Methodological approach to the implementation of a "2+2+2" higher education model at a technical university

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Abstract. The paper provides a solution to the task of implementing a "2+2+2" model of higher education while providing the students with an opportunity to choose the direction of training starting from the third year of studies; reviews the process of developing Primary Educational Programs as a complex technical object through the application of a systematic approach; identifies the conditions and restrictions that allow avoiding the destruction of the systematic nature of education, and, therefore, the degradation of its quality; proposes the principles of applying individual educational paths for achieving the target of granting the students with an opportunity to obtain one or more qualifications.

Nowadays, Russian universities operate using a "4 + 2" educational system, which means four years for obtaining a bachelor's degree and two years for getting a master's one. At the same time, there are cases when students, studying in a bachelor's degree program, understand that the chosen specialty does not suit them, dramatically change their area of training within a master's program, and, in fact, get a second profession during it. Some do this many years after they have completed their bachelor's or specialist's studies.

During his address on January 15, 2020, the President of the Russian Federation, set the task to the Federal Assembly of the Russian Federation to provide the students, mastering the primary educational programs of higher education (hereinafter referred to as the Primary Educational Programs), with an opportunity of choosing the direction of training starting from the third year of studies [1].

In Russia, experts have started active development of a new model of higher education, which is called a "2+2+2" model. The new model of higher education assumes the following gradation of the educational process (refer to figure 1):

- During their first 2 years of studies, students will master general subjects included in the range of "general developmental" ones, expanding the horizons and suitable for all special-

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ties, such as: history, philosophy, legal science, health and safety training, disciplines of the physical training block, disciplines of the basic economic block, disciplines of the block of project activities, disciplines of the basic foreign language studying block, disciplines of mathematical, physical, natural science and engineering modules, and disciplines of the information technology module.

- The following 2 years will be dedicated to a deeper study of specialized subjects that will be directly related to the specialty, meaning that the choice of a specific profession will be made after completing the first 2 years of studies, during which students will be able to understand which specialty suits them and which subjects and areas of science are more interesting for them.
- Another 2 years of studies will be devoted to a master's program, where certified bachelors can further deepen and refine their knowledge and skills within the framework of an already mastered profession. It is also allowed to take a new direction, but this will require a certain "base", forming minimal required knowledge and understanding.

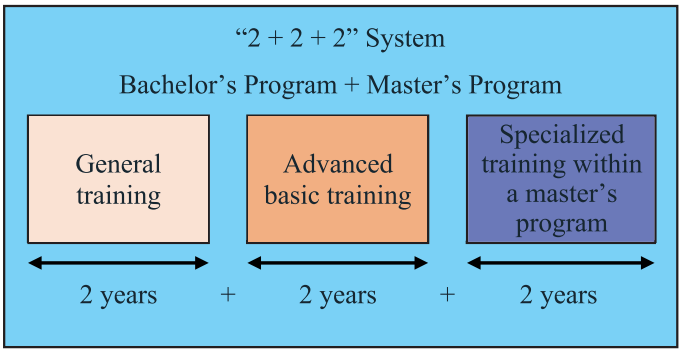

Figure 1. New system of higher education per "2 + 2 + 2" model

The "2 + 2 + 2" model is a more detailed version of the current education system, which is aimed at an accurate and effective outcome. Applicants will submit documents to a specific institute, which means that some of the basic subjects will have a certain "emphasis": economic, mathematical, humanitarian, technical. Then, while studying them, the student will be able to understand which of the areas/specialties is closer to him or her, which area of knowledge is more interesting, easier, etc.

It was the creation of the "2 + 2 + 2" model which was the background for introducing the new rules for admission into universities in Russia starting from 2021: applying to an institute (instead of a specific direction/specialty), enlarged competitive selection, a "postponement" of the selection of a specific profession (till the 2nd–3rd year of studies), etc.

At the same time, the following amendments were introduced into the Federal Law "On Education in the Russian Federation": "Primary educational programs may include competencies, which are attributed to one or more professions, specialties, and areas of training, taking into account the possibility for students to obtain several qualifications simultaneously". Therefore, the second task set for all Russian higher education institutions is to provide an opportunity for a student to obtain two or more qualifications [2].

In order to effectively implement the proposal of the President of the Russian Federation, it is first necessary to understand how the additional professional module will relate to the main part of the curriculum and be introduced into the educational process, taking into ac-

count all the restrictions governed by both the requirements of the education system and the requirements of the industry.

For this purpose, let us consider the Primary Educational Program development process as a complex technical object through the application of a systematic approach [3].

In this case, the designing of a complex technical object is usually viewed as a process of creation, transformation and presentation in an acceptable form, carried out for an object intended to perform a certain set of functions. Initially, the image of this object is expressed in the form of certain demands represented in terms of a set of its functional properties and characteristics, which must ultimately be transformed into a description of a technical object in terms of its structure, composition, dimensions, etc.

Let us apply this approach to the development of line Primary Educational Programs. The term "line" is used here in the sense of "widespread Primary Educational Programs, designed to support a significant number of jobs".

In this case, the designing process is carried out iteratively through sequences of stages, terminating with the creation of the next prototype of the design object with the generation of the corresponding intermediate definitions that summarize the solution of certain problems and are used to make the following design decisions.

While technical objects are handled in the design process (during formalization), various representations, reflecting their functional, structural, parametric, and constructive and graphic aspects, usually get tied to the development objects. In the course of designing, the following sequence of transformations is implemented:

$$F \Rightarrow S \Rightarrow P \Rightarrow G,$$

where F is functional presentation, S is structural presentation, P is parametric presentation (reflection of the appearance of the item being designed in the parametric space), and G is structural and graphical presentation.

As applicable to the Primary Educational Program development process, the domain F, functional presentation, contains the qualification characteristics of a graduate (competences); the domain S, structural presentation, includes elements of competence structuring, identification of their specific components, development of the competence formation flows; the domain P, parametric presentation, defines the Primary Educational Program support (methodological support, staffing, resources); and the domain G, structural and graphical presentation, is the development of schedules, curricula, work programs for disciplines (modules).

During the development of technical objects, the cycle of a single complete iteration of research activities consists of the following three main stages:

1. Identification of the demand for new functional qualities based on the efficiency analysis and identification of the deficient functions of the system fleet and elements currently available and being developed (development objects).

2. Generation of alternative tactical and technical ways to eliminate the deficit.

3. Synthesis of the structural and functional image of the alternative concepts in terms of their performance indicators within the framework of variable constraints.

The first stage consists in identifying the need for new functional properties of the designed object. Here, it is required to define the deficiency of the functional properties of the currently available "fleet" of Primary Educational Programs.

The second stage is associated with the generation of alternative technical options and tactical ways to eliminate the properties deficit identified at the first stage. This leads to

creating alternative concepts, i.e. a set of basic technical and tactical properties of the system, ensuring the achievement of the specified functions.

The third stage is dedicated to solving the problem of system synthesis, taking into account the existing constraints and the environment in which the development object will operate, applying the criteria of "efficiency vs. expenses vs. development time" type, and evaluating the dynamics of the system potential enhancement.

Based on one of the main provisions of systems analysis, which states that decisions should be made using the largest possible set of alternatives, this stage provides for the consideration of the greatest possible number of options for solving the original problem of eliminating the deficiency of properties through the creation of a new design object, update of the existing items for their better adaptation to the changed tasks and application conditions, and modification of the existing items and entire systems or the ones being developed for incorporating the desired functional qualities into them.

A morphological set of alternative solutions is formed for the main areas of functional properties deficiencies. The main life cycle stages and the resulting requirements, in particular, the ones to the system operation, material and technical support, standardization, as well as the possible development time and the necessary expenses are taken into account.

All the aforementioned aspects are also applicable when designing Primary Educational Programs.

When describing the algorithm for the development of "line" Primary Educational Programs, it is necessary to define the concept of program efficiency, since we are talking about the optimization of educational programs. Program efficiency will be interpreted as the achievement of the required qualification characteristics (competencies) within the time and cost constraints.

Within the framework of the outlined approach, the algorithm for developing "line" Primary Educational Programs consists of two stages.

Stage 1. External (conceptual) design.

The first stage, which is one of the product life cycle upper stages, is the external (conceptual) design, consisting of a sequence of steps as follows:

Step 1.1. Identifying the deficiency in staffing for the industry and the labor market.

The goal setting at this step provides for monitoring the needs of the industry and the labor market.

This step is when it is already possible to draw preliminary conclusions about the number of required jobs.

Step 1.2. Definition of job functions and activities at the workplace.

The goal setting at this step provides for selecting an area of training or specialty, within the framework of which a Primary Educational Program will be created or updated.

At this step, it is possible to determine the areas and spheres of professional activities, professional tasks and objects of professional activity of a graduate. It is also possible to carry out the initial "quality" optimization of the Primary Educational Program. If no suitable Primary Educational Program is available, a decision is made to develop a new direction (specialty), a federal state educational standard for higher education (hereinafter referred to as the Educational Standard).

Step 1.3. Formulation of the Primary Educational Program mastering outcomes—general professional and specialized competencies, determination of the Primary Educational Program scope and competence achievement indicators.

The goal setting at this step provides for defining the direction of the Primary Educational Program.

At this step, the final decision is made on the development of a new direction (specialty) or update of the existing Primary Educational Programs.

The main participants during the first stage process are members of the expert community of employers and university methodologists.

The main data sources are professional standards, profession data sheets, sectoral qualifications frameworks, regulatory documentation of industry excellence centers.

The main conclusion to be made at this design stage is what "consumption rate" the Primary Educational Program being developed is going to have. This shows whether it is necessary to open a new direction of training with significant admission control numbers or the problem can be solved by using individual learning paths of the graduates.

Stage 2. Primary Educational Program detailed design.

The second stage of the "line" Primary Educational Program development algorithm is associated with the preliminary and detailed designing of the product and consists of a sequence of steps as follows:

Step 2.1. Competence structuring—identification of the didactic units.

The goal setting at this step provides for defining educational technologies and making a decision on the curriculum structure.

The competence structuring process is a very important and time-consuming stage in the Primary Educational Program development. During it, it is first necessary to define a set of didactic units that contribute to the formation of the given competence and constitute its essential content. At the same time, we deliberately move away from the discussion and selection of disciplines, instead of which we talk about didactic units as a more stable category of the educational content. The discipline names vary according to the preferences and traditions of a particular university [4].

This step also includes finalizing the competence achievement indicators and determining the level of competence formation and the form of its certification. The levels of formation of didactic units, and, therefore, competencies, are defined in accordance with the levels of mastering the educational material (Bloom–Anderson's Taxonomy) [5].

Step 2.2. Identification of the projected learning outcomes (knowledge, skills, abilities).

The goal setting at this step provides for the optimization of the Primary Educational Program through the assessment of the achievability of the given competence formation level.

This step includes identifying the disciplines (modules) o be incorporated in the syllabus and the sequence of their mastering (discipline flows). It defines the required support for Primary Educational Program: methodological support, staffing, and material resources.

Step 2.3. Development of a calendar training schedule, curriculum, detailed programs of disciplines (modules), detailed practice programs, educational and methodological set, evaluation means bases.

The goal setting at this step provides for generating a completed Primary Educational Program.

Note that, in general, the process of Primary Educational Program detailed designing takes place within the university premises, but when determining the levels of competence formation, it is necessary to involve expert of the employers, since they can provide a more professional evaluation of this parameter, thus significantly influencing the effectiveness of the Primary Educational Program.

An evident trend in higher education today is the customization of training. As a consequence, it becomes necessary to form an individual? learning path (hereinafter referred to as ILP) with active involvement of the student. If we analyze most of the engineering Primary Educational Programs, developed based on the order of the industry and taking into account all the constraints of the educational system (financial, technical, etc.), we can conclude that

the potential for the implementation of student individual learning paths is quite limited. To expand it, it is proposed to review the approaches providing for deeper unification of Primary Educational Programs during junior years of studies.

Further on, let us define what the unified training during the first two years of studies means: whether it is some common training for all areas, or common training within the framework of an enlarged group of specialties and directions (hereinafter referred to as an Enlarged Group), or common training within a higher education institution.

Most Russian universities shall ensure the compliance of their educational process with the requirements of the Educational Standard. The Educational Standard defines the requirements for a university graduate in the form of a set of competencies: universal competencies (hereinafter referred to as UCs), which are common for all training directions/specialties, and general professional competencies (hereinafter referred to as GPCs), which vary depending on the training direction/specialty [6].

If we assume that unified training is common for all directions, then the first two years of studies in all universities should be composed of the disciplines, forming only the UCs; otherwise, the Educational Standard requirements will not be fulfilled. For technical universities, such an approach is not acceptable.

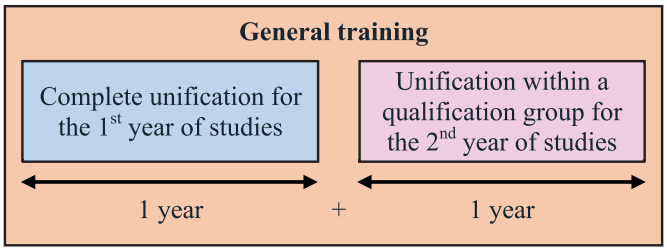

Figure 2. General training—2 years

The following approach is proposed for ensuring common training during the first two years of studies (refer to figure 2):

1) complete unification for the first year of studies;
2) unification within a qualification group for the second year of studies; for this, all the Enlarged Groups implemented at the university should be combined into groups depending on their qualification attribute. The following qualification groups are proposed:
   - **Group 1**—design and technological directions;
   - **Group 2**—design and systems engineering directions;
   - **Group 3**—physics and mathematics directions;
   - **Group 4**—information and communication directions;
   - **Group 5**—service and operational directions;
   - **Group 6**—economic and socio-humanitarian directions.

The complete unification for the first year of studies supports the following:

1. Image of the university—all university students, regardless of the direction they entered, study the same set of disciplines during their first year, except for one or two disciplines necessary to support the direction of training.
2. Student adaptation to the new environment.

3. Familiarization with the areas of professional activities—the "Core 2" module contains a discipline named "Introduction into professional activity", which provides for the participation of all the graduating departments of the relative directions, representing their training areas and profiles. Thus, a student has the opportunity to choose an enlarged group of directions/specialties during the 2nd semester of the 1st year of studies (refer to figure 3).

4. Mastering of the competencies at the level of "*Has an idea of...*" [5].

The unification of the 2nd year of studies within a qualification group supports the following:

- deliberate selection of the qualification group during the 2nd study semester;
- deliberate selection of the direction of training during the 3rd study semester;
- deliberate selection of the profile during the 4th study semester;
- basic part for the formation of generalized competencies of the qualification group;
- mastering of the competencies at the level of "*Ready to master...*" [5].

A student gets an opportunity to choose the direction/specialty of training during the 3rd semester of the 2nd year of studies, and the profile/specialization—during the 4th semester of the 2nd year of studies (refer to figure 3). The student performs it being assisted by a mentor from the graduating department, who is a specialist in the field of education, supporting students throughout their individual development paths [7].

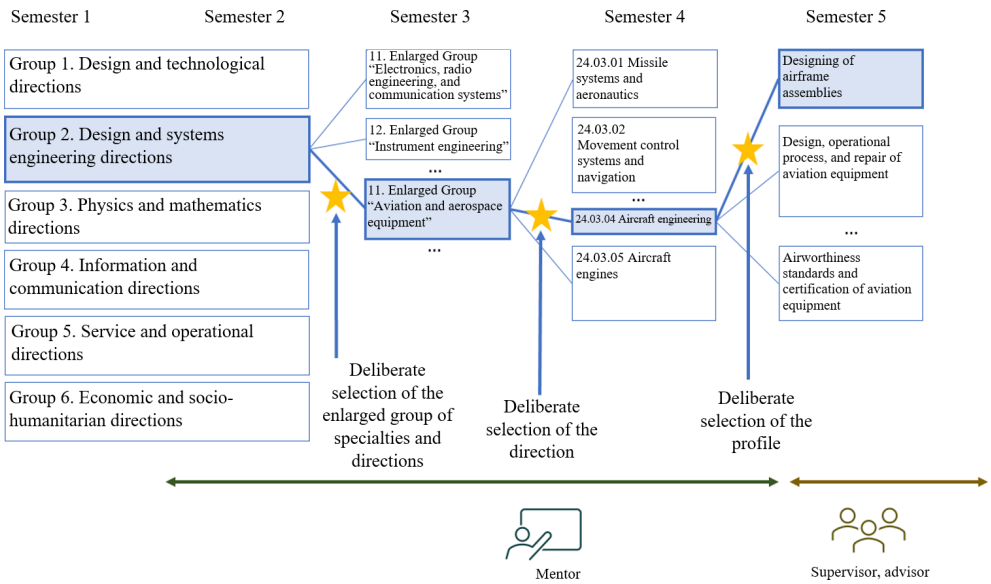

Figure 3. The selection of direction/specialty and profile/specialization

There are several directions within the framework of engineering specialties, and ILPs shall provide the opportunity to obtain a diploma in several qualifications. In Russia, graduates of higher education institutions will be able either to obtain several qualifications within a single engineering specialty or to change the directions of training. The universities will decide on their own, what specialties will be available for combined training. The demand for individual learning paths is growing every year, but such a transition requires profound

organizational and administrative transformation within the higher education institution. At the stage of applying to a university, such a concept as the "irreversibility of choice" of the selected profession for students is gradually disappearing. This means that if a student is currently admitted for the first year of studies within a certain direction of training, he or she finishes it, except for some individual cases when students move from one direction to another. Today, this irreversibility of choice is gradually disappearing and eroding, as the students can refine, readjust their learning process in accordance with their desires. The students select disciplines from a set of elective disciplines determined by the demands of the industry. The ILPs affect not only students. The faculty and teaching staff gain additional motivation to create high-quality training content, since now the learners themselves are entitled to decide, the lecture of which professor to attend.

The main potential of the ILP implementation is in the differentiation of the competence formation levels for different qualifications and directions. This provides "time", which can be used to master additional competencies or to deepen further the study of the main ones. The proposed algorithm for the ILP development, based on the needs of the industry, through the formation of competencies, didactic units, and learning outcomes makes it possible to implement the differentiation of the competence formation levels for different qualifications and training directions. Let us consider the stated differentiation using as an example the formation of the "Readiness to apply and develop working technical documentation and ensure its compliance with standards, technical requirements specifications, and other regulatory documents, as well as carry out the documentation of the completed design activities" competence, which is provided through a different set of disciplines with the different content amounts for various qualification groups. For example, for the group of design and technological directions, it is formed by the "Engineering and computer graphics", "Projective geometry", "Technical drawing", "Metrology and standardization", and "Quality systems" disciplines in the amount of 13 credit units, while for the group of design and systems engineering directions, it is formed by the "Engineering and computer graphics" and "Metrology and standardization" disciplines in the amount of 7 credit units. The "Engineering and computer graphics" discipline, which forms the aforementioned competence, has a greater scope for the group of design and technological directions than for the group of design and systems engineering directions. Thus, for the group of design and systems engineering directions, certain "time" is vacated either for in-depth mastering of another core competence of a direction or profile, or for acquiring new additional professional competencies. In a technical university, it is possible to master additional qualifications in related areas with similar basic training.

Advanced basic training during the next two years of studies (refer to figure 1) provides the following:

1. In-depth mastering of professional competencies at the level of "*Can apply in a standard situation...*", "*Possesses the methodology...*", "*Capable of developing...*" [5].

2. Individual learning paths.

3. An opportunity to obtain several qualifications within the training directions of a single qualification group, or within the related directions having similar basic training.

For the implementation of the new higher education model, the following curriculum structure is proposed:

- **"Core 1" module**—a compulsory part to be mastered by all students, regardless of their training direction/specialty (dedicated to the formation of universal competencies);

- **"Core 2" module**—a compulsory part to be mastered by all students within a single classification group (dedicated to the formation of general professional competencies);
- **"Profile foundation" module**—a compulsory part to be mastered by students of a certain profile/specialty (dedicated to the formation of professional competencies);
- **"Elective disciplines" module**—a mobility module supporting ILPs, designed for mastering elective disciplines (dedicated to the formation of additional professional competencies).

The first two years of studies within bachelor's/specialist's programs are composed of the disciplines belonging to "Core 1" and "Core 2" modules.

The disciplines of the "Profile foundation" module start from the third year of studies within bachelor's/specialist's programs.

The "Elective disciplines" module consists of the "General elective disciplines" block and the "Profile/specialization elective disciplines" block. For the "General elective disciplines" block, it is proposed to allocate 15–20 credit units. The introduction of new university-wide elective disciplines should be approved by the commission based on the provided scope of assessment tools for the discipline and student opinions.

For the implementation of the university-wide elective disciplines, it is proposed to introduce the competence formulated as "Capable of applying personality developmental training technologies, providing motivational support and formation of reflexive abilities as the basis for conscious self-governing during professional activities", which should be formed by general elective disciplines with the same indicators and learning outcomes.

The "General elective disciplines" block provides for the incorporation of the following five thematic blocks:

- **Block 1.** Digital development and information society.
- **Block 2.** Personal effectiveness, leadership, and teamwork.
- **Block 3.** Management technologies.
- **Block 4.** Innovative entrepreneurship.
- **Block 5.** Globalization processes and world culture.

The requirements for the university-wide elective disciplines are as follows:

- Absence of pre-requisites.
- All disciplines having 3 credit units, with the selection of one discipline per semester in semesters 3, 4, 5, 6, 7.
- The possibility for a student to choose a discipline of one block or several blocks. The student can choose one elective discipline from each block or "collect" disciplines belonging to 1–2–3–4–5 blocks.
- The same way of assessment—a graded examination or a rating.
- Part of the lecture material can be posted on online resources.
- If necessary, more in-depth study can be arranged through optional disciplines.
- 3 successive stages of the selection: for "A" level students, for "B" level students, and for the remaining ones.

The elective disciplines of the "profile/specialization" are introduced starting from the 5^{th} semester. Selecting the disciplines they are interested in, the students choose their own paths corresponding to the profile/specialization. Thus, a sequence of elective disciplines is constructed, allowing to master the professional competencies of the profile/specialization. The student's decision on which path to take depends on the demands of the industry. Customers

from an enterprise send a request to the educational institution, based which a set of competencies is formed and the ILPs are generated. On the other hand, there are dependences in the process of studying the disciplines, which must be observed when a student chooses an ILP. Therefore, while forming their ILPs, the students can be assisted by a mentor from the graduating department, who has the information necessary for this process [7].

The "2+2+2" system will allow to make the direction of training more specific, determine the student's future profession more accurately, and minimize the rate of expulsions from the first two years of studies. Moreover, students have two opportunities to choose a profession: during their bachelor's degree programs and during their master's degree programs. At the same time, this does not exclude the possibility of transferring to another profile, another institute or university.

The new education system has the following advantages:

- more informed choice of the profession;
- more practical training;
- general professional and personal development;
- in-depth study of the specialty during senior years of studies.

This structure has enhanced flexibility and removes one of the barriers for the most promising students. They get the opportunity to design a training program based on their individual needs and preferences.

Thus, a rigid "framework" is replaced by a "modular construction set", which can be assembled by the students on their own, who are certainly supported by experienced supervisors, advisors, and mentors (refer to figure 3). Mentors assist in choosing the ILP. The graduate project supervisors and industry advisors, assigned for on course projects and practices, assist in implementing the ILP through the selection of research and development topics. This is primarily relevant for motivated applicants, who have not yet determined their professional area but would like to adjust the curriculum to their own particularities as much as possible.

The proposed implementation of the new higher education model "2+2+2" at a technical university allows to provide the following:

1. Deliberate choice of the direction/specialty during the 2nd semester of the 1st year of studies and choice of the profile/specialization during the 4th semester of the 2nd year of studies, which and minimizes the rate of expulsions from the first two years of studies.

2. ILPs, focused on the students and the needs of industry and the market, which ensure the flexibility and mobility of higher education, provide differentiation of the competence formation levels for different qualifications and training directions, therefore vacating "time", which can be used either for in-depth mastering of another core competence of the direction or profile, or for acquiring new additional professional competencies. In addition, the ILP implementation makes the university more prestigious for applicants.

3. The set of elective disciplines is formed by the commission, considering student opinions as one of the factors; this determines the rating of the professors, increases the competition between the professors, makes it possible to award the most demanded professors, motivates the students to study, and additionally inspires the teaching staff to create high-quality educational content.

4. The possibility of changing the direction/specialty, which allows to keep the student numbers in the entire university.

5. Adaptation of the higher education to the new requirements of the industry and the market through the creation of a set of elective disciplines, research and development topics.

6. The ability to create a training program for promising students, based on their individual needs and preferences.

7. The ability to adapt the training of line personnel, intended to fill a significant number of jobs, to the new requirements of the industry and the market.

For the specialist's degree programs, the proposed approach to the construction of the higher education system can be implemented in the "2+2+1.5" form, where the first two years of studies are dedicated to general training, the next two years of studies are composed of advanced basic training, and the final 1.5 years of studies are formed by specialized training.

Thus, the following has been performed to ensure the possibility of choosing the direction of training starting from the third year of studies for the students mastering higher education programs, as well as to provide the students with an opportunity to obtain two or more qualifications:

1. The methodology for the unification of the general training during the first two years of studies has been proposed.

2. The conditions and limitations, allowing not to destroy the systemic nature of education, and, therefore, not to degrade its quality, have been identified.

3. The ILP application principles have been proposed.

4. The possibility of obtaining several qualifications has been evaluated.

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