Dual Education as a Bridge Between Theoretical and Practical Knowledge

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Abstract. It is proposed own algorithm for implementing a complex project in the training of aviation industry experts. The project takes into account the competence approach and allows to optimize the costs of the partner companies involved in the project from the production area.

Keywords: higher education institution, dual education, competence, specialist training.

1 Introduction

The development of the information society places new demands on professionals. The authority of any state in the world dimension is determined by the level of education and professional level of residents. Leading, high-ranking countries in the world have recognized the need to combine learning with practical skills, calling this approach as dual education. The concept of dual education (from the Latin dualis - dual) was introduced in the mid-1960s in Germany as a new, more flexible form of professional training. According to German experts, the duality implies the interaction of the educational and industrial sphere with the training of qualified staff of a certain profile.

The main task of introducing a dual form of organization of the educational process in Ukrainian higher education institutions is to eliminate the existing contradictions, to overcome the gap between theory and practice, to establish cooperation between educational institutions and employers in such a way as to improve the quality of training of skilled personnel taking into account production needs.

1.1 State of the Research Issue

Minggang Xu notes that dual education has become widespread in Germany and is a form of vocational education based on a combination of practice and theory in student

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learning [1]. The author compares German approaches to dual education and traditional Chinese vocational school education with an example of the Nanjing Technical College and notes the advantages of this approach.

S. Kh. Muhambetaliev and A. Kh. Kasymova point out that the dual education system in Germany has a long history and presents its benefits [2]. The authors emphasize the need to introduce such approaches in Kazakhstan and identify the tasks that need to be solved for the development of a dual education system in their homeland, in particular establishing the interaction between educational institutions and enterprises.

Some foreign researchers [3-7] also emphasize the benefits of dual education, focusing that this approach allows the development of a curriculum that facilitates students' acquisition of qualifications that they can practically apply in their work [8-20].

However, a model of the dual education system has not been developed yet.

2 Bridge between Higher Education Institution and Manufacture

The increasing speed of scientific and technological progress has led to the emergence of a new Industry 4.0, where information technology and specialist knowledge play a major role. Competition has increased on the markets for high-tech products. This led to the need to use innovation to create new products with the rapid implementation of achievements in development and production.

The education area with a traditional cycle of specialist training during four or more years is inertial and does not have time to respond to the employers' requests who, in order to ensure their competitiveness, are engaged in the search and formation of innovative projects that require specialists with new competencies. In this regard, the dual form of education, which is aimed at changing the traditional form by using modern tools with active interaction with an employer in the learning process, allows to create new competencies by changing the existing educational process of higher education institutions (HEI). First, this applies to senior, graduate courses, when the professional competencies of future specialists are formed. Considering the requirements of the employer, these competencies should be expanded and adapted to the requirements of new orders of the employer for a fairly short period of time, without breaking the education cycle of HEI. Thus, the dual form of education is a kind of "bridge" between the traditional form of training of HEI and real practice that appear in connection with new innovative orders of the employer.

Fig. 1 shows the interaction scheme of higher education institution and manufacture using a dual form of education.

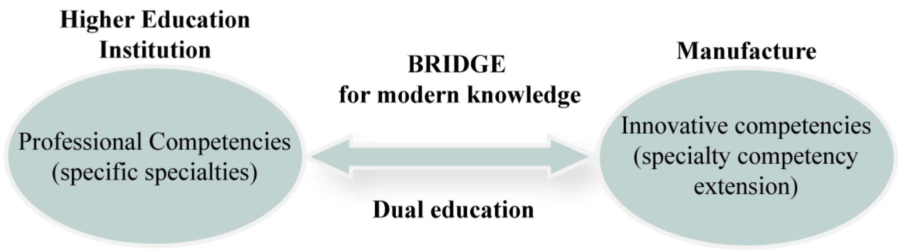

Fig. 1. The interaction of higher education institution and manufacture in the training of specialists using dual education

3 Dual Education

The dual form of education is aimed at career guidance within the HEI for senior students due to the requirements of current and future project portfolios of manufactures that produce high-tech products. There are various means and tools for the implementation of dual training (distance learning, a virtual form of training, working practices, master classes with the participation of employees of enterprises, etc.). All of them are aimed at the formation of competencies that correspond to the content of the requirements of the employer's project portfolio. Therefore, the topic of the proposed report is relevant, which examines the problem of forming the graduates' competencies of HEI in accordance with the requirements of employers.

The problem statement says that it is necessary, through the implementation of measures within the dual education, to form a set of competencies for graduates of HEI that meets the requirements of the employer as much as possible.

The set of competencies K_1 is available, which a senior student will receive studying at the HEI. Using the methods and tools of dual education, it is necessary to form a set of competencies K_2 for the graduate of the HEI that meets the requirements of the employer's project portfolio. The set of competencies K_1 is a set $K_1 = \{K_{11}, K_{12}, ..., K_{1n}\}$, where each competency K_{1i} has a value associated with a specific level of knowledge of j student of HEI.

Therefore, given the level of acquired knowledge for a particular j student, it is possible to present their set of professional competencies in the form as $K_{1j} = \{K_{11j}, K_{12j}, ..., K_{1nj}\}$. Taking into account the individuality of each j student and using the tools of dual education, it is essential to bring the j student's knowledge to such a level that they correspond to the competences required for the implementation of the employer's project $K_2 = \{K_{21}, K_{22}, ..., K_{1m}\}$.

In this case, the number of competencies K_1 and K_2 (n and m) may not necessarily coincide. So, in the process of dual training, it is necessary to remove the difference between K_1 and K_2 competencies by conducting activities and using tools related to dual education.

4 Steps of Solving the Problem

The solution of this problem can be accomplished in several stages:

1. Presentation of the employer's requirements in the form of a set of professional competencies with the selection of the most significant ones.
2. Conducting dual training, which results in the selection of multiple students that meet the employer's requirements.
3. Optimization of costs for the implementation of dual training activities.

To complete the first stage, we will use the expert assessments of the employer's representatives, which are associated with the ongoing or being formed a new project portfolio. Experts, based on the requirements of the employer, offer many competencies K_2 that are necessary for graduates of HEI. Further, it is required to evaluate the significance of individual competencies from the K_2 set and assess their impact on the general competence of future employer projects executives. In this case, it can be used a simple ball scale (1 ... 10). To assess the importance of individual competencies, and their impact on overall competence, a full factorial experiment (FFE) can be used. In the FFE, the columns are selected corresponding to individual factors (competencies), and the assessment of competence is presented in the form of a "response" (the last column of the FFE plan). An illustrative example of assessing the importance of individual competencies is examined. The project of creation of an unmanned aerial vehicle (UAV) for the customer requires performers with the following set of competencies:

1. On-board control system (factor x_1).
2. Organization of communication with the ground control point (factor x_2).
3. Control of the UAV electric motor (factor x_3).

Since the number of factors is three, it is essential to conduct $N = 2^3 = 8$ tests to conduct experiments with three factors using FFE. The values of the last column, which corresponds to competency, are filled by experts with their estimates. PFE plan is presented in Table 1:

Table 1. Plan of a full factorial experiment.

№	x_1	x_2	x_3	x_1x_2	x_1x_3	x_2x_3	$x_1x_2x_3$	Q
1	-1	-1	-1	+1	+1	+1	-1	0
2	-1	-1	+1	+1	-1	-1	+1	3
3	-1	+1	-1	-1	+1	-1	+1	1
4	-1	+1	+1	-1	-1	+1	-1	5
5	+1	-1	-1	-1	-1	+1	+1	2

6	+1	-1	+1	-1	+1	-1	-1	9
7	+1	+1	-1	+1	-1	-1	-1	7
8	+1	+1	+1	+1	+1	+1	+1	10

Here, +1 corresponds to the considered competency, and -1 - not to this competency. Each line of the plan is a combination of competencies, which is involved in this experiment with its assessment by the experts of the "response" Q in the last column of the FFE. The final line of the plan takes into account all competencies, therefore, it will be evaluated the gained knowledge Q, $Q_n = 10$. According to the results of the FFE, the following semi-quadratic dependence can be obtained:

$$Q = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 + b_1 x_1 x_2 + b_{13} x_1 x_3 + b_{23} x_2 x_{30} + b_{123} x_1 x_2 x_3$$

In this dependence, the values of the coefficients b_1, b_2, b_3 correspond to the influence of individual factors (competencies) on the general competence Q, and $b_{12}, b_{13}, b_{23}, b_{123}$ correspond to the influence of factor combinations (competencies). The factor combination can be represented as a synergistic effect from the joint influence of competencies on overall competence Q. The calculation of the coefficients is carried out according to the simplest formulas:

$$b_i = \frac{\sum_{i=1}^{N} x_i Q_i}{N}, \quad b_{iK} = \frac{\sum_{i=1}^{N} x_i x_k Q_i}{N}, \quad b_{iKl} = \frac{\sum_{i=1}^{N} x_i x_k x_l Q_i}{N},$$

As an example (see Table 1), it is received:

$$b_0 = 4;\ b_1 = 2,37;\ b_2 = 1,13;\ b_3 = 2,13;\ b_{12} = 0,375;\ b_{13} = 0,375;$$

$$b_{23} = -0,375;\ b_{123} = -0,625;$$

$$Q = 4 + 2,37x_1 + 1,13x_2 + 2,13x_3 + 0,375x_1x_2 + 0,375x_1x_3$$
$$-0,375x_2x_3 - 0,625x_1x_2x_3$$

From the analysis of the obtained dependence it follows that the most significant factor (competency) affecting the overall competence associated with the implementation of the UAV project is x_1 (knowledge of the onboard control system).

In the second place there is the factor x_2 (knowledge of UAV engine control). A less important factor is the factor x_3 (knowledge of the UAV communications with the ground control point). The greatest synergic effect of the factor influence (competencies) on the overall competence of the project is associated with three factors x_1, x_3, x_2.

In order to expand the received competencies of students K_1 at the HEI so that they correspond to the number of competencies of the employer K_2, it is necessary to conduct dual training events with the possible use of an individual learning trajectory for each student at HEI. Activities can be combined in nature and include various learning tools. According to the results of individual training, each j student will receive a set of competencies that meets the requirements of the employer:

$$K_{2j} = \left\{ K_{21j}, K_{22j}, ..., K_{2mj} \right\},$$

where K_{2ij} corresponds to the level of knowledge for i competency required by the employer obtained as a result of dual training of j student.

The value of the knowledge level for each competency can be assessed using the conducted tests or expert assessments. If the experts use the qualitative presentation of the values of competency ratings in the form of letters of the Latin alphabet, then:

$$K_{2i} = \begin{cases} A \text{ - highest level of knowledge for } i \text{ competence,} \\ B \text{ - high level of knowledge for } i \text{ competence,} \\ C \text{ - good level of knowledge for } i \text{ competence,} \\ D \text{ - satisfactory level of knowledge for } i \text{ competence,} \\ E \text{ - poor student knowkedge for } i \text{ competence.} \end{cases}$$

So, the competency assessment of j student based on the results of dual training can be presented in the form of a "word", where the most important employer competency is in the first place, and the least important one is in the last place. For example, for three competencies, the competency of i student based on the results of dual training is:

$$B_i, A_i, C_i$$

For a set of students (groups) who participate in dual training, we get an unordered set of "words", for example:

$$\begin{gathered} B_1, A_1, C_1 \\ A_2, B_2, B_2 \\ B_3, C_3, A_3 \\ A_4, C_4, B_4 \\ A_5, D_5, B_5 \\ B_6, A_6, A_6 \\ A_7, C_7, C_7 \\ B_8, B_8, C_8 \end{gathered}$$

This set of "words" is ordered using the method of lexicographic ordering (as in a dictionary) to highlight the best students, in the sense of employer competency requirements. As a result, it is received:

$$A_2 B_2 B_2$$
$$A_4 C_4 B_4$$
$$A_7 C_7 C_7$$
$$A_5 D_5 B_5$$
$$B_6 A_6 A_6$$
$$B_1 A_1 C_1$$
$$B_8 B_8 C_8$$
$$B_3 C_3 A_3$$

This shows that the highest competency values that are associated with the requirements for the employer are obtained by the results of dual training and are present in the second student. The lowest level of knowledge is in the third student.

If the employer needs not one but several workers to complete the portfolio of projects, they can set threshold values for individual competencies and select from the group of students those who overcome the assigned thresholds. For example, the "control word" for testing students' competence looks like B, B, B. It is included the "word" $\boxed{B, B, B}$ in the ordered set of "words" of the student group. It is got:

$$A_2 B_2 B_2$$
$$A_4 B_4 B_4$$
$$A_7 C_7 C_7$$
$$A_5 D_5 B_5$$
$$B_6 A_6 A_6$$
$$B_1 A_1 C_1$$
$$\boxed{BBB}$$
$$B_8 B_8 C_8$$
$$B_3 C_3 A_3$$

As a result of regulating the "control word" $\boxed{B, B, B}$ in a group of students, it is possible to distinguish many executors of HEI graduates to fulfill the planned project portfolio of an employer:

$$A_2 B_2 B_2$$
$$A_4 C_4 B_4$$
$$A_7 C_7 C_7$$
$$A_5 D_5 B_5$$
$$B_6 A_6 A_6$$
$$B_1 A_1 C_1$$

They were the following students: 2, 4, 7, 5, 6, 1.

5 Optimization of the Expenses Associated with Conducting Dual Training

From the employer's point of view, the optimization of the expenses associated with conducting dual training is important. Since, an individual trajectory of student training and various tools of dual training are used to increase the effectiveness of dual education, the optimization problem is reduced to the combinatorial task of choosing the optimal tool for dual education, taking into account the characteristics of training for each student.

It is introduced an integer variable X_{xj_K} , that shows the choice of a dual education tool for each student, i.e. X_{xj_K} , if it is necessary to use K tool of dual education for formation of i competence for j student, and X_{xj_K} otherwise. To assess the funds spent on dual education, there are the following indicators:

1. Cost of dual education – W .
2. Time spent on dual education – T .
3. Risks associated with dual education – R .

Then, considering the introduced integer variable X_{xj_K} , the indicators W, T, R can be represented as follows:

$$W = \sum_{i=1}^{m} \sum_{ji=1}^{n_i} \sum_{jk=1}^{n_j} w_{ij_K} \cdot x_{ij_K} ,$$

$$T = \sum_{i=1}^{m} \sum_{ji=1}^{n_i} \sum_{jk=1}^{n_j} t_{ij_K} \cdot x_{ij_K} ,$$

$$R = \sum_{i=1}^{m} \sum_{ji=1}^{n_i} \sum_{jk=1}^{n_j} r_{ij_K} \cdot x_{ij_K} .$$

where W_{ij_K} – expenses, associated with obtaining i competence by j student choosing K dual education tool;

t_{ij_K} – time spent on conducting dual education to obtain i competence of j student choosing K dual education tool;

r_{ij_K} – risks associated with obtaining i competence j student choosing K dual education tool;

n_j – the number of possible dual education tools that can be used for teaching j student (individual personality characteristics are taken into account);

n_i – the number of missing competencies of i student;

m – the number of students in the dual education group.

The following statements of the problem of cost optimization associated with the implementation of dual education are next possible ones:

1. Optimization of individual (local) cost indicators.
2. Multicriteria cost optimization or a compromise solution.

It is considered in more details the problem of optimizing local indicators of the costs of dual education.

1.1. It is necessary to minimize the cost indicator W:

$$\min W, W = \sum_{i=1}^{m} \sum_{ji=1}^{n_i} \sum_{jk=1}^{n_j} w_{ij_K} \cdot x_{ij_K} \ ,$$

under the following restrictions:

$$T \le T^{'}, R \le R^{'},$$

where $T^{'}$ is possible time for dual education (set according to the requirements of the employer);

$R^{'}$ is acceptable risks associated with dual education.

1.2. It is necessary to minimize the time for dual education:

$$\min T, T = \sum_{i=1}^{m} \sum_{ji=1}^{n_i} \sum_{jk=1}^{n_j} t_{ij_K} \cdot x_{ij_K} \ ,$$

under the following restrictions:

$$W \le W^{'}, R \le R^{'},$$

where $W^{'}$ is acceptable costs of dual education (set by the employer).

1.3. It is necessary to minimize the risks for dual education:

$$\min R, R = \sum_{i=1}^{m} \sum_{ji=1}^{n_i} \sum_{jk=1}^{n_j} r_{ij_K} \cdot x_{ij_K}$$

under the following restrictions:

$$W \le W^{'}, T \le T^{'}.$$

2. To solve the multicriteria problem, it is introduced a complex criterion, which is a simple additive “convolution” of local indicators:

$$Q = \alpha_W \cdot \hat{W} + \alpha_T \cdot \hat{T} + \alpha_R \cdot \hat{R},$$

where $\alpha_W, \alpha_T, \alpha_R$ are weight coefficients, which are set by the representatives of the employer and show the importance of individual indicators. Meanwhile:

$$\alpha_W + \alpha_T + \alpha_R = 1$$

$\hat{W}$ is a standardized cost indicator (0…1)

$$\hat{W} = \frac{W - W^*}{W' - W^*}$$

$\hat{T}$ is a normalized indicator of time spent on dual education (0…1)

$$\hat{T} = \frac{T - T^*}{T' - T^*}$$

$\hat{R}$ is a normalized indicator of possible risks during dual education (0…1)

$$\hat{R} = \frac{R - R^*}{R' - R^*},$$

The values W^*, T^*, R^*, were obtained during optimization for individual indicators. To optimize the complex indicator Q, it is essential:

$$\min Q, Q = \alpha_w \frac{W - W^*}{W' - W^*} + \alpha_T \frac{T - T^*}{T' - T^*} + \alpha_R \frac{R - R^*}{R' - R^*} =$$

$$= \frac{\alpha_w}{W' - W^*} \sum_{i=1}^{m} \sum_{ji=1}^{n_i} \sum_{jk=1}^{n_j} w_{ijK} \cdot x_{ijK} + \frac{\alpha_T}{T' - T^*} \sum_{i=1}^{m} \sum_{ji=1}^{n_i} \sum_{jk=1}^{n_j} t_{ijk} \cdot x_{ijK} +$$

$$+ \frac{R_w}{R' - R^*} \sum_{i=1}^{m} \sum_{ji=1}^{n_i} \sum_{jk=1}^{n_j} r_{ijK} \cdot x_{ijK} - \frac{W^*}{W' - W^*} - \frac{T^*}{T' - T^*} - \frac{R^*}{R' - R^*}$$

fulfilling restrictions: $W \le W', T \le T', R \le R'$.

It is advisable to use the proposed approach in planning and implementation of activities related to dual education for the specialist training among students of HEI to the implement a new project portfolio of an employer.

Conclusions

Project work with implementation of a dual form of education is actively used in higher education institutions. Project implementation is based on different approaches. The authors of the paper suggest their own algorithm for accomplishing such complex project in the training of industry experts. The project takes a competent approach and optimizes the expenses of institutions involved in the project.

The results of the study indicate the urgent need to introduce a dual education system, as this approach will contribute to:

- establish cooperation between higher education institutions and business as social partners and create a legislative framework for attracting qualified production staff to teaching activities (mentors, teachers);
- allow to form the basis for improving the quality of higher education, encourage joint development of educational and professional programs that will contribute to improving the quality of educational services;
- consider the needs of IT companies when creating the information content of training courses.
- introduce an innovative approach to the organization of the educational process mastering basic theoretical knowledge on the basis of educational institution, and then gaining professional skills at an IT companies.

References

1. Minggang, Xu: Development of Dual Educational System of Germany in China: Advanced Technology in Teaching. Advances in Intelligent and Soft Computing book series, 163, 289-293.
2. Muhambetaliev, S. Kh., Kasymova, A. Kh.: The Introduction of Elements of Dual Education System: Experience, Problems, Prospects. Indian Journal of Science and Technology, 9(47),.DOI: 10.17485/ijst/2016/v9i47/99711 (2016).
3. Dual education: New knowledge for the new age, https://www.srbija.gov.rs/tekst/en/129780/dual-education.php.
4. Harasim, L.: Shift happens: Online education as a new paradigm in learning. The Internet and Higher Education 3(1), 41-61 (2000).
5. Berge, Z. L., Mrozowski, S.: Review of research in distance education, 1990 to 1999. American Journal of Distance Education 15(3), 5-19 (2001).
6. Zawacki-Richter, O.: Research areas in distance education: a Delphi study. International Review of Research in Open and Distance Learning 10(3) (2009).
7. Zawacki-Richter, O., Anderson, T.: Online distance education: Towards a research agenda. Edmonton, Canada: AU Press (2014).
8. Lozynska, O., Savchuk, V., Pasichnyk, V.: Individual sign translator component of tourist information system. Advances in Intelligent Systems and Computing 1080, 593-601 (2020).
9. Davydov, M.V., Nikolski, I.V., Pasichnyk, V.V.: Real-time Ukrainian sign language recognition system. In: international Conference on Intelligent Computing and Intelligent Systems, 1, 5658812, pp. 875-879. (2010)
10. Pasichnyk, V., Shestakevych, T.: The application of multivariate data analysis technology to support inclusive education. In: proceedings of the International Conference on Computer Sciences and Information Technologies, 7325439, pp. 88-90 (2015).
11. Kazarian, A., Kunanets, N., Pasichnyk, V., Veretennikova, N., Rzheuskyi, A, Leheza, A., Kunanets, O.: Complex information E-Science system architecture based on cloud computing model. In CEUR Workshop Proceedings, vol. 2362, 366-377 (2019).
12. Pasichnyk, V., Nazaruk, M., Kunanets, N., Veretennikova, N., Nebesnyi, R.: Information analysis of procedures for choosing a future specialty using cognitive cards. In: 13th International Scientific and Technical Conference on Computer Sciences and Information Technologies, vol. 2, 8526626, pp. 215-220 (2018).

13. Holoshchuk, R., Pasichnyk, V., Kunanets, N., Veretennikova, N.: Information modeling of dual education in the field of IT. Advances in Intelligent Systems and Computing 1080, pp. 637-646 (2020).
14. Odrekhivskyy M., Pasichnyk V., Rzheuskyi A., Andrunyk V., Nazaruk M., Kunanets O., Tabachyshyn D. Problems of the intelligent virtual learning environment development. In: CEUR Workshop Proceedings, vol. 2386, 359–369 (2019).
15. Rzheuskyi, A., Matsuik, H., Veretennikova, N., Vaskiv, R.: Selective dissemination of information – technology of information support of scientific research. Advances in Intelligent Systems and Computing (AISC) 871, 235–245 (2019).
16. Romanenkov, Y., Pasichnyk, V., Veretennikova, N., Nazaruk, M., Legeza, A.: Information and technological support for the processes of prognostic modeling of regional labor markets. In: CEUR Workshop Proceedings, vol. 2386, 23–34 (2019).
17. Bomba, A., Kunanets, N., Nazaruk, M.,Pasichnyk, V., Veretennikova, N.: Information technologies of modeling processes for preparation of professionals in smart cities. Advances in Intelligent Systems and Computing 754, 702-712 (2019).
18. Bomba, A., Nazaruk, M.V., Kunanets, N.E., Pasichnyk, V.V.: Constructing the diffusion-like model of bicomponent knowledge potential distribution. International Journal of Computing 16(2), 74-81 (2017).
19. Bushuyev, S.D., Bushuyev, D.A., Rogozina, V.B., Mikhieieva, O.V.: The convergence of knowledge in project management. In: proceedings of the 8th International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications, IDAACS (2015).
20. Piterska, V., Kolesnikov, O., Lukianov, D., Kolesnikova, K., Gogunskii, V., Olekh, T., Shakhov, A., Rudenko, S.: Development of the Markovian model for the life cycle of a project’s benefits. Eastern-European Journal of Enterprise Technologies 5(4(95), 30–39 (2018).