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TÍTULO: La enseñanza de la Física a distancia en el sistema de formación de recursos humanos de ingeniería.

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RESUMEN: La física es una de las disciplinas importantes en el sistema de capacitación del personal de ingeniería; sin embargo, los hechos revelados en el curso de estudio atestiguan la presencia de problemas en la organización de la educación a distancia en física de estudiantes universitarios técnicos. La conocida teoría de la actividad psicológica se aplica para el estudio, mientras que el modelo de los métodos se desarrolla e introduce en el proceso educativo de las universidades rusas. Para la práctica, el autor está desarrollando un sitio web de aprendizaje dividido en módulos que permiten organizar la actividad de los estudiantes en la adquisición de conocimiento y la formación de métodos generalizados para resolver tareas estándar de ingeniería profesional. La evaluación de la eficiencia se implementa mediante el método de evaluación experto.

PALABRAS CLAVES: enseñanza de la Física a distancia a futuros ingenieros, preparación para la actividad profesional futura.

TITLE: Distance education in Physics in the system of training of engineering personnel**.**

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ABSTRACT: Physics is one of the important disciplines in the system of training the engineering personnel; however, the facts revealed in the course of study testify the presence of issues in organizing distance education in physics of technical university students. The well-known in psychology activity theory is applied as theoretical basis for the study, while the model of the methods is developed and introduced in the education process of Russian universities. For the practical introduction, the author is developing a learning web-сайт divided into modules that allow organizing students' activity in acquisition of knowledge and formation of generalized methods for solving standard professional engineering tasks. Efficiency assessment is implemented by expert evaluation method.

KEY WORDS: distant education in Physics of future engineers, training for future professional activity.

INTRODUCTION.

The importance of studying discipline "Physics" for future engineers is self-evident, that is why physics is one of the obligatory disciplines included in curricula of technical universities. However, analysis of the issue of distant education in physics of technical university students allowed revealing a number of tasks, their solution having paramount importance for training the future specialist. Such issues include:

1. All existing approaches to the organization of distance education in physics implement the so-called knowledge approach. The purpose of training, mainly, is to master the generalized results of what was created by predecessors and accumulated by human experience in the form of

formulated generalizations – scientific knowledge. However, issues regarding mastering of activities, ways, methods of their application in future professional activities, are not revealed in the process of teaching physics. The knowledge obtained this way "cannot possess a sufficient breadth of application in various situations, fields and activity conditions" [9], they quickly become outdated, while adding new information to existing curricula and programs cannot provide training for a qualified specialist – engineer.

2. Types of control applied in distant education in physics do not allow estimating whether the student can perform this or that activity based on the knowledge, that is, they cannot serve as means of controlling the process of acquisition knowledge in physics.

Study guides applied in distant education in physics of technical university students does not allow organizing the activity of application the physical knowledge in professionally significant situations. Study materials presented in video, audio and digital media do not reflect the specifics of the future professional activity of the student - this is extremely concise theoretical information on the discipline being studied, rarely accompanied by everyday examples or general-purpose technical devices.

The presence of the revealed issues motivated us to verify whether there is a possibility of training a significant number of future engineers for solving professional tasks with the application of physical knowledge including the distant students. Generalization of the study results showed that a significant number of technical university students:

1) Cannot solve specific tasks close to professional ones, applying physical knowledge.

2) The simplest actions that are part of a professional activity are not developed.

3) Individual substructures included in the generalized method for their solution are not formed as well.

4) Students don't memorize the examples describing operation principles of technical devices, that are described in textbooks, lectures and in conditions of tasks.

Thus, the revealed issues of distant education in physics of technical university students and the results of ascertaining experiment allowed establishing the fact that the existing ways of training technical university students to future professional activity (whether it’s an intramural, extramural form of study or extramural – distant education) aren’t efficient. Therefore, it is inexpedient to transfer them to distance learning and it is necessary to search for more effective approaches to training future engineers solving professional tasks with the help of physical knowledge.

DEVELOPMENT.

Purpose of the study.

The obtained results allowed formulating the purpose of the study: to establish and develop the methods of distant education in physics of technical university students. The application of these methods will allow future engineers to learn to apply physical knowledge in professional activity.

Method.

Our study was carried out in several stages. The initial stage was the informed choice of a theoretical basis for developing a model of methods of distant education in physics of technical university students. Analysis of academic literature in the fields of psychology and pedagogics of higher professional education as well as methods of teaching physics allowed determining that action theory may be used as theoretical bases [4,5,6,9 and others]. The main provisions of the activity theory are as follows:

1. Knowledge is necessary for a person not by itself, but for solving practically significant issues. This means that the result of the training process of a future engineer is the formation of certain types of activities related to solving professional tasks [11].

2. For making a future specialist independent of conditions in which he will have to perform his activity, it is necessary to form ways of performing the given activity in a generalized way. “The only way it can be implemented is the following: teaching students to solve specific tasks may be made means of independent identification of a generalized method of activity. Then students may be taught to apply the generalized method for solving tasks in any situation” [10].
3. “Learning process is not organized for getting the correct answers from students, but for teaching them the cognitive actions that lead to these answers” [1]. That’s why such a function of the routine control as feedback, must provide the step-by-step control giving the possibility to assess whether the student performs the correct actions or whether the actions are performed in the specified sequence.

The given provisions of activity theory allowed formulating the theoretical idea of the study: as a result of distant education in physics of technical university students the future specialists of engineering major must master methods of solving professional tasks. At the same time methods of solving professional tasks must be formed among future specialist during distant learning in a generalized way.

Various professional tasks may arise in the practical activity of an engineer. They can be solved with the application of knowledge in physics, chemistry, biology, mathematics, metrology and other sciences. Thus, the next stage of our study was to identify among the variety of professional engineering issues, the issues that can only be solved with the help of physical knowledge and to form the generalized methods of their solution. Applying such methods as modeling, extrapolation, expert judgment, analysis of a specialist’s model and others, we identified typical professional tasks of engineers of various profiles:

1) Obtaining (creating) a substance with predetermined properties with predetermined means.

2) Creating an object with the necessary properties in the specified conditions with special means.

3) Preserving (maintaining) the properties of the substance unchanged and corresponding the regulatory documentation or specified in the given situation.

4) Maintaining the properties of the object unchanged and corresponding to the regulatory documentation or specified in the given situation.

5) Preserving (maintaining) the properties of the environment in accordance with the regulatory properties.

6) Pumping the substance with the specified properties or the corresponding regulatory documentation.

7) Transfer (transportation) of objects with the specified properties, corresponding regulatory documentation or specified in the given conditions.

8) Transfer (transportation) of substances with the specified properties, corresponding regulatory documentation or specified in the given conditions.

9) Establishing compliance with the state parameters of objects (substances) obtained by direct measurement with the regulatory parameter.

10) Establishing compliance with the state parameters of objects (substances) obtained by indirect measurement with the regulatory parameter.

11) Control of a biological object (hydrobiont) in the given conditions.

12) Creating optimal conditions for the growth of hydrobiont".

For identifying the generalized methods for solving typical professional tasks, we used a method based on methodological knowledge that the goal, as a law, determines the way and nature of human activity [2], but only when the activity, its final product and its properties are indicated the statement of the goal. Moreover, to achieve the goal a person initially develops a program for converting the subject of activity into the final product with specified properties. The given stage is commonly referred to as a preliminary one. Then a person acting with material objects and means creates the final product. This is the executive stage. At the third, final stage, the obtained result as a product of activity is compared to the one indicted in the goals [9].

The above provisions determining the way of searching the generalized methods for solving tasks were repeatedly applied by a number of researchers [8, 9,12 and others]. Nowadays the content of the given type of activity is identified and it is presented in the form of scheme in fig.1.

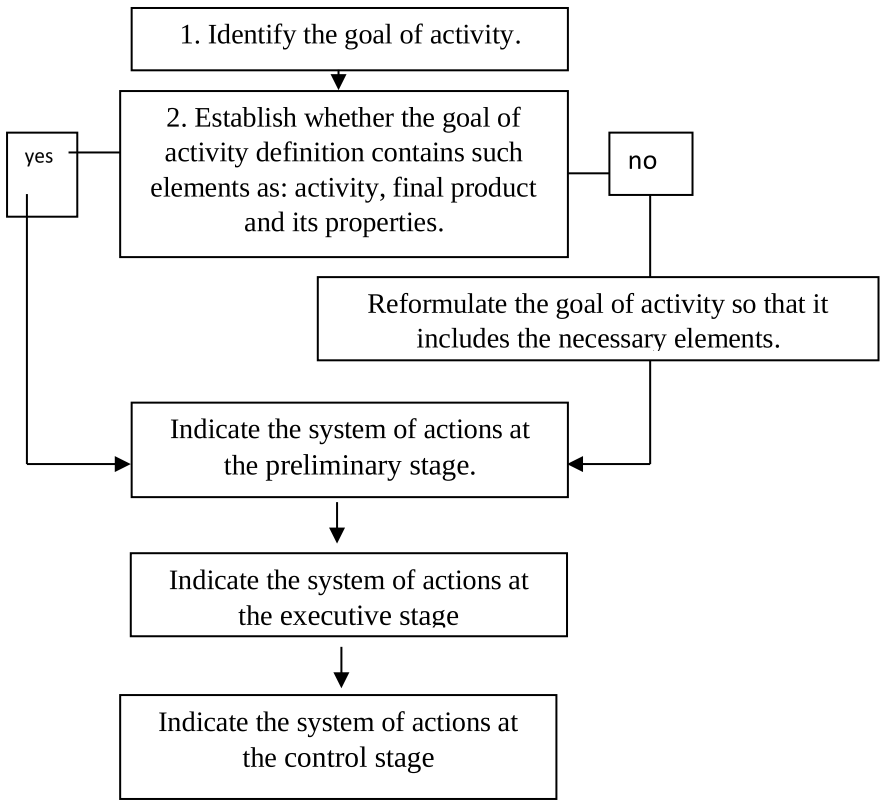


Fig.1. Generalized scheme of activity on indicating methods of solving typical tasks.

Here are the examples of the application of this generalized scheme for identifying the content of the method for solving typical professional tasks. Thus, for example, a generalized method for solving the task “Control the behavior of a biological object (hydrobiont)” consists of the following sequence of actions:

1. We identify the goal of activity – to control the biological object.

2. We establish whether the goal of activity definition contains such elements as: activity, final product and its properties. The definition contains activity (to control); final product and its properties aren't specified (behavior of the hydrobiont).

In this connection, there appears a need to reformulate the goal of the activity. For this, it is necessary to find out the content of terms "to control" and "behavior of a biological object". Thus, by "control", we mean the influence of such controlling parameters that would ensure the best course of the process from the point of view of the specified criterion, or otherwise - the best behavior of the system, its development towards the goal along the optimal path. By the statement "behavior of a biological object" we understand the ability of animals to alter their actions, respond to the impact of internal and external factors. This implies that the expression "control a biological object" can be understood as: the impact on a biological object by controlling elements in order to alter the actions of the latter, corresponding to specified criteria (conditions). Thus, the specified goal of activity includes activity – influence, the final product includes activity – altering the actions of the biological object, properties of the final product – correspondence to the specified criteria.

1. We identify the system of actions at the executive stage:
   - Establish the type of actions (behavior) of a biological object.
   - Establish the conditions the biological object is in.
   - Establish what controlling elements may be sued for altering the behavior of the given biological object in the specified conditions.
   - Establish the threshold parameter of the impact of the controlling elements on the biological object.
   - Calculate the parameters of controlling elements that correspond the threshold characteristics of the biological object in the specified conditions.

- Establish the sequence of application of control elements to alter the behavior of the object in a certain time interval.
- Develop a schematic layout corresponding to the specified conditions.

2. We identify the system of actions at the executive stage:
   - Choose the equipment.
   - Install the equipment.
   - Bring it to action.
3. We identify the system of actions at the control stage:
   - Establish whether the behavior of the biological object alters under the influence of the controlling element.

Thus, the generalized methods for solving all types of typical professional tasks for engineers of various majors were identified. Further on the following question arose how the process of distant education in physics of technical university students should be organized in order for the students to learn to solve professional tasks applying physical knowledge as well as to acquire methods for solving these tasks. Therefore, the following stage of our study was the development of the model of distant education in physics of technical university students. The given model is presented on figure 2.

The model of the methods includes the traditional components: training goals, contents, didactic means, and means of control. Each component has corresponding guidelines and the so-called techniques. The given techniques and guidelines allow to define:

1) The goals of distant education in physics (teaching the generalized methods for solving individual professional tasks).

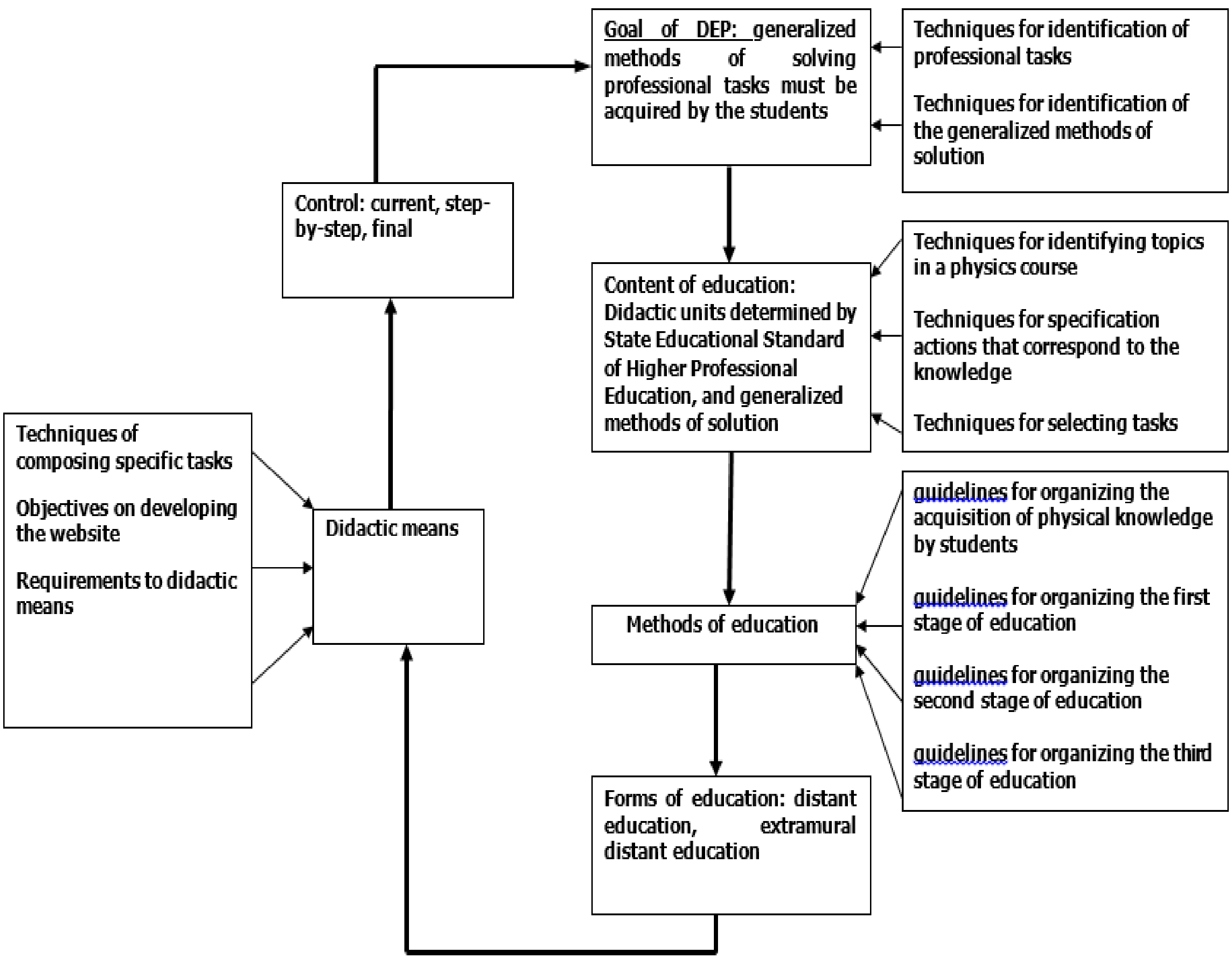
2) The content of distant education in physics (basic knowledge for solving typical professional tasks and the corresponding activities).

3) Means (special didactic means based on information communication technologies created according to the requirements and guidelines).

4) Teaching methods (organizing teaching the generalized methods for solving professional tasks in three stages, organizing special work on the assimilation of the basic concepts of a physics course.

5) Forms of the necessary control at each stage of education (current step-by-step control, final control).

Fig. 2. Model of the process of distant education in physics of technical university students.



For practical introduction of the developed model of distant education in physics of technical university students, we developed a special training website, which included in its structure traditional components as well as components that allow organizing activity on acquisition the elements of physical knowledge (comprehending physical objects, phenomena, physical quantities, scientific facts, laws and theories) and the generalized methods for solving typical professional tasks. Thus, for example, we named the component that allows organizing activity on acquisition of physical knowledge was “Learning to apply physical knowledge”. The given unit contained exercises on identification of elements of physical knowledge in various situations relying on the content of the notion. The performed actions are written in a special line, then the protocol of the assignment is sent to the university’s server, where the correctness and sequence of the actions performed is checked.

It was established that almost all the distant learning students can’t solve the given tasks, singularizing actions for solving them. Therefore, it is recommended to organize teaching in such a way that the first access to the given page of the website is carried out under teacher’s control. It is possible with the help of various means of communication (mobile phones, ISQ, web camera connection).

If the given technology is applied while organizing intramural education of future engineers, then the teacher explains working principles with the given pages of the website in a private discussion. The teacher explains that the activity performed by the students is called “activity bringing to the notion” and is implemented with the backup of the content of a specific notion, law and scientific fact. The teacher will have to remember the definitions of the notions; in this case he/she can use the definitions formulated in the links of the website. The student is explained that the definition includes the main features of the studied notion and their identification is demonstrated during an interactive dialogue by some examples. The student is also explained that for performing such tasks they may use an instruction card where the definition of the notion is formulated and the system of actions on solving the suggested task is highlighted.

After all the exercise tasks are solved correctly, the student is opened a unit that will help to learn solving tasks that are close to professional ones (similar to professional ones) with the help of physical knowledge. Methods of teaching the solution of tasks with the help of the given module consisted of 3 stages: I – preparatory stage. At this stage students solve specific professional tasks with the help of physical knowledge, individual methods of solving these tasks are developed; II – the stage of identification of the generalized method of solving professional tasks, when special work on the acquisition of these tasks is performed; III – the stage of independent solving of individual professional tasks with the application of the generalized method of solving tasks.

Preparatory stage. At the given stage the teacher creates motivation for performing the given type of activity and conducts instruction on working with the website. The most efficient means of communication in this case is online conference. For this the equipment includes videoconferencing systems that provide real-time interactive connection between distant students and teachers. The equipment also includes cameras, microphones, additional PC cards that input images from the camera and sound from the microphones. Such type of connection represents "natural" communication and helps remote students and teachers to discuss the course of solving tasks.

After the virtual groups are formed, the teacher starts the discussion with asking students the following question: "Why does the future engineer need physical knowledge?" Participants of the discussion share their opinions, which don't need to be assessed. As a rule, opinions are divided into 2 categories: one group thinks that an engineer needs this knowledge in his professional activity, the second group disagrees. Then, the teacher formulates several professional tasks of different types. The tasks may be of the following kind:

1. Does the vehicle speed before the accident correspond to the one indicated on the traffic sign that regulates the traffic condition.

2. Develop safe transportation of hydrogen at 20^0C in cylinders with a five-fold safety factor, if it is known that when transporting carbon dioxide in the same cylinder, it exploded at 350^0C.
3. Keep the concentration of oil products constant in the wastewater of the roadside zone, if it is known that their content in the exhaust gases deposited on the highway contains 2.3 g/l.

The given tasks may be presented to the students in the form of Microsoft Office PowerPoint presentations. The students are offered to solve tasks basing on physical knowledge. The students come across some difficulties and find the necessity to learn to solve professional tasks. The teacher offers to choose the tasks that can be solved with the help of the knowledge from the studied topic. The given step in teaching students' methods of solving professional tasks is conditioned by the necessity of understanding the types (type) of tasks. Afterwards, the teacher recommends the students to address the corresponding page of the website where the students are presented specific professional tasks.

Organizing a joint discussion of the solution of the first tasks, the teacher and the participants of the virtual group fill out the next page of the website, where it is necessary to record the actions for solving the given task in the specially designated fields. The students fill in the data and click "Send". Since the data transfer speed is high, the filling protocols are quickly transferred to the university's server, where the control over the correct execution of actions and the sequence of their implementation is carried out. The results of step-by-step control allow quickly correcting the students' activity with the help of videoconferencing. The comments on the performed work may be given confidentially via ISQ for example if the videoconference participant doesn't wish to have an open discussion.

Further, the students are offered to solve the following tasks, also emphasizing actions for solving them and sending them for similar control. The results of solution of specific professional tasks, presented in the form of a system of actions, are sent to the students' emails. As a result, each student accumulates a method for solving 10-15 tasks of the same type. In the case of integration of distance learning technologies into the intramural training of future engineers, students can accumulate methods for solving specific problems of several types recorded in notebooks.

The stage of the generalized method of solving individual professional tasks. After the students have accumulated methods for solving specific professional tasks in various topics, a special lesson is organized where students identify the general logical scheme of activities for solving tasks of a certain type. Such a lesson is recommended to be conducted under the guidance of a teacher. There is no doubt, that it is cost-effective to organize this lesson in a group. However, as the results of the training experiment show, the students approach this stage at the same time, in terms significantly different from each other. Therefore, the lesson is held individually, also using possible means of communication.

Initially, the students are advised to prepare in advance actions to solve specific tasks in previously studied topics and compare them. To help students, a page of the site is offered, where the table contains actions to solve two arbitrary problems. The students will definitely notice that the actions are identical. As a result, together with the teacher, a generalized method for solving a professional task is revealed.

Next, the screen shows a system of actions in a random movement, which needs to be restored in the right order. Then the students say the actions of the generalized solution method out loud (if audio or video means of communication are used) or write them down. The stage of independent solution of individual professional tasks using the generalized solution method. The purpose of this stage is independent solving professional tasks by students based on the content of the generalized method of their solution. This stage must also be carried out based on the material of one of the topics that contains knowledge necessary for solving individual professional tasks. Software of the website is developed in such a way that it independently “acts” as a teacher, his role being in providing students with specific professional tasks of the given type and establishing terms of carrying out the stage of independent solution of individual professional tasks using the generalized solution method.

Due to the fact that the content of the generalized solution method is learned by the students, they record only the results of their actions in specially designated fields of the website. Protocols of solving tasks of the specified type with the help of physical knowledge made it possible to ascertain the fact that tasks are completed by the students successfully and correctly, while the actions of the generalized method for solving tasks are accurately. The reason for this is that initially the elements of physical knowledge were learned by the students during recognition activities, and the actions of solution methods also became the subject of special assimilation.

Participants.

Pedagogic experiment on the introduction of the developed model was carried out between 2009 and 2019. It included 1100 students of engineering majors of intramural, extramural-individual, distant forms of education with the participation of 20 physics teachers from the universities of Astrakhan (Astrakhan state technical university, Astrakhan civil engineering institution), Tomsk (Ogarev Mordovia state university, Ruzayevka machine engineering institute, branch of Samara State Transport University), Ashgabat (Turkmen agricultural university after S.A. Niyazov), Almaty (Satbayev University).

Data collection and analysis.

To obtain an objective assessment, we considered it appropriate to apply such a research method as the expert assessment method. One of the important conditions for the application of this method is a careful selection of experts who are well aware of the evaluated area, the studied object and are capable of objective, unbiased assessment.

A variation of the method of expert assessments is the method of generalization of independent characteristics, in which competent experts give independent assessments of the observed pedagogical phenomenon or object, and the generalization consists in a detailed analysis and synthesis of the obtained data and the exclusion of random and contradictory one [7]. The given method was implemented in several stages:

Stage I – Identifying the goal of the experiment. Establish whether the developed methods can be considered efficient, that possesses a definite set of properties and satisfies the specified requirements; whether creation of these methods is efficient and positively affects the process of training future engineers to professional activity.

Stage II – Documents preparation. Information educational sources; competence and technical requirements of the website; protocols of the website operation; работы сайта; project program of distant education in physics of technical university students; comparative analysis of ascertaining and controlling experiment and others.

Stage III – Experts' selection. The expert group included experienced teachers, researchers, practicing educators, including university staff, psychologists, programmers, web designers. When forming the expert group, the following points were taken into account: work experience, presence of a scientific degree or rank, extent of awareness on the given issue.

Stage IV – Preparing questionnaires that include information on the expert (full name, education, job title, work experience) and a list of questions divided on topics (Attachment 10). Before the experts started their assessment, we conducted work on detailing a number of questions from the questionnaire and on the methods of assessment. Experts were offered to place statements that characterize the parameters of the methods of distant education in physics according to their significance.

Stage V – Of the expertise involved processing the obtained results with the method of defining the concurrence of expert assessments that enable to develop proper judgment. For this, a hypothesis (assertion) was formulated: if the opinions of experts are coordinated (the consent coefficient tends to **1**), then the developed methods can be considered high-quality, and their application for organizing the training of future engineers at a university is effective.

Estimation of accordance of the experts' opinions was carried out by calculating the quantitative measure that characterizes the degree of closeness of individual opinions. While ranking objects as a measure of accordance of the expert opinions concordance dispersion coefficient is applied (agreement coefficient). To calculate it, it is necessary to compose a ranking matrix of *m* objects by *d* experts$\|r_{is}\|$ $(S = \overline{1,d};\, i = \overline{1,m})$, where r_{is} is on object rank assigned by S expert. Then we define the rank sum:

$$r_i = \sum_{S=1}^{d} r_{is} \qquad (1)$$

Assuming that r_i s a random variable, then the variance is estimated:

$$D = \frac{1}{m-1}\sum_{i=1}^{m}(r_i - \bar{r})^2, \qquad (2)$$

$\bar{r}$- is a mathematical expectation, defined by the formula (3)

$$\bar{r} = \frac{1}{m}\sum_{i=1}^{m} r_i \qquad (3)$$

Labeling the coefficient of concordance (coefficient of agreement) W, it is calculated by the formula (4):

$$W = \frac{12 \cdot S}{d^2(m^2-m)} - d \cdot \sum_{S=1}^{d} T_s \qquad (4)$$

where T_s is an indicator of connected ranks, i.e. a cluster of consecutive identical expert ratings:

$$T_s = \sum_{k=1}(h_k^3 - h_k)$$

h_k – s the number of equal ranks in the в k-th group of related ranks when ranking by the sм expert.

Using these approaches, we calculated the coefficient of consistency of expert evaluation using the Internet service Copyright © Semestr.RU.

Stage 1. Gathering the expert commission. Number of factors n = 20, Number of experts m = 5

Stage 2. Accumulating specialists' opinions by means of questionnaire-based survey. The experts assess the degree of significance of the parameters by assigning them a rank number. Factor with the highest degree is assigned rank 1. If the expert finds several factors equivalent, they are assigned similar rank number. Integrated rank matrix is composed based on the questionnaire survey data.

Stage 3. Because the matrix includes connected ranks (similar rank number) in the assessments of the 1st expert, we will reorganize them. Reorganizing ranks is performed without changing the expert opinion, i.e. corresponding ratio should be preserved between the ranking numbers (greater, less than or equal). It is also not recommended to put a rank above 1 and below the value equal to the number of parameters (in this case, n = 20). Reorganization of ranks is made in tables 1-3.

Based on reorganization of ranks, a new ranking matrix is composed, where

¡Error!

Testing the correctness of matrix composing based on the calculation of the control sum:

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The matrix column sums are equal to each other and the control sum, which means that the matrix is composed correctly.

Stage 4. Analysis of significance of the studied factors. Factors according to significance were distributed as follows:

Stage 5. Assessment of the average degree of concurrence of all experts. We use the concordance coefficient for the case when there are connected ranks (similar ranks values in assessments of one expert): $_1 = [(2^3\text{-}2) + (2^3\text{-}2)]/12 = 1$; $T_2 = [(2^3\text{-}2) + (2^3\text{-}2)]/12 = 1$; $T_3 = [(2^3\text{-}2) + (2^3\text{-}2) + (2^3\text{-}2)]/12 = 1.5$; $T_4 = [(2^3\text{-}2)]/12 = 0.5$; $T_5 = [(2^3\text{-}2) + (2^3\text{-}2)]/12 = 1$.

$\sum T_i = 1 + 1 + 1.5 + 0.5 + 1 = 5$

¡Error!

W = 0.94 shows a high degree of concurrence of expert opinions.

Stage 6. Assessment of the significance of concordance coefficient.

For this purpose, we calculate Pearson Fitting Criterion:

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We compare the calculated χ^2 with the table value for the number of degrees of freedom K = n-1 = 20-1 = 19 and at the specified level of significance α = 0.05

Since the calculated χ2 89.74> tabular (30.14353), that is why the results obtained make sense and can be used in further studies.

Stage 7. Preparation of the expert committee decision. The calculated value of concordance coefficient close to **1**, calculated χ2 89.74> tabular (30.14353), then W = 0.94 is not a random value; the experts' opinions are coordinated, which confirms the hypothesis of the given research. That means that the developed methods of distant education in physics of technical university students are considered efficient.

Findings.

The obtained data allows drawing out the following findings:

1. Most students studying both intramurally with the application of the website developed by us, as well as distantly, successfully complete tasks on recognizing specific situations that correspond to elements of physical knowledge, relying on the content of knowledge. This means that physical knowledge is formed among the students in the form of actions that are part of the generalized methods for solving professional tasks, in particular in the form of recognition activities.

2. Most students – future engineers acquired the generalized methods and can independently apply them for solving individual professional tasks relying on physical knowledge.

The formulated findings allow ascertaining that the developed methods of distant education may be considered efficient, while using the website on physics without a doubt gives positive educating effect.

The following topics may act as the prospects of future study:

1) Developing technique for the formation of generalized methods for students to solve traditional physics tasks using distance learning technologies.

2) Creating methods for teaching students of technical universities to perform a laboratory experiment of remote access based on the ideas of the theory of activity.

3) Developing laboratory remote access that reflects future professional activity of a student.

4) Identification of methodological foundations for the use of multimedia technologies for the acquisition of basic concepts of the course of general physics by students of technical universities.

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