ITM Web of Conferences **59**, 03014 (2024) https://doi.org/10.1051/itmconf/20245903014
HMMOCS-II 2023

Methodology for assessing the predicted didactic effects from the use of educational and training tools

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Abstract. The assessment of didactic effect is the most important in evaluating the effectiveness of training simulators. Modern methods of training specialists have shown that the most applicable at present is the step-by-step formation of skills and abilities. The methodology of obtaining the value of a complex indicator that takes into account the degree of influence of didactic possibilities realized in training simulators on the reduction of training time based on the methods of expert evaluation, the method of selecting the main component, convolution of single indicators into private ones and selection of the type of its function of a private indicator

1 Introduction

One of the most important issues in assessing the effectiveness of the use of training and educational means (TEM) is the assessment of the didactic effect obtained from their use.

From the psychological and pedagogical point of view, the process of training with the use of TEM should be considered effective if the requirements are met:

the range of skills and abilities formed with the help of TEM, covers those actions and activities that are necessary for the learner (trainee) to perform operations on real equipment;

skills and abilities, formed on TEM, are adequate to the psychological structure of real activity and have the ability to transfer to real equipment;

the level of formation of skills and abilities at training with the use of TEM for a certain time is higher in comparison with other methods of training and there is a gain in the time of training to a given level.

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2 Materials and methods

Based on the definitions of operation, standard and training task, the practical training of a specialist can be presented as a repetitive process of performing the same actions and operations in a certain period of time.

At the same time, the practical experience of training specialists and the results of research analysis [1] show that the dependence of the operator's performance results (the number of errors n_{err} and the time of task performance T_{task} (operation, standard, training task)) on the number of trainings (training time) can be described by exponential functions of the form:

$$n_{err}(n) = n_{c\,err} + (n_{0\,err} - n_{c\,err})exp[-\varphi_1 n_{1tr}], \tag{1}$$

$$T_{task} = T_c + (T_0 - T_c)exp[-\varphi_2 n_{2tr}], \tag{2}$$

where T_{task} and $n_{c\,err}$ – are the stationary values of the time of task (operation, standard, training task) and the number of errors, respectively; T_0 and $n_{0\,err}$ – initial values of these indicators; n_{1tr} (n_{2tr}) – number of trainings; φ_1 and φ_2 – speed of training in terms of error-free performance of a task (operation, standard, training task) and quickness.

In the study, the time spent for training a specialist to perform the i-th operation (standard, training task), with an acceptable number of errors for a grade not lower than "good" is taken as stationary.

In the study, the relative stability of training results over time, with an acceptable number of errors, and the maximum possible performance results for given conditions are taken as the main condition for assessing the formation of skills and competencies in training specialists with the use of TEM [1].

Practice shows that it is usually faster to reach the steady-state level of training in rapidity than in error-free performance ($\varphi_1 < \varphi_2$). Therefore, the number of training sessions to reach the specified level of error-free performance is usually greater than that for fast performance, that is $n_{1tr} > n_{2tr}$. Taking this condition as the basic one, the time of operator training on the sample radio engineering complex (REC) (T_{REC}) and TEM (T_{TEM}) and the time of its additional training (T_{1REC}) can be defined in the form of expressions:

$$T_{REC} = t_{iREC} n_{REC},\ \ T_{TEM} = t_{iTEM} n_{TEM},\ \ T_{1REC} = t_{i1REC} n_{1REC}, \tag{3}$$

where $t_{iREC(TEM)}$ - time of one lesson on a sample REC (TEM);

n_{REC} – number of training sessions (drills) to be conducted on a sample REC to perform k-th number of operations in a given time with a permissible number of errors;

n_{1REC} – number of sessions (drills) required for additional training of specialists after the initial training on the TEM to achieve a given level of training;

n_{TEM} – the number of sessions (trainings), which can be conducted on the TEM sample to perform the k-th number of operations in a given time with an acceptable number of errors without taking into account the additional training on the REC sample.

At the same time, the number of n_{TEM} training depends on the possibilities realized in the TEM and is determined on the basis of the list of topics and the content of training sessions set out in the relevant specialist training programs, as well as the requirements to knowledge, skills and abilities. A practical training session (training) in the study is understood as 1 training hour, during which a specialist practically performs k-th number of operations.

This condition can be described by the expression:

$$t_{iREC} = \sum_{j=1}^{k} t_{jREC}\,,\ \ t_{iTEM} = \sum_{j=1}^{k} t_{jTEM}\,,\ \ t_{1REC} = \sum_{j=1}^{k} t_{j1REC}\,, \tag{4}$$

where t_{jREC} – training time of the j-th operation on the REC sample; t_{jTEM} – time of training of the j-th identical operation on the TEM sample; t_{j1REC} – time of additional training for training of the j-th operation on the sample REC; k – the number of operations that can be trained for 1 specialist in one session.

The curve describing the dependence of the time of fulfillment of the j-th task (operation, standard, training task) on the number of classes, shown in Figure 1, can have different steepness, which depends on the chosen methodology of conducting classes, didactic possibilities of the used training means, qualification of the teaching staff and the initial level of training of specialists.

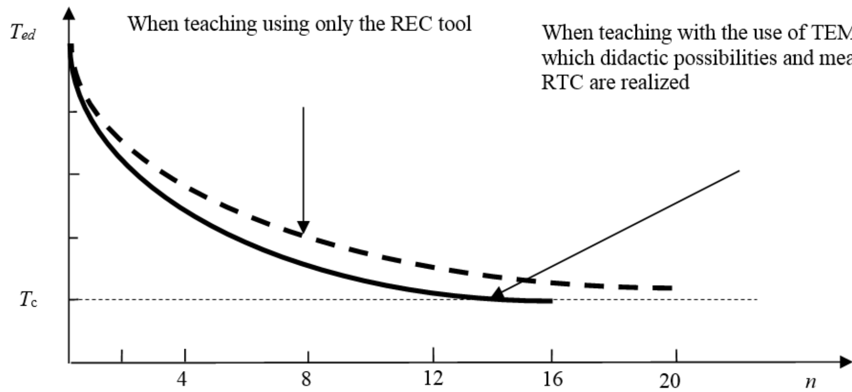

Fig. 1. Dependence of change in the time of j-th task completion on the number of classes and other influencing factors.

The analysis of modern methods of training specialists has shown that the most applicable at present is the method of step-by-step formation of mental actions and concepts in the operator. Its use allows to train specialists on real samples of REC means and with the use of modern TEM.

In this case, the training of trainees with the use of TEM and on real samples of REC is carried out by the same teachers (instructors) with a relatively equal average value of the initial level of training of operators of the same specialty.

It follows that the most significant factor influencing the time of training a specialist to perform the j-th operation (standard, training task) is didactic (training) capabilities of the used training means. At the same time, the implementation of didactic capabilities in the TEM, that is the ability to give reinforcements (hints) to trainees, accumulation and presentation of generalizing and controlling information allows to reduce the probability of errors in their work, intensify the training process and, as a result, to obtain a certain didactic effect from the use of TEM, which consists in reducing the training time.

The methodology of obtaining the value of the complex indicator represented by the coefficient of D, which takes into account the degree of influence of didactic opportunities realized in the TEM on the reduction of training time, is presented in the form of the sequence shown in Figure 2.

Determination of the value of this coefficient can be carried out in several stages.

At the first stage, the activity of specialists, as an object of management, is analyzed in the process of technical training, with the definition of professionally important qualities. Then, based on the conceptual model of the system of specialists' training with the use of TEM, the functions performed by training means are determined and a list of didactic possibilities that can be realized in TEM is compiled.

In this case, the list of didactic capabilities and their weight (α), is obtained on the basis of analyzing the values of indicators that reflect the effect of using the same type of didactic capabilities in the training of operators in the performance of a similar type of activity, given in [2], and using the method of expert evaluation.

The application of the expert evaluation method is caused by the insufficiency of objective information about the factors influencing the process of training specialists using TEM with different capabilities realized in them. Therefore, experts, in this particular case, acted as sources of additional subjective information, which made it possible to rank and evaluate qualitative factors that are difficult to obtain at this level of knowledge by other means.

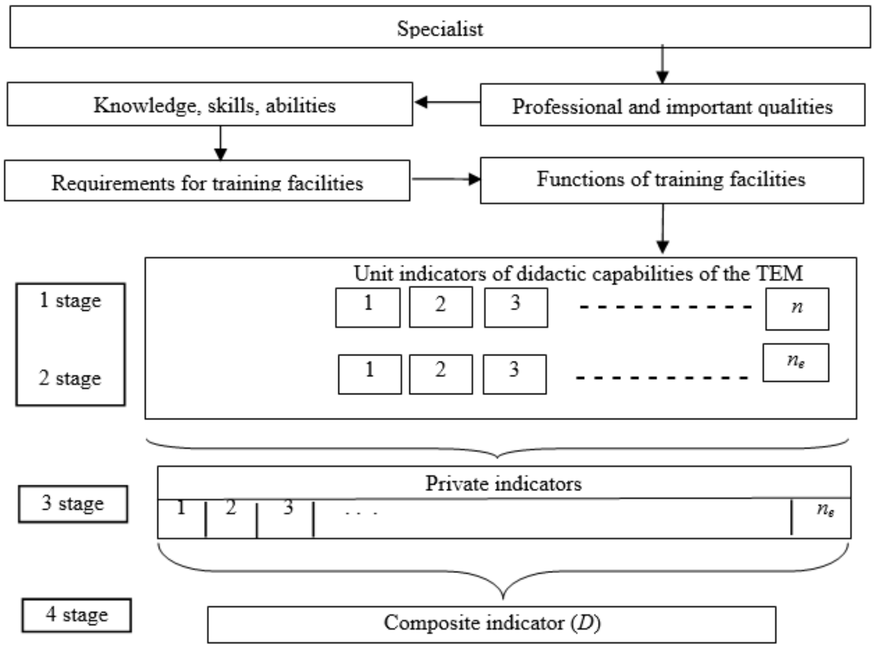

Fig. 2. Sequence of determining the coefficient that takes into account the degree of influence of didactic opportunities realized in the TEM on the reduction of training time.

The value of the weighting coefficient (α) determines the importance and preference of the realization of the i-th opportunity in relation to others within the framework of meeting the requirements for the level of training of a specialist and the time to achieve a given level. Based on the principles of general qualimetry [3], each didactic opportunity is defined by two numerical parameters - relative index (H) and weighting α. The sum of weighting coefficients of properties of one level is a constant value:

$$\sum_{i=1}^{n} \alpha_i = const = 1. \quad (5)$$

At the second stage, using the method of selecting the main component [4], the most important single indicators of didactic capabilities of TEM are selected and their weighting coefficients are adjusted.

At the third stage, the convolution of single indicators into private ones is performed and the type of function of the private indicator of didactic capabilities of the TEM is selected.

3 Results and discussion

Usually the type of functional dependence is set a priori [5], and the traditional way is the construction of their average values. These values characterize the tendency of behavior of single indicators in the average, as well as the possibility of this or that compensation of values of some indicators at the expense of others. The most frequently used of them are arithmetic mean and geometric mean [5, 6].

The application of the arithmetic mean assumes commensurability and interchangeability of private indicators, i.e. it is assumed that the shortcomings of one component can be compensated by a high value of the other. In addition, this type of aggregation is insensitive to the appearance of unacceptably low values for individual indicators.

The geometric mean has the property of converting the generalized indicator to zero, if the score of one indicator is equal to zero.

In the studies conducted in universities, the above methods have found their application, although greater preference is given to the arithmetic mean as more simple and understandable. In the conducted study this method is applied for the same reasons.

Partial indicators of didactic efficiency are arithmetic mean values of single indicators characterizing the coefficient of reduction of time of specialists' training at application of ATC and are defined by the expression:

$$D_j = \frac{1}{n_e}\sum_{i=1}^{n_e} \alpha_i \cdot H_{i,} \text{ at } i = \overline{1, n_e}, \quad (6)$$

where D_j – value of the private indicator, which takes into account the degree of influence of didactic possibilities of the TEM of one group on the reduction of training time; H_i – value of the indicator of the i-th didactic opportunity;

$$H_i = \begin{cases} 1 - \text{if the didactic opportunity is realized,} \\ 0 - \text{if the didactic opportunity is not realized;} \end{cases}$$

n_e – number of unit indicators in a private indicator; j – number of a private indicator in the group of private indicators; i – number of a single indicator in the group of private indicators.

The result of grouping of single indicators is a list of groups of didactic capabilities (private indicators) characterizing TEM, determined by the results of an expert survey of respondents and taking into account the recommendations set out in a number of sources [7] (Table 1).

Table 1. The list of private indicators of didactic possibilities of TEM.

Name of private indicator	Weight (β_j)
Operational management capability	0.55
Control possibility	0.35
Possibility to accumulate, store and issue information, including in the form of documents, on the results of control of trainees' activities	0.1

The fourth stage involves the aggregation of private indicators into a complex one. A number of requirements to this indicator and the mechanism of its determination were taken into account [8]:

completeness of assessment, i.e. the possibility of taking into account all single indicators of didactic capabilities of the TEM;

sufficient and directed sensitivity of the generalized indicator to changes in single indicators of didactic capabilities;

possibility of wide use in the task of assessment of didactic possibilities of training means;

simplicity, accessibility, low labor intensity in calculations.

Since the complex indicator D reflects the properties of all private indicators, the arithmetic mean method of aggregation was used in its determination. Linear dependence was chosen as a functional dependence of the complex indicator on private indicators [8]. Consequently, the value of the complex indicator can be represented as:

$$D = \frac{1}{n_p}\sum_{j=1}^{n_p} \beta_j \cdot D_{j,} \text{ at } j = \overline{1, n_p}, \quad (7)$$

where D – value of the coefficient (complex indicator), which takes into account the degree of influence of didactic possibilities of TEM on the reduction of training time; n_p – number of private indicators; β_j – weight of a private indicator.

The value of D depends on the number and type of realized opportunities. The change of this coefficient has an impact on the time spent on training specialists when using TEM.

Thus, the obtained list of single and partial indicators allowed us to determine the type of complex indicator, which takes into account the degree of influence of didactic opportunities realized in TEM of one type on the training of specialists with their use.

If at the stage of prediction the degree of influence of different didactic possibilities realized in TEM is known, then on the basis of these data it is possible to choose a training tool from among the proposed ones, with the help of which a higher didactic effect is achieved.

In order to obtain predictive results on the reduction of training time of specialists when teaching the j-th operation, it is advisable to use the expression obtained taking into account (3, 4):

$$t_{jTEM} = \left(t_{jREC} - t_{j1REC}\right) \cdot (1 - D). \tag{8}$$

Proceeding from the fact that when designing the TEM, didactic opportunities are put into it, assuming the support of the performance of all basic operations (actions), the total time of training specialists using the TEM can be determined using the expression:

$$T_{TEM} = \left(\sum_{j=1}^{k} t_{jREC} n_{REC} - \sum_{j=1}^{k} t_{j1REC} n_{1REC}\right) \cdot (1 - D). \tag{9}$$

It follows from formula (9) that the didactic effect from the use of TEM when realizing didactic possibilities in them is achieved by reducing the time of operator training on the training tool, with unchanged time of additional training to the specified level (T_{1REC}) on the sample communication tool and the total training time. On this basis, the expression will be true:

$$K_{1D\,TEM} = 1 - \frac{T_{TEM} + T_{1REC}}{T_{REC}} = 1 - \frac{(T_{REC} - T_{1REC})(1 - D) + T_{1REC}}{T_{REC}}. \tag{10}$$

The resulting didactic effect is proportional to the ratio of the time allocated to training using TEM and REC. This ratio depends on the degree of correspondence of the training sample to the real means of communication, called adequacy and denoted in the study by (α).

The graphical dependence of the change in the obtained didactic effect ($K_{1D\,TEM}$) on the number of didactic possibilities realized in the TEM *(D)* and the degree of correspondence between the REC and TEM samples (α) is presented in Figure 3.

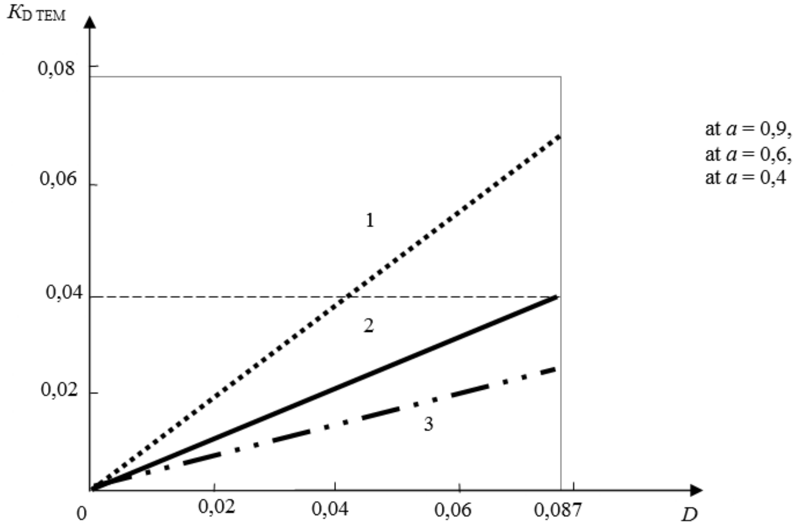

Fig. 3. Dependence of the change in the predicted didactic effect on the value of the coefficient *D* and the adequacy of the simulator used.

The practice of application of TEM shows that with increasing the degree of adequacy of the training tool to the real sample, the time of training a specialist using the training tool increases due to reducing the time of its additional training on the REC sample.

The experience of training specialists has shown that the time of their additional training up to a given level can be represented as a sum of time indicators characterizing the time of adaptation of operators after work on the TEM (ΔT) and the time of direct additional training (T_{ADTR}) of specialists on the REC facility (Figure 4).

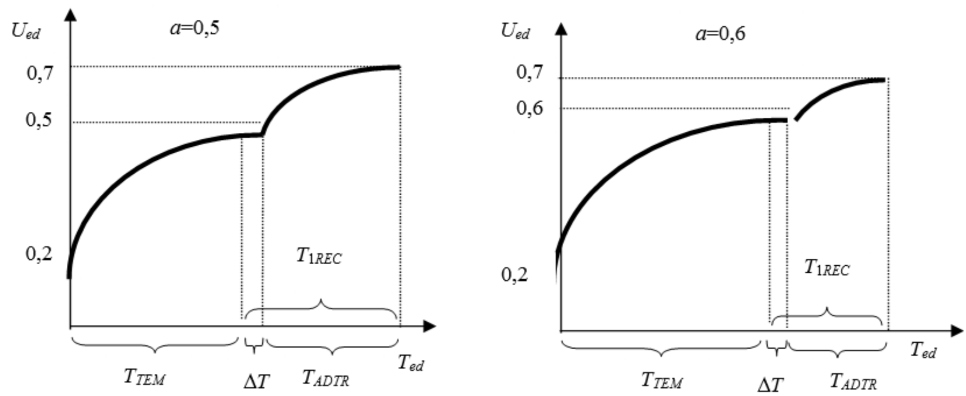

Fig. 4. Change of time of additional training of specialists with increasing adequacy of TEM to REC Means.

The above, can be described by the expression:

$$T_{1REC} = \Delta T + T_{ADTR}, \tag{11}$$

where ΔT – is the value characterizing the time of adaptation of operators to work on the real model of the REC tool after training on the TEM; T_{ADTR} – time of direct additional training of specialists on the REC tool.

The value of ΔT depends on the degree of adequacy of the TEM to the REC means, but the law accurately describing the dependence of the change of the first indicator on the second has not been revealed at this stage, therefore, based on the studies of other authors [9-11] and the experience of operation of existing simulators, it is assumed that the value of ΔT increases with decreasing adequacy of the TEM ($a \to 0$) and decreases with $a \to 1$.

The experience of training specialists using TEM of different degrees of adequacy has revealed that the value of ΔT practically tends to zero when simulators are used [12]. In the course of operator training, the value of this indicator tends to decrease. This is due to the ability of the human organism to quickly reorganize the attention functions during constant training with alternation of classes on simulators and real REC means. It follows from this that the greatest value of ΔT will have the greatest value only during the initial training sessions. At the same time, it will differ from one specialist to another, it depends on the development of attention functions in trainees, availability of computer skills and some others. In order to reduce the influence of this factor on the total training time, it is proposed to conduct familiarization sessions on REC in the initial period of training.

Researches of scientists have shown that time of additional training (T_{ADTR}) of specialists on real REC samples depends on the degree of adequacy of TEM (a) and varies according to the law close to the expression described:

$$T_{ADTR} = T_{REC}(1 - ka^2), \tag{12}$$

where k – is the value of the proportionality coefficient.

Graphically this dependence is presented in Figure 5.

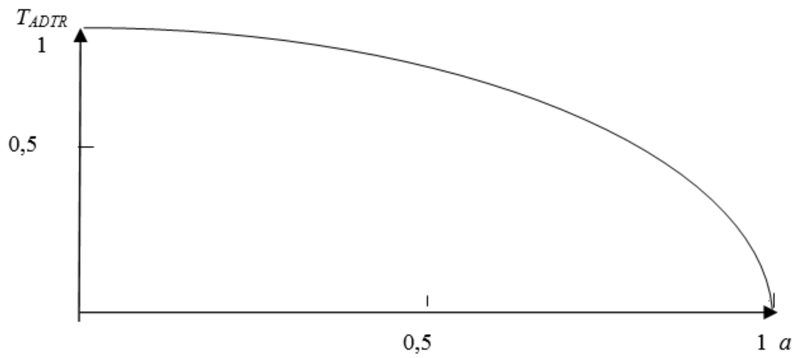

Fig. 5. Dependence of the time of additional training of specialists on the sample REC after TEM training on the degree of adequacy of the applied training tool.

The analysis of the graphical representation of the above dependence confirms the conclusions drawn from the results of the application of TEM in the process of training specialists, indicating the inexpediency of using training tools of low adequacy not only from the economic side, but also from the point of view of time costs for training specialists [9].

Taking into account the expression (12), the training time of specialists at the integrated use of TEM and REC means can be represented as follows:

$$T_{ed} = T_{TEM} + \left(\Delta T + T_{REC}(1 - ka^2)\right). \quad (13)$$

At the same time, the reduction of training time can be achieved either due to the realization of didactic possibilities in the TEM or due to the increase in the degree of adequacy of the training tool to the real one.

4 Conclusion

Thus, having the data on the influence of didactic opportunities, which are embedded in the TEM, it is possible at the stage of prediction to obtain an assessment of didactic effect from the application of training tools of one type, accompanying the creation of a sample of REC.

At the same time, the verification of the results of the predictive evaluation of the didactic effect that can be obtained through the application of the TEM with the implemented didactic capabilities should be carried out on the basis of practical data obtained as a result of psychological and pedagogical expertise in relation to those training systems (simulators, training complexes, simulators, etc.), which have been pre-selected for compliance of technical parameters with the requirements of guidance documents.

The didactic effect is estimated either by reducing the time of operator training to a certain specified level, or by increasing the level of training of specialists for a given time.

After the experiment it is necessary to compare the values of $K_{D\ TEM}$ indicators obtained at the stage of predictive evaluation and at the stage of testing. According to the results of the experiment it is recommended to refine the values ofα_i, β_j, to make recommendations on the use of TEM in the process of training specialists, to determine the list of topics and issues, the study of which it is advisable to conduct with the use of TEM.

In addition, at the stage of forecasting the estimated economic effect that can be obtained as a result of using the TEM is assessed.

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