**Boris I. MOKIN[1], Oleksander B. MOKIN[1], Olena M. KOSARUK[1], Mashat KALIMOLDAYEV[2], Waldemar WÓJCIK[3], Kuanysh MUSLIMOV[4]**

Vinnytsia National Technical University (1), Institute of Information and Computational Technologies CS MES RK (2), Lublin University of Technology (3), Kazakh National Research Technical University named after K.I.Satpayev (4)

doi:10.15199/48.2020.09.24

# Assessment of the knowledge quality level based on fuzzy models of its acquisition processes

***Abstract**. To assess the quality of knowledge acquisition by students of technical universities and to acquire relevant competencies, it is proposed to apply the idea of integrating education and the fuzzy mathematical model, supplemented by a procedure of probabilistic processing of fuzzy values. The fuzzy mathematical model is synthesized in the form of the Mamdani knowledge base, whose language variables characterize various parameters of the process of knowledge acquisition by students. A technique of assessing the quality of the knowledge acquisition process with the use of a synthetic model and suggested efficiency evaluation criteria have been developed. The testing of the suggested model and technique was performed in Vinnytsia National Technical University, the results of testing proved their efficiency.*

***Streszczenie.** Dla jasnej oceny jakości zdobywania wiedzy przez studentów uczelni technicznych i uzyskania odpowiednich kompetencji proponuje się zastosowanie ideę integracji edukacji i rozmytego modelu matematycznego, uzupełnionego o procedurę probabilistycznego przetwarzania wartości rozmytych. Rozmyty model matematyczny jest syntetyzowany w postaci bazy wiedzy Mamdani, której zmienne językowe charakteryzują różne parametry procesu zdobywania wiedzy przez uczniów. Opracowano technikę oceny jakości procesu zdobywania wiedzy z wykorzystaniem modelu syntetycznego oraz sugerowanych kryteriów oceny efektywności. Testowanie zaproponowanego modelu i techniki zostało przeprowadzone na Narodowym Uniwersytecie Technicznym w Winnicy, wyniki testów potwierdziły ich skuteczność. (**Ocena poziomu jakości wiedzy na bazie rozmytych modeli procesów jej zdobywania**).*

**Keywords:** technical education, electrical and power engineering, hybrid fuzzy modelling.
**Słowa kluczowe:** edukacja techniczna, elektrotechnika i energetyka, hybrydowe modelowanie rozmyte.

## Introduction

Nowadays the ideology of the dual higher technical education, development of which started in the ’90s of the last century from the idea of the integration of the education and production, gains growing popularity in the leading European and American Universities.

In Ukraine this idea was taken up as far back as in 1991 in Vinnytsia Polytechnic Institute (VPI), at the first stages of its implementation, the experience of the University of the Canadian town of Waterloo was used by one of the authors of the given paper. As it is shown in [1], already in two years after the start of the realization of this experience the conditions for the enhancement of the competitiveness of the graduates of VPI on the labour market were created, owing to the implementation of the borrowed and adapted to the Ukrainian realities the idea of integration of education with production.

The essence of the idea is that the students of the first two courses parallelly with studying the theoretical fundamentals of their future engineering speciality mastered the working profession [2], correlated with the engineering speciality, according to which at the third year of study, during one trimester the students worked at the enterprises and organizations as the workers. Owing to such practice these students, firstly, at the senior courses studied special subjects, applying the obtained practical knowledge; secondly, having become the engineer, they got in the production environment, having the experience of behaviour in this environment, without wasting time for the adaptation.

In the process of further realization of our variant of the ideology of dual higher technical education on the base of the implementation of the idea of the integration of education and production in VPI, later in Vinnytsia State Technical University (VSTU), which in 1994 became the legal successor of VPI, and in Vinnytsia National Technical University (VNTU), which in 2003 became the legal successor of VSTU, the attention was focused on the fact that as the departments even of one university have different possibilities concerning the provision of the working profession to the students and the students do not have the same motivation and the same abilities, then it is important to have the mathematical model, by means of which it would become possible to forecast the level of qualification, they are able to obtain at the end of the process, before the beginning of the process of mastering the working profession by the students. Due to such forecast, the department can plan and realize the measures, necessary that all the students before the working trimester had the qualification certificates on the level of the fourth, third or second worker’s rank.

The process of the synthesis of such a mathematical model in the form of a fuzzy knowledge base, using the theory of the linguistic variable [3] was described in the paper [4]. In the first part, the task was formalized, the authors carried out its structuralization and parameterization. In the second part the authors constructed the mathematical model in the form of the corresponding fuzzy knowledge base and carried out its algorithmization. In the third part, the technique of the application of the developed mathematical model in the applied problems was suggested.

But, in spite of the fact that our mathematical model had been published as far back as in 2012, it did not get widespread as the article was published in Ukrainian scientific editions, which, unfortunately, are not available in European and American Universities. That is why, to bring to the notice of the English speaking researchers our studies, we decided to publish the results obtained in the English scientific journal, that belongs to scientometrical base Scopus, as we think that the results of our research, after publication in English scientific journal will be of interest for the wide range of the reformers of higher technical education in various countries of the world [11,12].

## Synthesis of the fuzzy mathematical model for clear assessment

We will start the presentation of this material from the definition of those linguistic variables, on the set of which the synthesis of the forecast mathematical model of the qualification level, obtained by the students as a result of mastering the working profession, is carried out.

As it is shown in our research [4], for the synthesis of the above-mentioned model of the qualification level forecast it is sufficient to set nine linguistic variables, namely: $x_{111}$ – level of the theoretical fundamentals of the profession acquisition by the students; $x_{112}$ – level of student's access to the electronic and printed sources of information, which contain theoretical fundamentals of the profession; $x_{121}$ – level of the internal motivation of the student to learning the theoretical fundamentals of the profession; $x_{122}$ – level of the student's ability to learning the theoretical fundamentals of the profession; $x_{211}$ – match level of the educational equipment to the tasks of the student acquisition of the practical skills of the profession; $x_{212}$ – level of the student’s access to the educational equipment, allocated for the obtaining of the practical skills of the profession; $x_{221}$ – level of the internal motivation of the student for the acquisition of the practical skills of the profession; $x_{222}$ – level of the student's ability for the acquisition of the practical skills of the profession; $y$ – level of the qualification, obtained by the student as a result of the educational-production training.

By the notion “linguistic variable” we mean, as in the research [3], the variable which takes the value from the set of words or word combinations of certain natural language. Thus, the linguistic variable is used by us for the verbal description of the quantitative value.

It is obvious that the mathematical model of the readiness level forecast as the output linguistic variable, is a function from the above-mentioned eight input linguistic variables, i. e., in the generalized form this mathematical model is defined as:

(1) $$y = f\left(x_{111}, x_{112}, x_{121}, x_{122}, x_{211}, x_{212}, x_{221}, x_{222}\right)$$

As in the generalized model, all the linguistic variables belong to one type – “level of something”, then they can be structured by one and the same set of terms, namely: “high (H)”, “sufficient (S)”, “average (A)”, “low (L)”, that corresponds to the marks: “excellent (5)”, “good (4)”, “satisfactory (3)”, “unsatisfactory (2)” in 5-points system of marks and grades: “4th class”, “3th class”, “2th class”, “1th class”, – in 7 grading qualification scale.

In order to identify the mathematical model (1) by fuzzy knowledge base, as it is shown in [5,6], it is necessary to use a number of rules that equal $(4)^8$=65536. That is why, it is logical to use the hierarchical principle of knowledge base construction for the identification of the dependency (1), as a result of the usage of this principle the amount of rules, needed for the identification of this dependence, is considerably reduced. For the set task three-level tree of the fuzzy derivation tree is shown in Fig. 1.

As it is seen from Figure 1, between the output linguistic variable *y* and input linguistic variables $x_{111}$, $x_{112}$, $x_{121}$, $x_{122}$, $x_{211}$, $x_{212}$, $x_{221}$, $x_{222}$ there appeared a number of intermediate linguistic variables, namely: $x_1$ – level of the student's mastering of the theoretical fundamentals of the profession; $x_2$ – level of the student's acquisition of the practical skills of the profession; $x_{11}$ – level of the positive impact of the external factors on the mastering of the theoretical fundamentals of the profession by the student; $x_{12}$ – level of the positive impact of the internal factors on the mastering of the theoretical fundamentals of the profession by the student; $x_{21}$ – level of the positive impact of the external factors on the acquisition of the practical skills of the profession by the student; $x_{22}$ – level of the positive impact of the internal factors on the acquisition of the practical skills of the profession by the student.

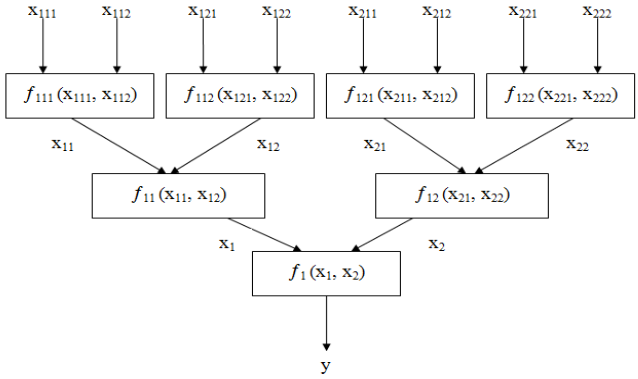

Fig. 1. Fuzzy logic derivation tree for the dependency (1)

Using the fuzzy logic inference tree, shown in Figure 1, the generalized dependence (1) can be represented by the equivalent system of the dependences:

(2) $$\begin{aligned} y = f_1(x_1, x_2),\ x_1 = f_{11}(x_{11}, x_{12}),\ x_2 = f_{12}(x_{21}, x_{22}), \\ x_{11} = f_{111}(x_{111}, x_{112}),\ x_{12} = f_{112}(x_{121}, x_{122}), \\ x_{21} = f_{121}(x_{211}, x_{212}),\ x_{22} = f_{122}(x_{221}, x_{222}). \end{aligned}$$

For the reproduction of the system of equations of the linguistic variables (2) in the form of fuzzy knowledge base while using the set of terms H, S, A, L only $7 \times 2^4 = 112$ rules are needed. But if we take into consideration that all linguistic variables are of the same type, then for the construction of the necessary knowledge base only 16 rules will be sufficient.

As it is known [3,5,6] the next stage of the fuzzy model synthesis in the form of the knowledge base after the definition of all the linguistic variables and the set of their terms is the identification of the universal set $U$, elements of which fill the defined terms and membership function $\mu(u)$ of these elements to each of the terms.

Since 100-points grading scale is widely used all over the world, then we took 100-points scale as a universal set $U$ for this task. Thus, the universal set – it is the section $U = [0,100]$. As the membership function of the elements from the set $U$ to the terms H, S, A, L we have chosen the functions:

(3) $$\mu(u) = \exp\left(-\frac{1}{2}\left(\frac{u-m}{\sigma}\right)^2\right)$$

by means of which, in the probability theory, supplementing it by the normalizing factor $1/\sigma\sqrt{2\pi}$, the normal law of continuous random quantities distribution is set in the differential form, which is boundary for all other laws of continuous random quantities distribution. Thus, by analogy and using the function (3) as the membership function for the terms of the linguistic variable, it is logical to assume that it also can be called “normal” membership function. In this function *m* is the coordinate of the maximum and $\sigma$ is the concentration factor, it has the advantages over the others that it is characterized only by two parameters and is differentiated, that is very important in case of optimal regulation of these parameters by means of the method of back propagation of the error [5,6].

For the set of the terms H, S, A, L, proceeding from the practice of the marks comparison by 100-points and five-points scales, it is expedient to take the following values as the coordinates of the membership functions maximum: $m_H = 100$ , $m_S = 80$ , $m_A = 60$ , $m_L = 40$ .

Regarding the concentration coefficients of the membership functions, it is expedient to take the same functions for all the terms from the set (2) with the value, obtained from the condition that the membership functions for the elements which are in the middle between the maxima of two neighboring terms, equal 0.5 each. That is, on the condition, which for the neighboring terms, for instance H and S, has the form:

(4) $$\mu(u) = \exp\left(-\frac{1}{2}\left(\frac{90-100}{\sigma}\right)^2\right) = 0.5$$

it follows $\sigma = 8.48$ .

Fig. 2 shows by the shaded lines the graphs of the membership functions of the elements from the universal set U to the terms of the set H, S, A, L low indices show this.

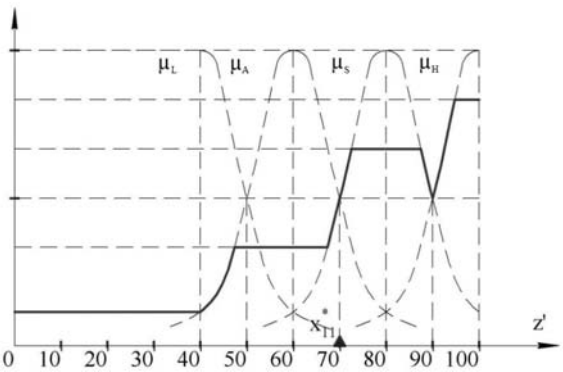


Fig.2. Graphs of the membership functions (shaded lines) of the elements from the set $U$ to the terms H, S, A, L and graphic interpretation the operations of the implication and membership functions aggregation (solid bold line) for the linguistic variable $x_{11}$

Further on the low level of the tree of fuzzy logic we will allocate four low equations of the system (2) and we will show how they can be identified by the Mamdani fuzzy knowledge base [5,6]. We will start the identification from the first of these equations. Applying the recommendations of the experts, involved, we will have relatively it, the following Mamdani knowledge base:

(5) $$\begin{gathered}\text{IF}\,(x_{111}=L)\,\text{AND}\,(x_{112}=L)\ \text{OR}\,(x_{111}=L)\,\text{AND}\,(x_{112}=A)\\ \text{OR}\,(x_{111}=A)\,\text{AND}\,(x_{112}=L),\ \text{THEN}\ (x_{11}=L)\end{gathered}$$

(6) $$\begin{gathered}\text{IF}\,(x_{111}=A)\,\text{AND}\,(x_{112}=A)\ \text{OR}\,(x_{111}=S)\,\text{AND}\,(x_{112}=A)\\ \text{OR}\,(x_{111}=A)\,\text{AND}\,(x_{112}=S),\ \text{OR}\,(x_{111}=L)\,\text{AND}\,(x_{112}=H)\\ \text{OR}\,(x_{111}=H)\,\text{AND}\,(x_{112}=L),\ \text{THEN}\ (x_{11}=A)\end{gathered}$$

(7) $$\begin{gathered}\text{IF}\,(x_{111}=S)\,\text{AND}\,(x_{112}=S)\ \text{OR}\,(x_{111}=H)\,\text{AND}\,(x_{112}=A)\\ \text{OR}\,(x_{111}=A)\,\text{AND}\,(x_{112}=H),\ \text{OR}\,(x_{111}=S)\\ \text{AND}\,(x_{112}=H),\text{THEN}\ (x_{11}=S)\end{gathered}$$

(8) $$\begin{gathered}\text{IF}\,(x_{111}=H)\,\text{AND}\,(x_{112}=H)\ \text{OR}\,(x_{111}=H)\,\text{AND}\,(x_{112}=S),\\ \text{THEN}\ (x_{11}=H)\end{gathered}$$

Keeping in mind that operation *min* (finding of the minimum) corresponds to logic operation IF in the theory of logic variable [5,6] and operation OR – operation *max* (finding of the maximum), for the input vector $X(x_{111}, x_{112})$ with the specified values of the coordinates $x_{111} = x^*_{111}$ , $x_{112} = x^*_{112}$ , where $x^*_{111}, x^*_{112} \in \overline{[0,100]}$ , proceeding from the knowledge base (5)–(8) we synthesize the following system of fuzzy logic equations relatively the membership functions of the corresponding terms:

(9) $$\mu^L_{11}(X^*) = \max_{j\to 1,2,3}\left\{\begin{array}{l}\min\left[\left(\mu^L_{111}\left(x^*_{111}\right),\mu^L_{112}\left(x^*_{112}\right)\right)\right]_{j=1},\\ \min\left[\left(\mu^L_{111}\left(x^*_{111}\right),\mu^A_{112}\left(x^*_{112}\right)\right)\right]_{j=2},\\ \min\left[\left(\mu^A_{111}\left(x^*_{111}\right),\mu^L_{112}\left(x^*_{112}\right)\right)\right]_{j=3}\end{array}\right\}$$

(10) $$\mu^A_{11}(X^*) = \max_{j\to 1,2,3,4,5}\left\{\begin{array}{l}\min\left[\left(\mu^A_{111}\left(x^*_{111}\right),\mu^A_{112}\left(x^*_{112}\right)\right)\right]_{j=1},\\ \min\left[\left(\mu^S_{111}\left(x^*_{111}\right),\mu^A_{112}\left(x^*_{112}\right)\right)\right]_{j=2},\\ \min\left[\left(\mu^A_{111}\left(x^*_{111}\right),\mu^S_{112}\left(x^*_{112}\right)\right)\right]_{j=3},\\ \min\left[\left(\mu^L_{111}\left(x^*_{111}\right),\mu^H_{112}\left(x^*_{112}\right)\right)\right]_{j=4},\\ \min\left[\left(\mu^H_{111}\left(x^*_{111}\right),\mu^L_{112}\left(x^*_{112}\right)\right)\right]_{j=5}\end{array}\right\},$$

(11) $$\mu^S_{11}(X^*) = \max_{j\to 1,2,3,4}\left\{\begin{array}{l}\min\left[\left(\mu^S_{111}\left(x^*_{111}\right),\mu^S_{112}\left(x^*_{112}\right)\right)\right]_{j=1},\\ \min\left[\left(\mu^H_{111}\left(x^*_{111}\right),\mu^A_{112}\left(x^*_{112}\right)\right)\right]_{j=2},\\ \min\left[\left(\mu^A_{111}\left(x^*_{111}\right),\mu^H_{112}\left(x^*_{112}\right)\right)\right]_{j=3},\\ \min\left[\left(\mu^S_{111}\left(x^*_{111}\right),\mu^H_{112}\left(x^*_{112}\right)\right)\right]_{j=4}\end{array}\right\},$$

(12) $$\mu^H_{11}(X^*) = \max_{j\to 1,2}\left\{\begin{array}{l}\min\left[\left(\mu^H_{111}\left(x^*_{111}\right),\mu^H_{112}\left(x^*_{112}\right)\right)\right]_{j=1},\\ \min\left[\left(\mu^H_{111}\left(x^*_{111}\right),\mu^S_{112}\left(x^*_{112}\right)\right)\right]_{j=2},\end{array}\right\}.$$

As a result of fuzzy logic inference on the base of the equations (9)–(12), we obtain fuzzy output variable $x_{11}$ in the form

(13) $$x_{11} = \left(\frac{\mu^L_{11}\left(X^*\right)}{L},\frac{\mu^A_{11}\left(X^*\right)}{A},\frac{\mu^S_{11}\left(X^*\right)}{S},\frac{\mu^H_{11}\left(X^*\right)}{H}\right),$$

on the carrier [L, A, S, H] for the transition of which on the carrier $U = \overline{[0,100]}$ , applying the technique, suggested in [7], we will find the implied membership functions $\mu_L(x_{11})$ , $\mu_A(x_{11})$ , $\mu_S(x_{11})$ , $\mu_H(x_{11})$ of the terms L, A, S, H of the output linguistic variable $x_{11}$ "truncated" by the values $\mu^L_{11}(X^*)$ , $\mu^A_{11}(X^*)$ , $\mu^S_{11}(X^*)$ , $\mu^H_{11}(X^*)$ , as it is shown in Figure 2 for one of the variants.

Further, again applying the technique, suggested in [7], we will find the aggregated membership function of this linguistic variable on the carrier $U = \overline{[0,100]}$ in the form $\mu^{[1,100]}_{11}(x_{11}) = agg\left(\mu_L\left(x_{11}\right),\mu_A\left(x_{11}\right),\mu_S\left(x_{11}\right),\mu_H\left(x_{11}\right)\right)$, its graph in Figure 2 is shown by the by-passing bold line. For finding the exact value of $x^*_{11}$ of the output linguistic variable $x_{11}$ , the operation of the defuzzification will be performed, applying the method of weight centre [5,6] in the form [8]:

(14) $$x^*_{11} = \frac{\sum_{i=1}^{100} i\cdot\mu^{\overline{[1.100]}}_{11i}(x_{11})}{\sum_{i=1}^{100}\mu^{\overline{[1.100]}}_{11i}(x_{11})}\,.$$

In Figure 2 the exact value of $x^*_{11}$ of the output linguistic variable $x_{11}$ , calculated by the formula (14), is indicated by the black triangle on the axis *i*.

It is quite obvious, that the above-mentioned procedure will also be valid also for the identification by the fuzzy knowledge base (5)–(14) of the second equation of system (2), the components of the input vector of which are the linguistic variables $x_{121}$, $x_{122}$ and the output linguistic variable is $x_{12}$, the only difference is that in the formulas (5)–(14) index 111 must be replaced by 121, index 112 – by 122 and index 11 must be replaced by 12.

Similarly identifying the third and fourth equations of the system (2) and all three upper levels of this system we obtain all the necessary data to write down the algorithm of the identification by the fuzzy knowledge base of all the equations of the system (2).

**Development of a technique of clear assessment on fuzzy models**

The essence of the developed technique is that at the stage of the assessment of practical training quality of the students applying the ideology of mastering of the working profession, empirical laws for distribution of the defuzzificated values of linguistic variables are constructed in the direction from the upper level of hierarchy to the low level and those which have deviations from the normal are determined; at the stage of the increase of practical training quality those empirical distribution laws, having deviations from the normal are normalized by means of creation of the additional control impacts on the corresponding linguistic variables of the basic level, which are the input for the low level of the hierarchy of the suggested structure.

For the realization of these stages the following technique was developed.

To make the forecast assessment $y_i^*$, $i = 1,2,...,N$ of the students' working qualification level reliable, we will define them for the flow, which comprises at least two academic groups, i. e., we will define them for the set of *N* students which contains not less than 50 homogeneous elements. As a result of application of the above-mentioned mathematical models in accordance with the suggested algorithm we obtain the set of grades –

(15) $$\{y_i^*\} = \{y_1^*, y_2^*, y_3^*, ..., y_i^*, ..., y_N^*\}, N \geq 50 .$$

For the convenience of the calculations further we will assume that *N = 50*.

It is quite obvious that the defuzzificated grades from the set (15) are simultaneously random numbers, to which we can apply the methods of the probability theory and mathematical statistic, which we will take from the sources [9–13].

We will divide the 100-points range into 5 equal parts $\Delta_j$, 20 points of width each (in the general form there may be $r$ such parts). We will define ranges of grades in the following ways: the range from 81 point to 100 points we will call the fifth and denote as $\Delta_5$, the range from 61 point to 80 points we will call the fourth and denote as $\Delta_4$, the range from 41 point to 60 points we will call the third and denote as $\Delta_3$, the range from 21 point to 40 points we will call the second and denote as $\Delta_2$ and the range from 0 points to 20 points we will call the first and denote as $\Delta_1$. We will calculate the quantity of $n_j, j = 1,2,3,4,5,$ grades from the set (15) that entered each of the defined ranges. The experimental histogram of the density (consistency) of the distribution of $f(y^*)$ probabilities of the random value $y^*$ will be constructed, applying the technique, known from the probability theory and mathematical statistics [9,10].

If the experts determine that the theory of working profession is taught by a normal teachers, the laboratory of working profession is equipped with normal equipment, library and laboratory are provided with manuals in paper or in electronic form, motivation of the students fore mastering working profession is normal and abilities of each of the students to mastering working profession is normal then the density of the distribution $f(y^*)$ of grades probabilities from the set (15) according to the central boundary theorem of the probabilities theory will be subordinated to the normal law, the density of the probabilities distribution according to which has the form (3), to which the normalizing multiplier $1/\sigma\sqrt{2\pi}$ is added, and the parameters $m$, $\sigma$ are now the estimates of the mathematical expectation and mean square deviation of the random value $y^*$, substituting them into the normalized formula (3) we obtain the empirical normal law of the distribution density of the random value probabilities. To make sure that the set (15) of the random values is subordinated to the normal law, we will evaluate the reliability of expression, applying $\chi^2$ – Pearson distribution. This empirical law is considered to be valid if the probability belief $P_\partial$ will equal to 0.9.

If this proves true, then practical training of the student applying the ideology of obtaining working profession, correlated with the future engineering profession, is carried out at the university at a normal level and does not require additional measures for its improvement.

But if this is not the case, i. e., the histogram constructed for the random value $y^*$, set by the totality of values (15) has a tilt to the left or right and is not "straightened" by a normal distribution law, that will be affirmed by the low level of the confidential probability, calculated applying $\chi^2$ – distribution, then it will show that either the theory of working profession is taught by bad teachers or the laboratory of the working profession is equipped with the out-dated equipment or the library and laboratory are not provided with manuals in sufficient quantity or the motivation of the students to master their working profession is not sufficient or the abilities to mastering the working profession are not developed in the majority of the students.

To define which of the above-mentioned deviations from the normal takes place, we must proceed to the construction (applying the above-mentioned technique) of the empirical laws of the distribution of the defuzzificated values $x_1^*, x_2^*$ of those linguistic variables $x_1, x_2$ which on the upper level of the hierarchy (Figure 1) directly form the deuzzificated values $y_i^*$, *i = 1,2,…,N*, of the linguistic variable $y$, i. e., form the dependence $y = f_1(x_1, x_2)$.

In case, if the empirical law of distribution $f(x_1^*)$ of the defuzzificated values $x_1^*$ of the linguistic variable $x_1$ turns out to be normal then it can be stated that the theoretical training on the fundamentals of working profession by this specialty at the university is carried out normally, that is why, there is no need to study the defuzzificated values of all those linguistic variables which form the linguistic variable $x_1$.

If the empirical law of distribution $f(x_2^*)$ of the defuzzificated values $x_2^*$ of the linguistic variable $x_2$ turns out to be different from the normal then it can be stated that practical training on the fundamentals of the working profession by this specialty in the university is insufficient. That is why, to clarify the reasons of this insufficiency, we need to construct, according to the above-mentioned technique, the empirical laws of distribution of the defuzzificated values $x^*_{21}, x^*_{22}$ of those linguistic variables $x_{21}, x_{22}$, which on the average level of the hierarchy (Fig. 1) directly form the defuzzificated values $x^*_2$ of the linguistic variable $x_2$, i. e., form the dependence $x_2 = f_{12}(x_{21}, x_{22})$.

We will assume that both these empirical distribution laws turned out to be different from the normal.

In this case it can be stated that insufficient attention is paid to the practical training of the students on working profession at the university both on the line of linguistic variable $x_{21}$ formation and linguistic variable $x_{22}$ formation. To clarify the reasons of this insufficiency, we should construct, applying the above-mentioned technique, empirical distribution laws of the defuzzificated values $x^*_{211}, x^*_{212}$ of those linguistic variables $x_{211}, x_{212}$ which on the low level of the hierarchy (Fig. 1) directly form the defuzzificated values $x^*_{21}$ of the linguistic variable $x_{21}$, i. e., form the dependence $x_{21} = f_{121}(x_{211}, x_{212})$. and empirical laws of the distribution of the defuzzificated values $x^*_{221}, x^*_{222}$ of those linguistic variables $x_{221}, x_{222}$, which on the low level of the hierarchy (Fig. 1) directly form the defuzzificated values $x^*_{22}$ of the linguistic variable $x_{22}$, i. e., form the dependence $x_{22} = f_{122}(x_{221}, x_{222})$.

We will assume that two of these four empirical laws of distribution, for instance, $f(x^*_{211})$ and $f(x^*_{221})$ turned out to be normal, and the other two – $f(x^*_{212})$ and $f(x^*_{222})$ do not correspond to the conditions of normality. It means, that in the university, in the course of practical training on the given specialty, applying the given ideology, the level of the access to the equipment, maintenance of which must be performed by this working specialty, and which is characterized by the linguistic variable $x_{212}$, and the level of the students' skills for performing the practical functions, inherent to the given profession, characterized by the variable $x_{222}$ is insufficient.

In the given case, to improve the quality of practical training of the students by the ideology of mastering working profession, it is necessary to create for the students the conditions of the wider access to the equipment, maintenance of which must be performed by this working profession and provide them the possibility to improve the level of skills, necessary for carrying out the practical functions, inherent to this working profession. That is, allocate for these students not only additional time, needed for the access to the equipment and provide them with the experienced creative master, who is able to teach them quickly practical skills, necessary for performing functions, inherent to the given working profession, even to those students, who have never had any relations to these functions.

As a result of these actions, empirical laws of distribution $f(x^*_{212})$ and $f(x^*_{222})$ of the defuzzificated values $x^*_{212}, x^*_{222}$ of the linguistic variables $x_{212}, x_{222}$ are normalized, this will lead to the normalization of the empirical laws of distribution on the other levels of hierarchy.

Summing up, we would like to underline that the essence of the technique is that at the stage of assessment of the quality of the students' practical training by the ideology of the working profession mastering the empirical laws of the distribution of the defuzzificated values of the linguistic variables are constructed in the direction from the upper level of hierarchy to the low level and those that have the deviations from the normal are detected , at the stage of the quality increase of practical training the empirical laws of distribution which have the deviations from the normal, are normalized by means of creating the additional controlled impacts on the corresponding linguistic variables of the basic level, which are the input for the low level of hierarchy of the suggested structure.

**Experimental testing of the clear assessment technique on fuzzy models**

On the base of the results, obtained, regarding the levels of the determined linguistic variables general level of the qualification, which the students of the Department of Civil Engineering, Heat Power Engineering and Gas Supply, Department of Machine Building and Transport and Department of Electric Power Engineering and Electromechanics of Vinnytsia National Technical University obtained as a result of educational-production training in the course of the ascertaining experiment, is calculated.

The total number of the students who participated in the research, was 405 persons, among them – 121 students of the Department of Civil Engineering, Heat Power Engineering and Gas Supply (CEHPEGS); 124 students of the Department of machine building and transport (MBT) and 160 students of Department of Electric Power and Electromechanics (EPEEM).

The construction of the empirical laws of distribution of the determined linguistic variables is carried out separately for each of the selected Departments and are presented in [4].

As a result of the application of the suggested mathematical model in accordance with the algorithm and technique of its application, it was defined that for the experimental group the empirical law of distribution $f\left(x^*_1\right)$ of the defuzzificated values $x^*_1$ of the linguistic variable $x_1$ turned out to be different from the normal, this showed that the theoretical training on the fundamentals of working professions "Bricklayer", "Painter" and "Fitter for maintenance and repair of gas equipment", "Fitter-repairman" by the directions "Civil engineering" and "Heat power engineering" was insufficient in Vinnytsia National Technical University (VNTU). Also it was determined that the empirical law of distribution $f\left(x^*_2\right)$ of the defuzzificated values $x^*_2$ of the linguistic variable $x_2$ turned out to be normal, that characterized practical training on the fundamentals of working profession on the given specialties in VNTU as sufficient.

In the process of construction of the empirical laws of distribution of the defuzzificated values $x^*_{11}, x^*_{12}$ of the linguistic variables $x_{11}, x_{12}$ it is defined that for the given case the empirical laws of the distribution $f\left(x^*_{11}\right)$, $f\left(x^*_{12}\right)$ also turned out to be different from the normal distribution law. The detected deviations showed that not enough attention was paid to the theoretical training of the students of the above-mentioned working professions both regarding the formation of the linguistic variable $x_{11}$ and the formation of the linguistic variable $x_{12}$.

In the process of the construction of the empirical laws of distribution of the defuzzificated values $x^*_{111}, x^*_{112}$,

$x^*_{121}$, $x^*_{122}$ of the linguistic variables $x_{111}$, $x_{112}$, $x_{121}$, $x_{122}$ it is defined that for the given case the empirical laws of distribution $f\left(x^*_{112}\right)$, $f\left(x^*_{122}\right)$ turned out to be normal, and the empirical laws of distribution $f\left(x^*_{111}\right)$, $f\left(x^*_{121}\right)$ turned out to be such that do not correspond to the condition of the normality. In this case it can be stated, that for the students of the Department of CEHPEGS during the ascertaining stage of the experimental research theoretical training by the ideology of mastering the working professions was insufficient, regarding such indices: level of mastering of the theoretical fundamentals of the profession by the student, which is characterized by the linguistic variables $x_{111}$, and level of the internal motivation of the students to studying the theoretical fundamentals of the profession, which is characterized by the linguistic variable $x_{121}$.

Graphic interpretation of the mechanism of detecting the deviations from the norm of the defined linguistic variables for the experimental groups of the Department of CEHPEGS is shown in Fig. 3.

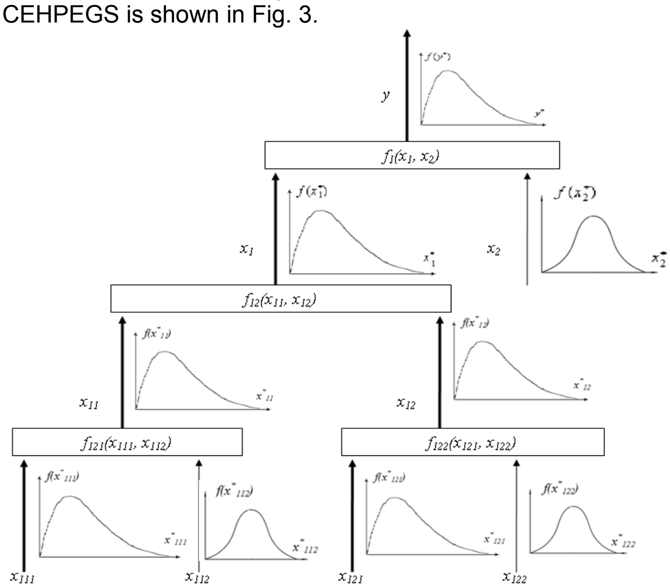


Fig.3. Graphic interpretation of the mechanism of detecting the deviations from the norm at various stages of hierarchy in the process of the formation of the forecast assessment of the professional training quality of the students of the experimental groups of the Department of CEHPEGS by the ideology of mastering the working profession

The discrepancy of the values of enumerated indices affirms mainly liberal style of teaching the major subjects by some teachers, low level of their requirements, passivity and disinterest in the presentation of the material, unsystematic character of the organization and control of the educational activity of the students.

In the same way, the calculations are performed, histogram and graphic of the distribution density for the experimental group of the Department of MBT are constructed and for the experimental group of the Department of EPEEM.

After the completion of the working trimester, the control stage of the experiment is performed, applying the same technique as in the ascertaining experiment, aim of which was to compare the results obtained in both experiments. The obtained results assured the fact of the normalization of the empirical laws of the distribution of the linguistic variable and this is the evidence of the fact that the students of the Departments of CEHPEGS MBT EPEEM obtained sufficient level of practical training.

**Conclusions**

For the clear assessment of the quality of the knowledge acquisition by the students of high technical educational institutions and obtaining the corresponding competences by the ideology of the integration of study and production fuzzy mathematical model, supplemented with the procedure for the probabilistic processing of the defuzzified values, characterizing the quality of the process and are the sets of the random numbers, is suggested.

Fuzzy mathematical model is synthesized in the form of Mamdani knowledge base. Criterial provision of the assessment process, using the normalized membership functions of the linguistic variable values to the corresponding terms and normal distribution law of the random value, which is the defuzzified value of each linguistic variable, is substantiated. The technique of the clear assessment of the quality of knowledge acquisition process, using fuzzy model of this process is suggested.

Testing of the suggested model and technique is carried out at three Departments of Vinnitsa National Technical University.

***Authors:*** *Boris I. Mokin; Oleksander B. Mokin; Olena M. Kosaruk, Vinnytsia National Technical University, 95 Khmelnytsky, 21021, Vinnytsia, Ukraine, e-mail: lena.menzul@gmail.com; Mashat Kalimoldayev, Institute of Information and Computational Technologies CS MES RK, Almaty, Kazakhstan, e-mail: mnk@ipic.kz; Waldemar Wójcik, Lublin University of Technology, 38A Nadbystrzycka Str., 20-618, Lublin, Poland, e-mail: waldemar.wojcik@pollub.pl; Kuanysh Muslimov, Kazakh National Research Technical University named after K.I.Satpayev, e-mail: k-u-a@mail.ru*

REFERENCES

[1] Mokin B.I., First results of the experiment in the technological scheme "Bachelor – Engineer – Master", *Bulletin of Vinnytsia Polytechnic Institute*, 1 (1993), no. 1, 81-85
[2] Higgs J., The Effect of Career and Technical Education on Urban Student Preparation for College and Career Readiness, *Union University, ProQuest Dissertation Publishing*, (2017)
[3] Zadeh L.A., Notion of the linguistic variable and its application to the notion of the approximative solutions, *MIR, Moscow,* (1976)
[4] Kosaruk O.M., Mokin B.I., Mokin O.B., Ideology of duality in Higher Technical Education on the base of the integration of education and production, *VNTU, Vinnytsia,* (2019)
[5] Mityushkin Yu.I., Mokin B.I., Rotshtein A.P., Soft Computing: Identification of the regularities by fuzzy knowledge bases, *Universum-Vinnytsia,* (2002)
[6] Rotshtein O.P., Lariushkin E.P., Mitiushkin Yu.I., Soft computing in biotechnology: multifactoral analysis and diagnosis, *Universum-Vinnytsia,* (2008)
[7] Shtovba S.D., Design of fuzzy systems, applying MATLAB. *Moscow: Hotline-Telecom*, (2007)
[8] Zlepko S.M., Tymchyk S.V., Novikova A.O., Moskovko M.V., et al., An informational model of sportsman's competitive activities, *Proc. SPIE*, 10031 (2016).
[9] Tutubalin V.N., Probability theory, *Publishing House of Moscow University*, *Moscow,* (1972)
[10] Gurskyi E.I., Problem book on the probability theory and mathematic statistics, *Publishing House Vysheishaia Shkola*, *Minsk,* (1975)
[11] Smolarz A., Lytvynenko V., Wojcik W., et al., Multifractal spectra classification of flame luminosity waveforms, *Proc. SPIE*, 10808 (2018).
[12] Grzechca D.E., Construction of an expert system based on fuzzy logic for diagnosis of analog electronic circuits, Intl Journal of Electronics and Telecommunications 61 (2015), no. 1, 77–82
[13] Kukharchuk V.V., Bogachuk V.V., Hraniak V.F., Wójcik W., Suleimenov B., Karnakova G., Method of magneto-elastic control of mechanic rigidity in assemblies of hydropower units, *Proc. SPIE* 10445 (2017), 104456A
[14] Smolarz A., Lytvynenko V., Wojcik W., et al., Multifractal spectra classification of flame luminosity waveforms, *Proc. SPIE*, 10808 (2018).