diagnose a large number of students in a limited period of time. The tests used in the study contain 50–60 questions and consist of tasks of theoretical and practical content, which can be conventionally divided into thematic blocks (3–5 questions in each). The simplest single-choice tests can check the formation of fundamental, professional knowledge and basic skills and abilities: (the ability to solve practical problems involving mathematical methods, the ability to read diagrams, transform them, graphically display the electromechanical properties of objects, the ability to solve problems related to operation of electric machines and devices, etc.). The systems of test tasks are placed on the MOODLE platform, which allows the use of a wide variety of tests, provides the possibility of conducting diagnostics at a time convenient for students, and impartiality and objectivity of evaluation. [18]. The authors have the experience of repeatedly conducting a test control (current control, thematic, modular, final control in the form of a credit), in which the forms of questions are preserved, but the content is partially changed, which allows academic staff to check the flexibility and awareness of the content of educational information by students and the systematicity of knowledge in the discipline.

A survey of 54 teachers of the institute made it possible to find out that research only on synthesized mathematical models led to the fact that students had difficulties in understanding the physical nature of electromagnetic and mechanical processes of real objects [8]. The mentioned became the impetus for the development and research of virtual complexes. These are simulations of real physical objects created with the help of computer systems, which can act as substitutes for real production devices and processes, provide visual and sound effects based on the technology of non-contact information interaction, which allows the user to act directly with the help of special touch devices and management devices [8], [11]. Working with virtual complexes allows the student to get closer to the conditions of real production, enables the development of diagnostic skills, management of production equipment and technological processes, the ability to find the causes of emergency situations in production and learn how to eliminate them, etc. When creating virtual complexes, LabView software was used, which is a universal programming system focused on solving the tasks of managing instrumental means of measurement, collection, processing and presentation of experimental data. However, work with virtual complexes and simulators is mainly analytical in nature, although it allows students to learn the content and sequence of certain actions necessary for a future specialist in electrical engineering in production.

Further development of professional competences is provided by performing tasks on physical stands, where it is necessary to demonstrate not only theoretical knowledge, analytical skills, but also operational and motor skills of working with equipment: turn on (turn off) the system, eliminate damage, select equipment, set task signal levels, to conduct research according to methodological instructions and according to the task of scientific research, for example, “Using a stand to investigate the electromechanical and regulatory properties of an electromechanical system, its static characteristics and dynamic modes”, to acquire skills in planning a research experiment and processing the obtained experimental data, graphical visualization of work results and displaying them in the form of a report.

Professionally oriented tasks play a significant role in assessing the development of students’ professional competencies. They make it possible to solve a real possible production situation, using the synthesis of tools of professional educational disciplines. This type of tasks is as close as possible to situational modelling and is designed to reveal the level of development of professional thinking, analytical abilities, theoretical training, understanding of the production situation, the ability to evaluate it, which allows future specialists to make the right decisions in the situation at work. After all, a competent professional must not only understand the essence of the problem, but also be able to solve it practically, demonstrating his own method and ability to make prompt and non-standard decisions [19], [20].

Journal of Theoretical and Applied Information Technology
31st October 2022. Vol.100. No 20

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

In Table 1 a list of professional competencies and means of their diagnosis are presented.

Table 1: Diagnostic tools for the formation of professional competences of future bachelor engineers

Test	Working with a virtual laboratory stand	Working with a physical laboratory stand	Solving professionally oriented tasks
1) knowledge of the fundamental and professional foundations of the discipline; 2) the ability to analyse and synthesize; 3) the ability to make models of electrotechnical, electromechanical objects	1) the ability to read diagrams, transform them, graphically display the electromechanical properties of objects; 2) mastering software tools for modelling; 3) study of characteristics of operating modes and energy processes of direct and alternating current electric drives; 4) the ability to promptly take effective measures in emergency situations in electric power and electromechanical systems.	1) mastering the principles of operation of electromechanical equipment; 2) ability and skills to work with measuring devices, computer equipment, technological equipment; 3) research of control systems of various technological objects	1) the ability to solve practical problems involving the methods of mathematics; 2) the ability to make decisions and choose the most optimal alternative, arguing its feasibility from the point of view of evaluating the efficiency of the equipment, possible risks, etc.

The result of the diagnosis is a sufficiently extensive characteristic that should reflect the type of competence, the level of its development, dynamics, recommendations for improvement, etc. The authors are absolutely convinced of the need to detail each result by each indicator, which will allow teachers and students to imagine a holistic picture of educational achievements and, in the future, make a successful self-development strategy for the student. To do this, we need to familiarize applicants with at least 12 indicators, each of which can be characterized by several levels. In order to reflect the dynamics, it is necessary to collect the diagnostic material of at least three, and preferably five, control measurements during the academic semester. Therefore, the characteristic will be difficult to perceive, will require some time for study, awareness, determination of conclusions and perspectives of one's own development. The evaluation in points, unfortunately, does not reflect the quality level of students' training, which was repeatedly noted by researchers. So, Zvonnikov [20], Tytova [15], Chernyavska [21] are convinced that the traditional session-examination control of students' educational achievements, although it stimulates the educational activity of students, it does not solve the problems of ensuring the quality of specialist training in accordance with the criteria of professionalism and competitiveness, which are objectively put forward by modernity [20]. The content of the modern assessment paradigm is to demonstrate to the student possible ways of further achievement and improvement, generalization of acquired knowledge, updating of skills, and development of professional competencies. In such a context, it is extremely important to offer a convenient, effective type of assessment that would allow students to quickly understand their own educational achievements.

The graph given in Figure 2 shows the results of the test diagnosis of students of one group. However, it is extremely difficult for the teacher to understand the general trend of the successful completion of test tasks in the group as a whole, actually to compare the educational achievements of one student with others, or to follow the dynamics of success of a specific student in different tests on such a graph.

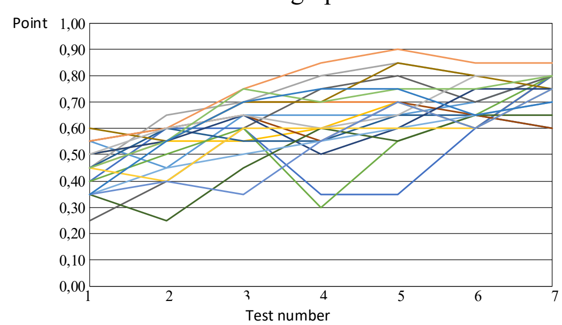


Figure 2: Graphs of the results of students' performance of test tasks

In Figure 3 the performance of nineteen students on seven tests is demonstrated. Like a graph, this type of visualization, when many indicators are entered at the same time, becomes excessively heavy and loses visibility. The situation will become more complicated if, in addition to one diagnostic tool, several more tools are added that would allow checking the system of defined competencies. In our study, these are four tools that make it possible to diagnose the levels of formation of twelve competencies. It is clear that visualization with the help of a single diagram or graph will lose visibility, make it difficult to understand, and

Journal of Theoretical and Applied Information Technology
31st October 2022. Vol.100. No 20

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

increase the time to study due to information overload.

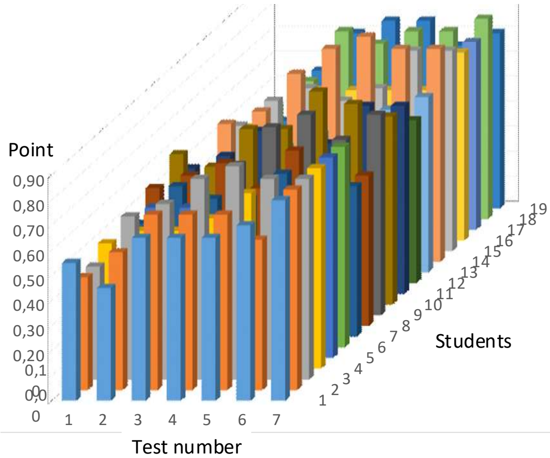


Figure 3: Histogram of performance of test tasks

Therefore, the need to find visualization techniques capable not only of visualizing the results of diagnostics, but also of solving a complex of important tasks is becoming urgent. Among the tasks are the following:

- the ease and speed of a person's perception of the necessary information;
- data structuring into a complete image;
- the possibility of analysing the visualized information according to specific criteria and indicators;
- emotional colouring and aesthetic appeal;
- ease of demonstration of relationships between various analysed indicators;
- prevention of information overload;
- maintenance of attention, intensification of thinking and memory;
- possibility of cluster analysis.

These tasks are mainly solved by the pictography technique. So, for example, to ensure a quick perception of the results of the test control (estimated in the ECTS system), tables of signs with elementary geometric objects were used: no sign means up to 60 points, dot is 60-63 points, dash - 64-73 points, triangle - 74 -81 points, circle means 82–89 points, circle with a cross is 90–100 points.

Analysis of Figure 4 allows us to state that the speed of perception of assessment and awareness of one's own results increases significantly. Thanks to this pictography, a teacher can easily identify positive and negative trends in the performance of the group as a whole, as well as individual students. However, simple pictography does not allow us to reveal the relationships between different levels of competence formation.

1			|	|	|	|	Δ	Δ	Δ	O
2			|	|	|	•	Δ	Δ	O	⊕
3		|	|	Δ	O	Δ	Δ	|	Δ	Δ
4				•	|	•	Δ	Δ	Δ	Δ
5		•	•			•	Δ	Δ	Δ	Δ
6			•			|	Δ	Δ	|	|
7		•			|	|	•	|	|	Δ
8		•	|		|	|	•	|	|	|
9			•	Δ	Δ	|	Δ	|	|	Δ
10	•		|	|	O	Δ	Δ	Δ	O	O
11			|		•	Δ	Δ	Δ	Δ	O
12				•		|	|	|	Δ	Δ
13					•	|	|	|	Δ	Δ
14		•	Δ	O	⊕	O	O	O	O	⊕
15		•	|	•	|	Δ	Δ	Δ	O	Δ
16			•	•		•	Δ	Δ	|	|
17					|	•	Δ	Δ	Δ	Δ
18			Δ	|	Δ	Δ	Δ	Δ	Δ	O
19			|	Δ	Δ	|	|	|	Δ	Δ

Figure 4: Simple pictograph of test results

An interesting method of visualizing the level of educational achievements of students can be the "Chernoff faces" method. Its main idea is based on a person's ability to "automatically" fix complex relationships between many variables, if they appear in a certain sequence of elements. Sometimes the understanding that some elements are "somewhat similar" to each other comes before the analyst can explain which variables caused this similarity. That is, the analysis of information using this method of display is based on a person's ability to intuitively find similarities and differences in facial features [22].

"Chernoff face" is one of the most interesting types of pictographs, a scheme of visual representation of multifactorial data in the form of a human face [23]. It allows us to focus on the elements placed next to each other. For each indicator, a separate facial feature is drawn, where the relative values of the indicators are presented as their shapes and sizes (for example, the length of the nose, the angle between the eyebrows, and the width of the face).

Types of information coding in faces can vary from simple to the most complex. As an example, Figure 5 shows the distribution of data for further analysis [24], represented by two characteristics: the size of the face and the relative size of the forehead. Notably, there are few faces with broad foreheads and narrow jaws, or vice versa, indicating a positive linear correlation between the variables.

In order to identify the most expressive facial image, which is easily perceived by students, a survey of fifty people was conducted, which allowed the authors to note the following: 90% of the respondents preferred a realistically modelled face with a bright emotion; 10% would prefer a symbolic image (for example, a smiley); 100% believe that the dynamics of change should be encoded in the change in the size and shape of the face.

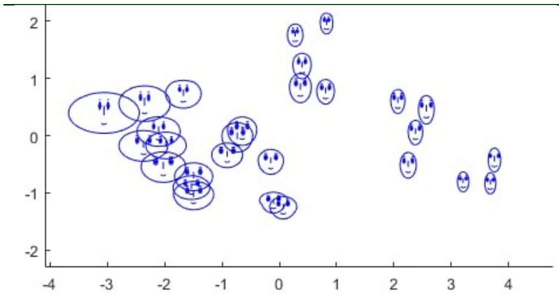


Figure 5: An example of data distribution based on "Chernoff faces"

To track the most elementary changes in the image and to carry out a more precise analysis, a standard image is developed separately. We take it as a high level of development of defined competencies. The standard image will have classic facial features with an emotion of satisfaction and positivity.

Figure 6: "Chernoff face" for a student with a high level of professional competence development (standard image)

If the level of formation of the indicators is less than the standard, the oval of the face is elongated, the eyes are narrowed, and the corners of the mouth are lowered to the bottom, making a grimace of dissatisfaction. The conclusions made by Soboleva [25], who identified several difficulties in the construction of the faces, were chosen as the basis. These difficulties are: 1) scaling of facial features (for example, the nose cannot be larger than 2/3 of the face) requires calculating the average value of the indicator and the proportions of facial features; 2) displaying not numerical, but determinant values and bringing them to an interval form.

In our work, we had the task of visualizing the diagnosis of educational achievements, which is a complex process that can be carried out thanks to the verification of the twelve indicators chosen by us and the corresponding levels of their development. To simplify the process of constructing a visual image of the diagnosis of acquired competencies, four levels were defined and characterized: "Unsatisfactory", "Low", "Medium", and "High".

"Unsatisfactory" means lack of thorough knowledge of professional fundamental disciplines; low level of analytical abilities and the ability to summarize information, opinions and draw conclusions; inability to make mathematical models of electromechanical objects, read diagrams, reproduce them graphically; lack of understanding of the principles according to which electromechanical equipment operates; inability to use software tools for modelling; inability to use measuring devices for researching control systems of various technological objects, solving practical problems and making decisions about analysis of production situations.

"Low" means the development of shallow superficial knowledge of professional disciplines, the ability to reproduce them according to a sample or provided algorithm; low level of analytical and synthetic abilities. Students with a satisfactory level of development of professional competences can make simple mathematical models of electromechanical objects, read diagrams, reproduce them graphically, but at the same time make significant mistakes. Such students partially understand the principles of operation of electromechanical equipment; they know how to use software tools for modelling and how to use measuring devices for researching control systems of various technological objects, they can solve simple practical problems. However, they experience difficulties in analysing production situations and making adequate decisions.

"Middle" means a sufficient level of possession of fundamental and professional knowledge, the ability to use it to solve problems of a certain class or type, demonstrate analytical and synthetic abilities, mastery of the principles of operation of electromechanical equipment, software tools for modelling. Students with an average level of development of professional competences can conduct research on the characteristics of operating modes, static, dynamic and energy processes of direct and alternating current electric drives, based on the teacher's recommendations; Such students can eliminate simple problems in the operation of production technological equipment, make decisions regarding production situations.

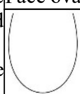
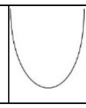
"High" means a high level of fundamental and professional knowledge, the ability to use it flexibly in atypical situations, to establish interdisciplinary and cross-thematic connections, to demonstrate a high level of analytical and synthetic abilities, mastery of the principles of operation of electromechanical equipment, software tools for modelling, the ability to independently compile programs; such students can conduct research on the characteristics of operating modes, static, dynamic and energy processes of direct and

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

alternating current electric drives; on the basis of the results of measurements they identify and eliminate problems in the operation of production technological equipment, make decisions about situations in production.

The authors were guided by the mentioned in the development of visual characteristics. The coding of indicators is presented in the Table 2. To design a face that will correspond to the levels of formation of the relevant competencies, a program was created based on the MATLAB software package, which "stitches" (compiles) facial features, superimposing visual elements on top of each other.

Table 2: A fragment of the table for coding indicators through facial features

Group of competencies	Facial features			
knowledge of the fundamental and professional foundations of the discipline	Face oval			
				
the ability to analyse and synthesize	Hair			
				
mastering the principles of operation of electromechanical equipment	Mouth			
				
The ability to solve practical problems involving the methods of mathematics	Right ear			
				
ability and skills to work with measuring devices, computer equipment, technological equipment	Left ear			
				

Files with facial features form an array and are placed in the IMAGES folder (Figure 7).

```
pictFolder = strcat(pwd, "\IMAGES");
jpgImages = [
 "1_1.jpg", "1_2.jpg", "1_3.jpg", "1_4.jpg";
 "2_1.jpg", "2_2.jpg", "2_3.jpg", "2_4.jpg";
 "3_1.jpg", "3_2.jpg", "3_3.jpg", "3_4.jpg";
 "4_1.jpg", "4_2.jpg", "4_3.jpg", "4_4.jpg";
 "5_1.jpg", "5_2.jpg", "5_3.jpg", "5_4.jpg";
 "6_1.jpg", "6_2.jpg", "6_3.jpg", "6_4.jpg";
 "7_1.jpg", "7_2.jpg", "7_3.jpg", "7_4.jpg";
 "8_1.jpg", "8_2.jpg", "8_3.jpg", "8_4.jpg";
 "9_1.jpg", "9_2.jpg", "9_3.jpg", "9_4.jpg";
 "10_1.jpg", "10_2.jpg", "10_3.jpg", "10_4.jpg";
 "11_1.jpg", "11_2.jpg", "11_3.jpg", "11_4.jpg"
 ];
```

Figure 7: Creating an array with files of facial features

The correspondence of professional competences to the received grades is carried out according to the algorithm displayed in Figure 8:

```
% Student number
NS = 20;
sgrade = grades(:,NS);
% picnums = sgrade;
for i = 1:length(sgrade)
 if (sgrade(i) >= 90)
  pictures(i) = jpgImages(i, 1);
 elseif (sgrade(i) >= 74)
  pictures(i) = jpgImages(i, 2);
 elseif (sgrade(i) >= 60)
  pictures(i) = jpgImages(i, 3);
 else
  pictures(i) = jpgImages(i, 4);
 end
end
```

Figure 8: Algorithm of the correspondence of professional competences to the received grades

It is necessary to note that the level of development of the corresponding competence matches the range:

60> "unsatisfactory";
60⋜ "low" <74;
74⋜ "middle" <90;
90⋜ "high" ⋜100, evaluated according to the ECTS system.

The "stitching" the face, taking into account the established correspondence of the grades to files with facial features, is carried out according to the algorithm:

```
pictFolder = strcat(pwd, "\IMAGES");
StartFileName = fullfile(pictFolder, pictures(1));
blackface = rgb2gray(imread(StartFileName));
for i = 1:length(pictures)
 NextFileName = fullfile(pictFolder, pictures(i));
 nextpic = rgb2gray(imread(NextFileName));
 mask = (nextpic < 200);
 masked = nextpic(mask);
 blackface(mask) = masked;
end
figure;
imshow(blackface);
```

Figure 9: Algorithm of "stitching" the face

Based on the results of the diagnostic slice for 12 key competencies "Chernoff face" was constructed for a student with an unsatisfactory level of development of professional competencies (Figure 10a) and with a low level (Figure 10b).

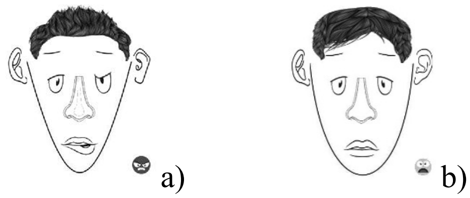


Figure 10: "Chernoff face" for a student with the appropriate level of formation of professional competences: a) unsatisfactory, b) low

As can be seen from Figure 10a, facial features are distorted (elongated face, crooked mouth, disproportionate eyes, dishevelled hair). This indicates problems in mastering this or that competence. The perception of the visual image allows the student to instantly find differences with the ideal, which prompts him to improve his own work, to activate it in accordance with the solution of the problems identified in the diagnostic process and reflected thanks to the visualization of "Chernoff face".

5. DISCUSSION AND LIMITATIONS

Analysis of modern research by Araujo et al. [26], Kostromina et al. [27], Ferreira et al. [28], [29], [30] allows us to highlight visualization as 1) a possible, effective method of assimilation of information [26-28]; 2) an analytical tool for researching data on the success of learning courses, the effectiveness of homework and designing the content of exams in accordance with the obtained results [31]; 3) evaluation [30, 32, 33], which can simultaneously act as the form and type of obtaining and presenting information, simplifying rational and symbolic interpretations (including marks). Moreover, visualization of the diagnostic results allows students to better understand the results of their studies and adjust them, as well as simplifies the analysis of the results of evaluation by teachers to adjust teaching methods [32]. The cognitive value of visualization is enhanced by the sensory-figurative mechanism of the human intellect. As Yarovyi [33] noted, "sensuous-figurative (and this is its fundamental difference from rational) is oriented towards the reflection of the individual (single) in the subject, while the rational, through the development and operation of abstract-logical (conceptual) forms, achieves the reflection of the general (typical)".

The study [13] examines the use of ICT in higher schools in the context of the COVID-19 pandemic, highlights the problem of active involvement of students in learning, the combination of formal and informal approaches in education in order to ensure better perception and understanding of the content of learning. The authors are aware of the risks of implementing e-learning: lack of communication with the teacher, ever-increasing stress caused by the fear of not completing the proposed tasks, lack of usual socialization, impossibility of tracking children's progress, mechanization of the activities of students who can solve the proposed tests, but are unable to use their knowledge outside school; lack of opportunities for creativity. The process of observing students to identify their emotions, needs and interests is complicated. To solve these problems, the authors offer active learning methods: creating dynamic presentations, laboratory tutorials, modelling, conceptual discussions for the organization interaction and cooperation.

Haozhang Deng et al. [34] consider the factors affecting the organization of e-learning: expected productivity, expected duration of efforts, social impact, price, favourable conditions and motivation to use acquired knowledge. They influence the formation of intentions to use e-learning.

5.1 Difference from Prior Research

The difference of our work from the recent research is that it takes into account the possible risks of using ICT. The authors' contribution has become the investigation of factors of ICT implementation in educational practice. In the context of the prior research our reflection is significant as it has shed light on describing ICT use in the process of offline, mixed, and distance learning from the point of view of solving the practical task of assessing the development of professional competences of students using visual ICT tools. This makes it possible to assess a wide range of competencies, provides an opportunity to present the dynamics of the levels of their development, relieve the emotional tension of waiting for an assessment, the ease of the proposed visual assessment for students to perceive, allows students to identify the content of the assessment: which competence is not formed, insufficiently formed, etc.

Regardless of the originality of the mentioned visualization method, there is certain difficulty of its use. It is the need to correctly match the studied indicators with parts of the face, because in case of an error, important characteristics may remain unnoticed.

Among the shortcomings of the method the impossibility of displaying minimal deviations from the standard should be clearly defined.

Prospects for further research are seen in the improvement of the proposed methodology and the development of an individual learning trajectory for students, based on the received data about the formation of professional competencies.

The methodology of the organization was developed by Dzina, who conducted the research as well. An overview of modern works on the problem, highlighting the positions of world scientists on similar problems was prepared by Holubnycha, Herasimenko, and Zelenska. The stated authors advanced the levels of formation of students' professional competences in the field of electrical engineering, as well as determined the criteria for evaluating these competences. Tytyuk and Chernyi, based on the proposed methodology and criteria for assessing the levels of professional competence formation, developed a program for creating "Chernoff faces".

6. CONCLUSIONS

Thus, in the course of research the possibilities of information technologies for data visualization in multidimensional non-metric spaces were identified. It was done using the example of determining the level of formation of individual competencies of future electrical engineers.

The use of "Chernoff faces" allows teachers to visualize the level of formation of professional competences, which will be useful for students. Comparing the results of current, thematic, modular diagnostics allows academic staff to build a number of faces, identifying similarities and differences between them and with the standard will allow students to identify problems in mastering certain competencies and adjust their educational and cognitive activities. Teachers, in their turn, will have possibility to analyse images for each student of the group and identify problems in mastering the content of the academic discipline in general and its individual topics. This will provide an opportunity to change the teaching methodology, the choice of appropriate methods and forms of work.

Thus, the visualization of the diagnostic results of the competences formation with the help of information and communication tools expands the possibility of conducting a qualitative analysis of the preparedness of future specialists, allows teachers to visually present data (in particular, "Chernoff face") in multidimensional non-metric sets using the example of the aggregated results of the assessment of certain competencies development in future electrical engineers; ensures ease and speed of perception of the result, allows to establish the relationship between different competencies and their levels of development, allows to avoid information overload, ensures an emotionally positive perception of the diagnostic results.

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