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ERROR-FREE ACTIVITY OF THE INFORMATION PROCESSING OPERATOR: TARGETED TRAINING CONCEPT

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The relevance of the paper is reflected in the investigation of the activities structure in numerous modern professions, with a significant share devoted to an operator's activities. Therefore, a problem of ensuring the quality of operators' activities, and the error-free and timely computer processing of text, graphic and figurative information must be solved. Assumptions that the high-quality training of operators is based on the profound knowledge of the qualitative and quantitative characteristics of the errors flows are verified. The concept of the targeted training of information processing operator to perform error-free activity is highlighted and described. The essence of the targeted training is to develop the theoretical foundations of a methodological system for the formation of the operator's readiness to perform error-free activity, taking into account the professional level of individual groups of students. The correct construction of the concept is enhanced if it takes the form of a set of clearly separable statements. The set is complete, consistent and contains elements that cannot be inferred from each other. The consistency and non-deduction of the provisions were proved within the framework of the presented study, and the completeness was proved based on the theory of ergonomic training of engineers-teachers specializing in computers to perform professional activity. Experimental ergonomic research enhances the introduction of the targeted training of an information processing operator into the practice of vocational training, along with mass and individual training. Targeted training allows one to rely on the laws of mathematical learning theory. Prospects for further research would include conducting an experiment to find an experimental coefficient characterizing the operator's ability to learn; conducting a comparative pedagogical experiment to determine the pedagogical effectiveness of the targeted training of computer typing operators, and the introduction of the innovative methodological support into the educational process.

Keywords: information processing operator, quality of activity, engineers-teachers, mistakes, target training of operators.

Г. Сажко, Д.Піршл «Безпомилкова діяльність оператора обробки інформації: концепція цільового навчання»

Актуальність даної статті в тому, що в структурі діяльності великої кількості сучасних професій значну частину займає операторська діяльність. Тому існує проблема забезпечення якості діяльності операторів, яка зводиться, до забезпечення безпомилковості і своєчасності комп'ютерної обробки текстової, графічної та образної інформації.

Надано обґрунтування того, що в основі якісної підготовки операторів є знання якісних і кількісних характеристик потоків здійснюваних помилок.

Виокремлено й описано основні положення концепції цільової підготовки операторів обробки інформації до безпомилкової діяльності. Суть цільової підготовки полягає в розробці теоретичних основ методичної системи формування готовності операторів до безпомилкової діяльності, що враховує професійний рівень окремих груп студентів. Правильність побудови концепції в тому, що вона відображена у формі сукупності чітко розподілених тверджень, и ця сукупність повна, несуперечлива і з елементами, що не виводяться один з одного. Несуперечливість й невиводимість положень доведено в рамках представленого дослідження, а повнота доведена з позиції теорії ергономічної підготовки інженерів-педагогів комп'ютерного профілю до професійної діяльності.

Експериментальні ергономічні дослідження дозволяють ввести в практику професійного навчання поряд з масовою й індивідуальною підготовкою цільову підготовку операторів обробки інформації. При цільовій підготовці можна спиратися на закономірності математичної теорії навчання.

Перспектива подальших досліджень: проведення експерименту з метою знаходження експериментального коефіцієнту, що характеризує здатність оператора до навчання; проведення порівняльного педагогічного експерименту з визначення педагогічної ефективності цільової підготовки операторів обробки інформації та впровадження в освітній процес інноваційного методичного забезпечення.

Ключові слова: оператор обробки інформації, якість діяльності, інженери-педагоги, помилки, цільова підготовка операторів.

Formulation of the problem. Operator labor takes an increasing share in modern production. In the structure of the activity of many modern professions, a significant share is occupied by the operator's activity. These professions include cashiers-operators of railway and bus offices, cashiers-operators of supermarkets, operators of mobile communication systems, gas stations personnel, power plants operators, information processing operators, bank operators, etc.

A definition [1] states that an operator is "a person, or a group of people whose responsibility is the establishment, operation, regulation, maintenance, cleaning, repair and transportation of machines". Among the workers trained in vocational schools, the share of workers capable of performing flawless operator's activities, for example, a computer operator, an adjuster of machine tools and programmed manipulators, electronic office staff, an information processing operator, etc., is growing. The professiograms [2] and professiocards [3] of these professions show the need for more proficient ergonomic knowledge of the engineers-educators who train these workers. Usually, a distinction is made between mass and individual training. In this paper, an intermediate type of training is considered – a targeted training, which is possible only on the basis of the ergonomic research. The essence of targeted training is the development of educational assignments that will take into account the professional level of the individual groups of trainees.

The educational and qualification characteristics of an operator for information and software processing define his professional activity as follows: "Information and telecommunications. Computer programming, consulting and related activities. Data processing, posting information on websites and related activities" [4]. The educational and qualification characteristics of a computer layout operator defines the curriculum focused on the formation of information, communication and technological competence [5]. In this study, the author is interested in the direction of text computer processing, graphic and figurative information, since this type of work takes up at least 80% of the working time. In accordance with the qualification requirements, an operator for information and software processing must be able to work with a text editor, spreadsheet processor, publishing systems, and must perform operations with databases [4, p. 9-10]. Naturally, when working with these software tools, operators make many different mistakes. However, the erroneous activity of operators causes significant economic losses. Protasenko [6] claims that due to the mistakes of one operator, a bank can annually lose about 0,001% of its income, and there are more than 130000 such employees in Ukraine, representing 0,6% of the working-age population. Therefore, there is a problem to ensure the quality of the operator's activities, which, in fact, boils down to ensuring the error-free and timely computer processing of text, graphic and figurative information.

Analysis of recent research and publications. Knowledge of the types and numerical characteristics of error streams operators make is one of the foundations of the theory of reliability and quality of man-technology systems [7]. In connection with the rapid development of ergonomics and engineering psychology, stimulated, in turn, by the development of aviation, astronautics and rocketry, an active study of the operator errors was carried out [8], [9]. Many of these studies were of an applied nature. Later, ergonomic research from the field of science and practice began to move to education [10], [11], [12], [13], [14], [15], [16]. In the educational program "Vocational training. Computer Technologies" courses "Ergonomics of Information Technologies" and "Human-Computer Interaction" were developed and introduced in the curriculum for future engineers-teachers of a computer profile, including topics on the study of operator errors, their accounting and prevention. With these courses, in fact, the ergonomic education of the engineers-teachers of a computer profile began.

The purpose of the work. A concept of a targeted training of information processing operators for error-free activity is generally formulated as follows: 1) on the basis of the experimental data to reveal the quantitative and qualitative characteristics of mistakes made by junior students in the process of their computer training; 2) to determine the peculiarities of the student's educational activity during his training to become an operator and a qualified user, 3) to modernize the educational material of computer training disciplines (first of all, "Information and communication technologies", "E-learning instrumentation", "Computer documentation"), through better choice of pedagogical technologies and the development of special teaching aids, all of which can as a result: 1) increase the level of students' readiness for their own error-free operator activities; 2) form students, as future engineers-teachers, and perfect their ability to provide high-quality training for computer typing operators. Consequently, the qualitative training of operators is based on the knowledge of the qualitative and quantitative characteristics of the flows of mistakes made by their future teachers.

The purpose of the paper is thus to outline the main provisions of the above concept, and substantiate these provisions.

Presentation of the main research material. It is well- known that a correctly constructed concept is the axiomatic foundation of the corresponding theory, in this case, the theoretical foundations of the methodological system of forming operator's readiness for error-free activity. The correct construction of the concept assumes that it is expressed as a set of clearly separable statements, that it is complete, consistent and with elements that cannot be inferred from each other. The consistency and non-deduction of the provisions can be proved within the framework of the study, and the completeness can be proved only by metatheory, in this case, by the theory of ergonomic training of engineers-teachers - computer profile for professional activity.

Thesis 1. "Determination of error". Error is derived from the more general concept of failure. By analogy with the definition of the failure of technical devices, the failure of a human operator in engineering psychology is considered as a failure to fulfill the prescribed actions, or such a decrease in the quality of their implementation which does not allow achieving the goal. The refusal of the operator is associated with a deviation beyond the permissible limits of the output characteristics of the system, i.e., characteristics for which he is responsible and which determine the achievement of the activity goal. Human error, in contrast to refusal, does not interfere with the performance of specified functions in the system, but reduces the quality of their performance beyond the limits determining the correct functioning of the system. These limits are defined in the normative and technical documentation for each function performed by a person in the system. The teacher should proceed in his teaching activity from the following definition of an error. An error is the result of an action performed inaccurately or incorrectly, which manifests itself in a deviation from the intended goal or in the mismatch of the result obtained with the intended one, or in the inconsistency of the achieved result with the intended goal.

Thesis 2. "On the basics of motivational learning technology". The motivational technology of teaching should be based on the following assumptions: a) the concept of "error of activity" at the everyday level is well known to students, so they can easily identify educational information about errors with information available in memory; b) mistakes in activity are numerous and multifaceted, their consequences often remain in the memory of a person for a long time, therefore, their study affects the emotional sphere of each student; c) knowledge of the classification of errors, methods of their detection and prevention is the "key" to ensuring the quality of operator activities.

Thesis 3. "On identifiers of operator errors". Each profession has its own range of errors and their identifiers. In the concept of targeted training, one can limit oneself to mistakes made when working with MS Office software products as the most important factors in the quality training of information processing operators.

It is assumed that each error of the information processing operators can be identified by the following set of parameters:

- *P1* - the level of activity at which the mistake was made; *P1* takes the following values: *a* - action level; *f* - the level of functions or operations; *t* - the level of tasks of the activity.
- *P2* - the type of software product with which an error was made; *P2* takes the following values: *W* - MS Word; *E* - MS Excel; *A* - MS Access; *P* - MS PowerPoint.
- *P3* - the type of error according to the classifier within a certain type of software product, while working with which an error was made.
- *P4* - the level of preparedness of the student who made a mistake; *P4* takes the following values: *h* - high level of preparedness; *av* - average level of preparedness; *l* - low level of preparedness.

Example 1. The experiment was carried out with full-time students of the first and second years in three specialties during laboratory classes in the disciplines "Information and communication technologies", "E-learning tools" when working with MS Office applications and the Google cloud service. To collect statistical data, observation cards were developed, filled in by a teacher observing the student's work during classes. Errors were recorded at the time of their commission in the form of a mark on the time axis, and an error code. The observation was carried out separately for each student. In general, the activity of 10 students was studied at each level of activity for each type of software product. The total number of detected errors is presented in Table 1.

Thesis 4. "On classification of errors". There are various classifications of errors. Nine such classifications are described in [17]. Figure 1 shows the two upper levels of error classification adopted in this study. For each type of software product, two more levels of classification have been compiled, an example of which is given in Table 2.

Table 1

Distribution of the number of errors recorded during the observation period

Activity levels	**Number of software bugs**				**Total**
	MS Word	**MS Excel**	**MS Access**	**MS PowerPoint**	
Actions	51	126	116	66	359
Operations	64	52	109	57	282
Tasks	42	36	47	70	195
Total	157	104	272	193	836

Thesis 5. "On the characteristics of a stream of errors of a specific type i, committed by one operator at a specific level of activity when working with a specific type of software product." There is reason to believe that the sifted stream of errors of type *i*, committed over a long time, is the simplest one. The simplest flow is a flow that simultaneously possesses the properties of stationarity, ordinariness, and absence of aftereffect. A flow is called stationary when the probability of committing a certain number of errors during a certain period of time does not depend on the origin of this interval, but on its length. Thus, the nature of the stationary flow of requirements does not change over time. An ordinary flow is a flow in which the probability of committing more than one error in a short period of time is infinitely small. Thus, no more than one error can be committed in an ordinary stream at any time. A flow without aftereffect is a flow in which the probability of committing a certain number of errors after some arbitrarily chosen moment in time does not depend on the number of errors committed up to that moment.

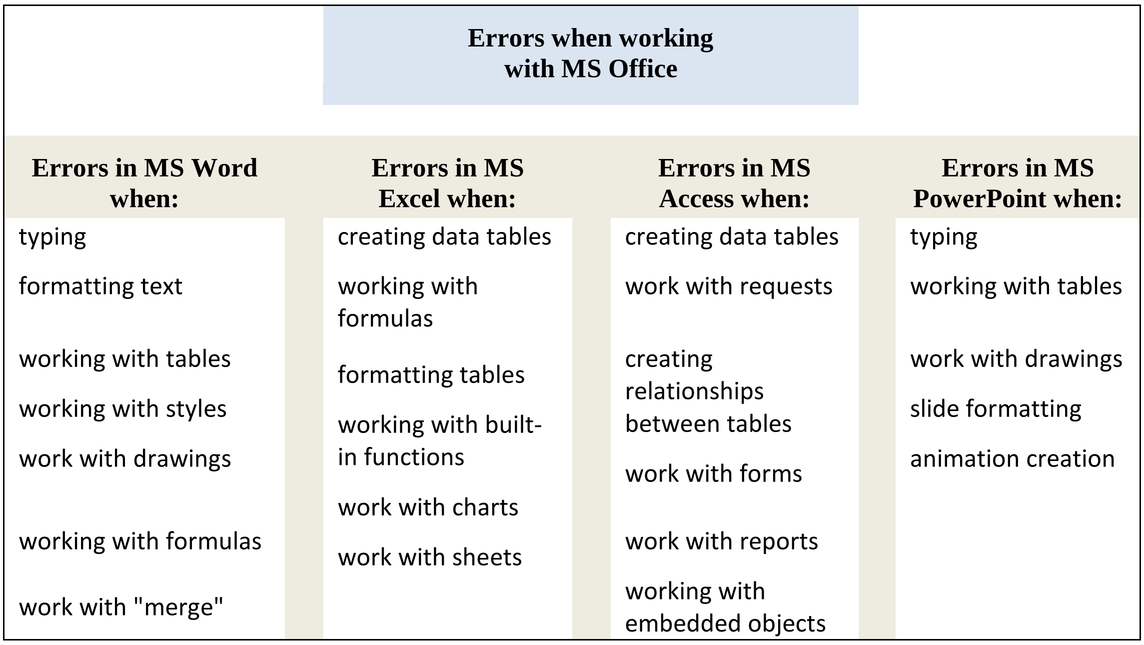

Fig. 1. Upper levels of the "classification tree" of operator errors

Table 2

Errors made by operators when working with MS Word (fragment)

Error code	The nature of the error
At the action level	
Wд1	One character is replaced by another symbol
Wд2	Confused the order of letters
Wд3	Missing space after separator
Wд4	Missing space before service character
Wд5	Extra character typed
Wд6	The register is messed up
Wд7	Language change not performed
Wд8	Missing symbol
Wд9	The indentation of the first line of a paragraph is not set
Wд10	Blank line inserted
Wд11	Wrong type of auto shape inserted
Wд12	Incorrectly selected menu item for insert picture
At the level of activity of operation	
Wo1	Font size is set incorrectly
Wo2	The type of list marking is set incorrectly
Wo3	Incorrectly set text style
Wo4	The size of the text is incorrectly set
Wo5	Incorrectly set text color
Wo6	Incorrectly set text animation
Wo7	Incorrectly set text modification
Wo8	Color highlighting is set incorrectly
Wo9	Incorrect character spacing
Wo10	Text alignment is set incorrectly
Wo11	Hyphenation not set
At the level of activity objectives	
Wз1	Incorrectly designed stylistic scheme
Wз2	Style options are set incorrectly (style applied to the wrong text)
Wз3	An error was made while creating the styles
Wз4	Error applying styles to text
Wз5	Error in the formatting of a text document (styles are not used)
Wз6	Error while placing merge fields in document
Wз7	Error while creating an initial database in Excel to fill a document
Wз8	Error while composing a complex text document

If we assume that the flow of errors of type *i* is the simplest, then the intensity of errors λ_i of type *i* can be calculated by the formula

$$\lambda_i = \frac{1}{T_{i\ av}}$$

Example 2. During the period of observation of a particular student, he made a mistake *Wd1* (see Table 1) 14 times. Based on the data on T_{ij}, the value λ_i = 0,9 (pcs/min). Another student made mistake *Wo43* (not removed indentation in AutoShape labels) 8 times. The average error time *Wo43* is equal to T_{iav} = 3,04; therefore, λ*i* = 0,3.

Thesis 6. "On the characteristics of a stream of errors of any kind, committed by one student at a specific level of activity when working with a specific type of software product." This position is based on the same premises as thesis 5. Average error time of any kind (in minutes) T_{av} and the intensity λ of the flow of errors of any kind are calculated by the formulas

$$T_{av} = \frac{\sum_j^n T_j}{n}, \lambda = \frac{1}{T_{av}},$$

where T_j is the *j*-th time for an error of any kind.

Example 3. Numerical characteristics of a stream of errors of any kind, committed by a student at the level of operations when working with MS Word:

Indicator		**Value**	**Unit of measurement**
Number of observations		188	quantity
Mean time to error	T_{iav}	1,86	minutes
Error rate	λ	0,54	quantity per minute

Thesis 7. "On the possibility of dividing students into groups according to readiness for error-free activity based on error statistics." Let *M* students study in the surveyed groups. This means that according to the results of data processing, we have *M* values of T_{av}. Let us build from T_{av} ascending series. Let us single out the T_{av} value from this series (min) and T_{av} value (max). Dividing the entire range of values into 3 equal parts, we obtain $\tau = [T_{av\ (max)} - T_{av\ (min)}] / 3$. Then we divide all students into 3 groups:

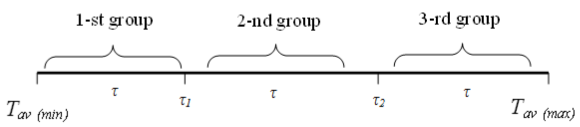

Fig. 3. Diagram explaining the principle of dividing students into groups

- 1-st group - students for whom the average time T_{av} an error of any kind falls within the range $[T_{av\ (min)}, \tau_1]$, i.e., $T_{av\ (min)} < T_{av} < T_{av\ (min)} + \tau = \tau_1$;
- 2-nd group - students for whom the average time T_{av} an error of any kind falls within the range $[\tau_1, \tau_2]$, i.e., $\tau_1 < T_{av} < \tau_2$;
- 3-rd group - students for whom the average time T_{av} error of any kind falls within the range $[\tau_2, T_{av\ (max)}]$, i.e., $\tau_1 < T_{av} < T_{av\ (max)}$.

We will label these groups: groups of high, medium and low training, respectively. The above procedure should be repeated for the data obtained for each type of software product. Then we get 12 groups of different fitness (4 types of software products are combined with 3 levels of training). The choice of a three-level scale is justified by the pedagogical practice of assessing the educational achievements of pupils/students.

Example 4. Table 3 gives the characteristics of error streams when working with a specific product for students of the three levels of preparedness.

Figure 4 shows a diagram characterizing the distribution of students. The analysis of the distributions showed the following (Table 4): 1) the percentage of more prepared students decreases with the transition from actions to tasks; 2) the percentage of students with high preparedness when working with different products ranges from 10-30%; 3) the majority of students (about 70%) have a low level of preparedness.

Table 3

Characteristics of error streams when working with MS Word

Identification signs of errors				**Error Stream Characteristics**	
				$T_{av.,M}$	λ_i
level of training	High	Activity levels	actions	7,5	0,13
			operations	10,5	0,095
			tasks	14,5	0,07
	Middle		actions	4,2	0,24
			operations	5,1	0,2
			tasks	9,0	0,1
	Low		actions	2,6	0,38
			operations	2,5	0,41
			tasks	4,5	0,22

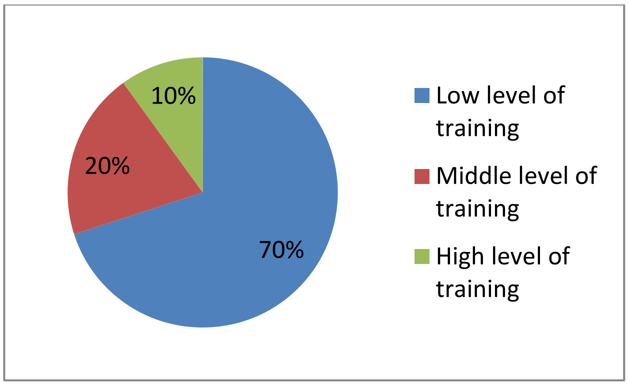

Fig. 4. The percentage of students by training levels when working with MS Excel at the task level

Table 4

Distribution of students by levels of preparedness

Activity levels	**Percentage of students with a certain level of training**											
	MS Word			**MS Excel**			**MS Access**			**MS PowerPoint**		
	l	**m**	**h**	**l**	**m**	**h**	**l**	**m**	**h**	**l**	**m**	**h**
Actions	57	14	29	50	30	20	60	20	20	56	25	19
Operations	50	38	13	80	10	10	50	20	30	80	10	10
Tasks	67	22	11	70	20	10	50	30	20	70	20	10

Thesis 8. "On the possibility of identifying the most typical errors based on their statistics." Based on the λ parameter, it is possible to identify the most typical mistakes made by students of this preparedness group when working with a specific software product as computer typing operators.

Example 5. The three most common mistakes when working with MS Word: 1) the language has not been changed; 2) the style of the text is incorrectly set; 3) the style parameters are incorrectly set. The three most common mistakes when working with MS Excel: 1) substitution of symbols; 2) incorrect insertion of the column (the column was not inserted or inserted in the wrong place); 3) the wrong type of diagram (graph) is selected. The three most common mistakes when working with MS Access: 1) the language has not been changed; 2) when inserting a table into a query, the user did not click the "Close" button for the table; 3) the menu was incorrectly selected when creating a computational field, form, table. The three most common mistakes when working with MS PowerPoint: 1) substitution of symbols; 2) a new document was created instead of a slide; 3) the adopted effect for highlighting the object does not meet the requirements.

Thesis 9. "On the possibility of targeted training for computer typing operators." Knowledge of the characteristics of the streams of mistakes made by students can be used as follows: 1) to differentiate the approach to teaching students with different levels of preparedness; 2) for the development of diagnostic tools for the level of training; 3) for targeted training of computer typing operators.

Example 6. Students are asked to be tested at three levels of diagnosis. Special tests have been developed. In each test, one situation is considered and tasks are given to correct the error. At the first level of diagnostics, the student is asked to answer two questions: the first question is about the cause of the error, the second is about the way to correct it. At the second level of diagnostics, the student is asked to answer three questions: the 1-st and 2-nd questions - in accordance with the first level of diagnostics, the 3-rd question - about recognizing the type of error. At the third level of diagnostics, the student is called to recognize the essence of the error and is asked to answer four questions: 1-st, 2-nd and 3-rd questions - in accordance with the second level of diagnostics, 4th question - about the essence of the error.

Thesis 10. "On the regularity of the formation of operators' skills for error-free activity." Knowledge of the parameter λ allows using the results of mathematical learning theory, in particular, using the model of Trapeznikov [18]. In an adapted form, it has the following form:

$$\lambda_t = \lambda_{av} - (\lambda_{av} - \lambda_0)e^{-\frac{t}{t_0}},$$

where λ_t, λ_l, λ_o current, limiting and initial values of the quality criterion for the actions of a human operator in the form of error rate; t is the time spent on training a human operator, hours; t_o is an experimental coefficient characterizing the operator's ability to learn.

Conclusions and prospects for further research.

Ergonomic research makes it possible to introduce into the practice of professional training a targeted training of information processing operators as an intermediate form between mass and individual training. With targeted training, one can rely on the laws of mathematical learning theory.

The authors see the prospects for further research in the following: 1) conducting an experiment to find the to experimental coefficient, characterizing the operator's ability to learn; 2) conducting a comparative pedagogical experiment to determine the pedagogical effectiveness of the targeted training of information processing operators; 3) continuing the development and implementation of the innovative methodological support.

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