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Student's electronic portfolio as a tool for creating project teams

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***Abstract* — the purpose of the research work was to develop a methodology for the formation of project groups. The analysis of the features of the implementation of projects at the multidisciplinary technical university has been carried out. The criteria for the selection of applicants to participate in project teams have been formulated. A mathematical model for assessing the characteristics and personal achievements of the student according to these criteria has been built. The research of decision-making models on the inclusion of the applicant in the project team has been conducted. On the basis of the models obtained, a hierarchical structure of the electronic portfolio has been proposed, which allows automating the process of forming project groups. A software prototype of an electronic portfolio has been developed with the information stored in it in the form of an intelligence card. The proposed approach to estimating a student for making a decision by joining a project team can be used for various purposes - for awarding scholarships, presenting to employers, planning each individual trajectory of development.**

Keywords — e-portfolio, project-based learning, team formation, competency assessment, software prototype.

I. INTRODUCTION

The intensive development of post-industrial society has significantly changed the requirements for the graduate. The most valuable qualities are the level of education, excellence and qualifications, readiness to obtain new knowledge and learning skills, a desire for results, the ability to bring the work started to the end, a creative attitude to the tasks. It has led to the introduction of project-based learning technologies into the educational process [1, 2]. As a part of the implementation of the strategic project “Transformation of Voronezh State Technical University (VSTU)”, a roadmap for the modernization of educational activities for 2017-2019 has been prepared, providing for the use of the project approach in the implementation of educational programs of our university.

Project-based learning is a system of training, which involves the implementing a series of projects performed by students. This model of organizing the educational process is focused on the development of intellectual, physical, creative abilities of the individual in the process of performing a certain sequence of projects. It is designed to instill and consolidate the skills of conducting research and own innovative developments.

The use of project activities in the educational process necessitates the formation of students' general cultural and professional competencies. Project work allows forming systematic way of thinking (as opposed to fragmentary) [3], it develops communication skills [4], contributes to gaining analytical and research experience [2,5], enhances students' self-organization [6].

However, the desired result can not always be achieved. The reasons for ineffective project activities are poor organization of teamwork, incorrect setting of goals and objectives, the lack of clear criteria for evaluating project results and the contribution of each project participant [7,8]. Especially important is the formation of project teams for the implementation of interdisciplinary projects. Their implementation requires the involvement of students of various specialties. In this connection there is a great need for new methods and technological approaches to create project teams.

In connection with the foregoing, the purpose of this research work is to develop a method for forming project teams based on the construction of a hierarchical system for evaluating the personal achievements of applicants. In the course of the study, the organization of project activities — the formation of a team, structuring the tasks for the formalization of assessment criteria — was investigated in detail, and a mathematical model was adopted for making decisions on the selection of project participants.

II. STATEMENT OF PROBLEM

According to the Project Management Institute standard, a project is a temporary enterprise aimed at creating unique products, services, or results. Each project is limited in time, has

clear criteria for results and involves the implementation of a separate group of people specifically dedicated to this event.

In accordance with the professional and practical orientation of our university, the projects can be divided into three types - practice-oriented, research and social.

- A practice-oriented project is a solution of an applied problem, which is based on evidence or obtained by empirical research, computational and laboratory experiments. A common type of our practice-oriented projects is service. It is initiated to solve specific tasks within the framework of organized events or current activities of VSTU and its structural divisions. The result of such project may be a reasonable design decision, model, business plan or other custom-made product for both internal and external orders.
- A research project involves conducting research to obtain a new scientific knowledge. It requires well-thought-out goals, putting forward a hypothesis with its subsequent testing, thought-out research methods, experimental work, methods for processing results. Research projects allow students to deepen their knowledge of the disciplines they study during theoretical and practical classes, instill in them the skills of independent study of the material, and also train students in the selection, study and compilation of data, the ability to formulate their own theoretical ideas. The forms of organizing research projects depend, as a rule, on the goals and objectives of the study. The results of the study are made out in the form of an article, report, course work, final qualifying work, master's thesis.
- The social project includes a sequence of events and actions aimed at preventing, minimizing or resolving problems caused by deficiencies in socio-cultural integration, adaptation, rehabilitation, socialization, inculturation and self-realization of the individual.

All presented types of projects can be custom-made for both internal and external customers, implemented within the framework of strategic projects of the university, current activities of VSTU and its structural divisions, and presented at various events. Usually our projects are interdisciplinary. To implement them, a project team is required that includes students from different areas of training.

When initiating a new project in according to the rules established by VSTU, a project application is being prepared. It contains a description of the planned results and the content of the project work performed by the project participants, the terms and conditions of the project, as well as special requirements for the project participants. This information is the requirements for the project team. On the basis of the project application, the following project characteristics can be compiled (Table 1).

These general characteristics should be divided into partial criteria for specifying requirements for project participants by analyzing the objectives tree [9] or by other methods of system analysis [10]. So the profile of the project determines the list of specialties of the participants, which specifies the requirement - knowledge of definite disciplines. This approach allows you to create a set of criteria $C = (c_1, c_2 .. c_k)$ for determining the competence of a future project participant.

TABLE I. PROJECT CHARACTERISTICS

Title	Content	Requirements
direction of training (training profile)	list of required specialties (competencies)	mastering basic, professional disciplines
target	applied, research, social	initiative analytical experience interpersonal skills
level of difficulty	state order university development, training	experience of project work, ability to work in a team, general professional competence

Background information about applicants are usually the personal data provided by them. Thus, it is possible to operate with the values of its basic properties $X = (x_1, x_2, ... x_k)$. This set of characteristics of the applicant must be entered, stored and modified for each project, that is, it must be reusable.

At in universities, personal, socially significant achievements of students and academic success outside an educational institution are indicated in the portfolio [11]. Achievements are considered to be the results that the student has achieved in the period of study. These achievements can be confirmed by diplomas, certificates, reviews, commendations by the leaders organizing practices, abstracts from conferences and seminars, a copy of articles or links to publications with student articles, letters and other types of awards or prizes in various events. Therefore, we propose to use for obtaining initial data for solving the task of forming project groups - the student's electronic portfolio. E-portfolio is used for self-assessment of students [12], verification of learning goals [13], accreditation of educational programs [14] and a number of emerging practices [15] which gives good results, so this experience can be applied.

Thus, the task is posed from the set of applicants for participation in projects $V_1, V_2, V_3 \dots V_p$, which is described by a set of characteristic X values to select the best alternative for a given set of criteria C.

III. THEORETICAL PART

The procedure for solving the problem of multi-criteria evaluation includes several stages. First, it is possible to reduce the dimension of the attribute space by building a hierarchical system of composite criteria [16]. Next, the scales of all the composite criteria are consistently formed. The procedure of aggregation of indicators is consistent, i.e. the resulting groups of criteria are merged alternately into new groups of the next level of the hierarchy, and so on up to the single integral criterion of the highest level that will be used to rank the applicants.

A. *Formation of a set of baseline indicators and the determination of their scale of measurement*

Each applicant can be characterized by any achievements in the learning process, participation in the youth movement, in

projects or other events. As a rule, any achievement in a portfolio is a copy of a document or a link to a supporting document. Therefore, it is necessary to initially determine the characteristics and their possible estimated values.

It is the most simple and understandable way to characterize academic activities through the results of the final control of the studied disciplines. These data can be easily obtained from the information system of the university.

Other professional achievements, expressed by productive results - publication, patent, project, prototype are difficult to evaluate. In the process of creating a single product, several people can participate, each of them, fulfilling their role, makes a certain contribution and gains a unique experience. Publications can also vary journal impact-factor, the number of citations and so on. It already requires the description of this characteristic by a set of values.

Important components of all student activities are actions related to events: the organization of events and competitions, the demonstration of skills and achievements in competitions, workshops and other activities, the receipt of awards or prizes, participation in master classes and conferences. In assessing the activities of universities take into account [17, 18]:

- level of the event - within-university, regional, all-Russian;
- type of participation or awards - participant, winner, prize-holder;
- performance characteristics - individual, team.

Separately, one should take into account the participation of the student in the public life of the university, participation in sports, artistic and creative associations, student government, volunteer activities.

The analysis of the possible content of the portfolio allows us to highlight the characteristics of the following applicants.

- Event characteristics is the number of events for each category of the appropriate level and degree of participation, measured by a scale of integer values, from 0 to ∞.
- Assessment characteristics is the results of evaluation, for example, the mid-term control of knowledge in a discipline, expert assessment of personal qualities. They are measured in ordinal scale. Each measurement is actually orderly relative to the others and the scale is limited to the maximum value for each indicator $x_{\max i}$.
- Chronological characteristics determines the time interval for student participation in a youth movement or a creative team. They are measured on a continuous scale ranging from 0 to ∞.

B. Definition of composite criteria

To search for an effective composite criterion, we first consider the additive estimation [19]: $J(x) = \sum_{i=1}^{k} w_i x_i$, where w_i - the weighting factors determine the relative importance of the i-th characteristic in the overall assessment and the conditions $w_i > 0$ and the weight of the estimates $\sum_{i=1}^{k} w_i = 1$ are satisfied.

For the characteristics measured in the ordinal scale, rationing can be applied to the corresponding upper (maximum) values of the scales $x_{\max i}$ and the linear index is defined as:

$$J1(x) = \frac{1}{k}\sum_{i=1}^{k} w_i \cdot \frac{x_i}{x\max_i} \quad (1)$$

If there is no limit on the scale, for example, participation in conferences, then the calculation of the index from (1) leads to an overstating of the estimates and inadequate comparison with the characteristics measured on the ordinal scale. This problem can be solved by introducing artificial limitations - threshold:

$$J1(x) = \frac{1}{k}\sum_{i=1}^{k} \begin{cases} \frac{x_i}{p_i}, & if \ \frac{x_i}{p_i} < 1, \\ 1, & then \end{cases} \quad (2)$$

where $P = (p_1,...,p_k)^T$ - is the vector of threshold values corresponding to characteristics $X = (x_1,...,x_k)$.

The presented modification of the linear integral index (2) makes it possible to compensate for the values of indicators: a large excess of the value of one of the indicators can compensate for only a single value of the "failure" indicator and is equivalent to the introduction of threshold functions $U(x)$ and $J(x) = U(\sum_{i=1}^{k} p_i x_i)$.

The threshold function must be monotonous from 0 to ∞ and have a range of values ranging from 0 to 1 (asymptotically tends to 1). These requirements are satisfied by the sigmoid $U(x) = \frac{a+b}{1+e^{-x_i}}$ with coefficients *a=-1* and *b=2*, normalizing the range of values to the interval (0,1).

Application of this function in the integral index allows using any number of events in calculations without artificial limitations, since with a small number it quickly increases and then gradually grows. (Participation in 2-4 events of the same scale gives experience and a further increase in the number of events does not give linear growth and makes a smaller contribution than initial experience). Therefore, the integral index with logistic compensation:

$$J2(x) = -1 + \frac{2}{1 + e^{-\sum_{i=1}^{k} p_i \cdot x_i}}, \quad (3)$$

can be applied to characteristic values measured on an integer scale.

Consequently, the task of selecting the m-participants of the project according to the *k* characteristics is solved by drawing up a hierarchical system of integral indices $J1$ or $J2$ (determined by the type of the initial measurement), which variously aggregate the initial characteristics in accordance with a given criterion C .

C. Compiling an aggregation tree of indicators

The number, composition and content of the criteria for each level of the hierarchy are determined according to the goals and requirements of the project. But the overall solution of the task to form project groups is resulted in to building a hierarchical system of criteria in which various combinations of initial features (assessment tuples) are sequentially aggregated into smaller sets of new features until the final estimated value of the applicant's competence is obtained J . The hierarchical structure of the characteristics of the applicant for building the aggregation tree is shown in fig. 1.

The algorithm for calculating the integral index for a given criterion C is as follows:

- to formulate a set of initial indicators of categories *Academic, Scientific, Innovation* (list of necessary disciplines, practices, elective courses, and others in fig.1.);
- determine the vector of threshold values *P* for each category indicator;
- calculate the integral index of competence.

D. Constructing an Applicant's Choice Model

The candidate selection model, which makes it possible to assess his level of competence and, accordingly to, take the governing decision, is presente

d as an equation

$$y = \sum_{j=1}^{m} f_j(x)\theta_j + e, \quad (4)$$

e – unmeasured random interference that characterizes the effect of an unrecorded, uncontrolled factor, for example, the employment of the applicant at the time of the formation of the project team, and other. It is assumed that the interference has a normal distribution with independent samples, zero expectation and constant variance σ^2 .

$\theta_1, \ldots, \theta_m$ - a set (vector θ) of unknown parameters (coefficients) characterizing the actions of the controlled variables on the applicant's competence level y ;

$f_1(x), \ldots, f_m(x)$ - a set (vector $f(x)$) of the applicant's competence values from his set of characteristics. For example, if it is known that there is a quadratic dependence of the applicant's competence on a set of its characteristics, then the vector $f(x)$ has the form:

$$f(x) = \left\| 1, x_1, \ldots, x_k, x_1 x_2, \ldots, x_{k-1} x_k, x_1^2, \ldots, x_k^2 \right\|. \quad (5)$$

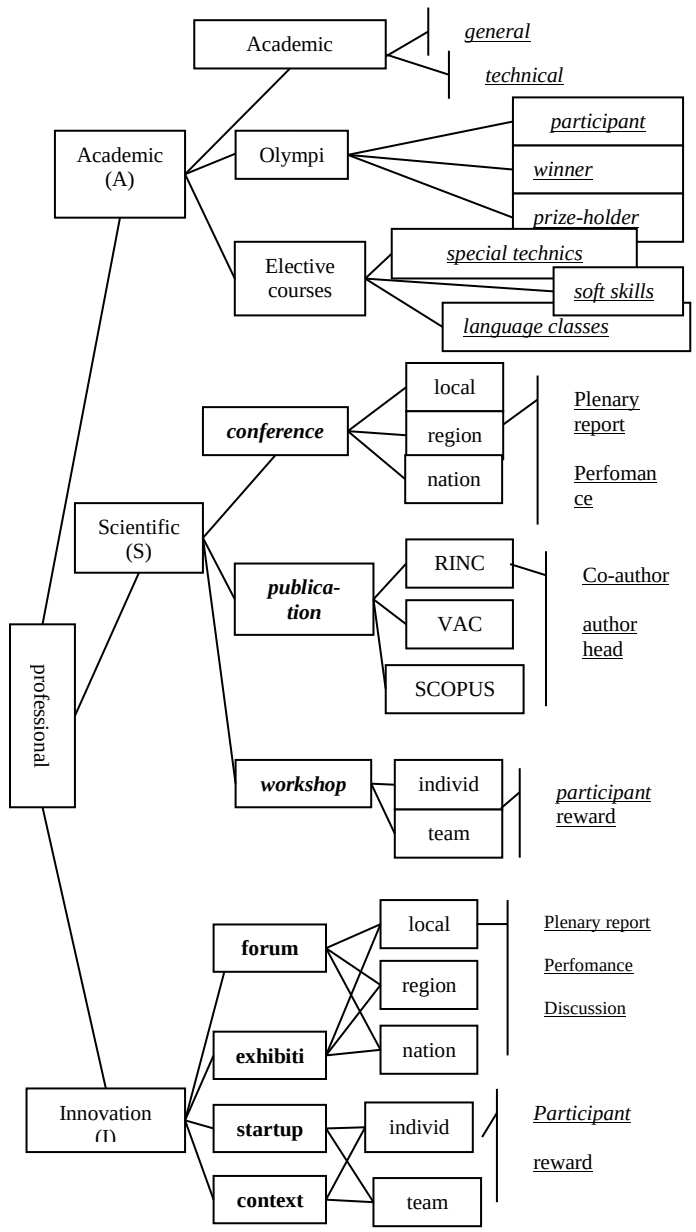

Fig. 1. Structure e-portfolio of student

Depending on the specific conditions, when deciding on the inclusion of an applicant in a project, optimization problems of two types may arise.

In type I models, it is assumed that when selecting an applicant for a project team, it is desirable to provide a lower limit of competence level values.

Model I with a guaranteed threshold

When using this model, a threshold value of the k_r the applicant's competence level is set, below which the value of the applicant's competence is undesirable. The model is formed as a task: $\lambda \xrightarrow[x \in S_P]{} \min,$ where $S_p : x_j^- \le x_j \le x_j^+$, $j = \overline{1,k}$, $P(y \le k_r) \le \lambda$.

The following notation is adopted: k_r - preset threshold; $P(y \le k_r)$ - probability at which the value of the applicant's competence is below the threshold k_r.

Model I with a minimum threshold and guaranteed probability

The mathematical model of the specified task is formulated as $k \xrightarrow[x \in S_k]{} \min$, where $S_k : x \in X$, $P(y \le k) \le \lambda_r$, λ_r - given (guaranteed) probability (rather small).

Model I with a guaranteed dispersion

When using this model, the guaranteed variance of the applicant's competence is established in the form of a value of d_r, selected from a priori considerations of the level of competence according to the project. It is expedient to apply the model in assessing the competence of an applicant in one profile of specialties. The model is formed as a task: $y(\lambda) \xrightarrow[x \in S_\lambda]{} \min,$ where $S_\lambda : x \in X$ and $d(x) \le d_r$.

In type II models, it is assumed that when selecting an applicant, it is desirable to provide an upper limit of competence level values.

Model II with a guaranteed threshold

If the applicant's competence values are below a certain upper limit of competence level, which is undesirable, for a project that minimizes the likelihood of this phenomenon, it is necessary to solve the problem: $\frac{k_r - \bar{y}(x)}{\sqrt{d(x)}} \xrightarrow[x \in X]{} \min$.

Model II with a minimum threshold and guaranteed probability

The model is similar to the previous one, but in this case it is desirable to maximize the applicant's level of competence and it is necessary that the probability of the values of competence is no more than specified λ_r, that is, the condition must be met: $P[y(x) \le k] \le \lambda,$ where k – is the maximizing threshold, λ_r – is the given probability.

To find the optimal level of competence of the applicant, it is necessary to solve the conditionally extremal problem: $\bar{y}(x) - g(\lambda_r)\sqrt{d(x)} \xrightarrow[x \in X]{} \max,$ where $g(\lambda_r)$ - is a positive table value.

Model II with guaranteed dispersion

In this case, it is necessary to maximize the level of competence of the applicant on average and to ensure acceptable (not more than a specified value d_r) variance, that is, a valid variation relative to the average.

The optimal level of competence of the applicant is defined as the solution of the conditionally extremal problem: $\bar{y}(x) \xrightarrow[x \in S_d]{} \max,$ where $S_d : x_i^- \le x_i \le x_i^+;_r$ $i = \overline{1,k}; d(x) \le d_r$. The choice of model is determined by the terms and conditions of the project.

IV. Practical Significance

The proposed model for assessing the competence of applicants is incorporated in the prototype of the electronic portfolio module in the information and educational environment of our university. Its design took into account the diversity of data types (event, assessment and chronological characteristics) and their various levels.

The concept of a portfolio consists not only of the demonstration of personal achievements, but also in assessing and planning the academic and professional growth of a student. Therefore, it must be constructed in the form of an intelligence card [20].

We have proposed a hierarchical structure of the formation of the portfolio. Student achievements are divided into three categories - professional, personal, psychological. They turn are divided into a number of subsections, each of which includes a specific set of characteristics - the status of the event (within-university, regional, all-Russian, international), the degree of participation (performance, winner, prize-holder). The subdivisions “Disciplines studied” and “Optional courses” include the name of the course, the number of credits, and the final grade obtained.

The student independently creates a portfolio by adding a new event to the appropriate subsection [21]. The hierarchical portfolio formation makes it possible to establish any criteria and rules for obtaining estimates for various categories and subsections in them, which can be used for various purposes.

When designing a software prototype, an object-oriented approach was used. Due to the fact that the portfolio structuring information about personal achievements has a hierarchical organization, the “Composite” design pattern was used, which allows grouping many objects into a tree structure and then working with it as if it were a single object. Figure 2 shows the layout of the objects in the structure of the student's personal achievements map (table). Each object corresponds to the end point of the map (sheet) or a directory (folder) containing them.

Such an application architecture provides an opportunity to expand the list of both types of activities, as well as activities and works, which makes it easy to make changes the map structure during its use.

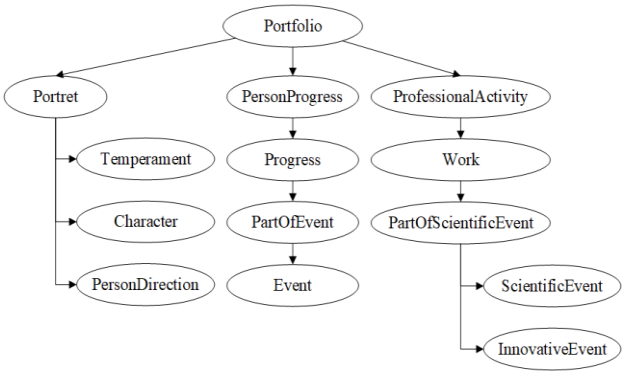

Fig. 2. Portfolio Layout

According to the results of the design, a prototype of a Java program with a Swing graphical interface has been developed that allows you to display a psychological portrait of a student, his personal achievements and professional achievements in the form of an intelligence card. Figure 3 shows the working window of the developed program. Each achievement is displayed as an icon in the corresponding section, which facilitates the extraction and evaluation of personal achievements.

Fig. 3. Interface of the program, which stores intellect cards of student's achievements

In our opinion, a big problem is that the support of E-portfolio systems is linked to an educational institution. In view of student mobility and the concept of continuing education, the portfolio should be stored in the personal space of the individual with an open interface for access by interested persons and organization. Our proposed model for organizing data and analyzing will allow us to create a unified personal information management system (digital trace of individual achievements).

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