CALS conception for the educational program at the university in the study of metrology and other technical disciplines

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Abstract. The educational program at the university is designed taking into consideration the university wishes and the requirements of regulatory documents. The basis of the training program is the curriculum. It contains academic disciplines with the appropriate parameters: a semester, a number of credit units, the number of hours for classroom work, types of classes. For its implementation the resources are used: a lot of teachers (in departments), a lot of students (in groups), a lot of classrooms (for classes), a lot of equipment (of various types), a lot of training materials, a lot of e-learning courses. Many academic disciplines are combined with each set of resources. Each resource has its own parameters. To allocate the resources, these parameters and many conditions should be considered. This is a multi-criteria optimization task. The resource parameters and restrictions can change during the educational program’ functioning. It requires the development of a new educational program plan. This can be done using the concept of Continuous Acquisition and Life-Cycle Support (CALS) which is widely used in industry but not in education. The CALS concept is based on the use of automated information systems.

1. Introduction
The educational program at the university contains a set of documents that regulate the implementation of this program. These documents reflect the academic disciplines and material resources for their teaching – classrooms, teachers, students, laboratory equipment, educational and methodological support, e-learning courses [1, 2, 3, 4, 5].

The educational program is planned for the well-known initial conditions. Subsequently, these conditions can be changed. This happens in accordance with the decisions of government bodies or changes in resource parameters. In both cases it is required to change the educational program.

But these changes should be minimal compared to the existing option. Then one can easily continue the implementation of the educational program using the existing resource base.
Sometimes it is required to make changes to the implemented program, for example, from the 3rd academic year of the 4-year bachelor's program. Then the additional task occurs – to link the new version of the program with a part of the executed program.

These tasks can only be solved using the computer-aided design of an educational program based on CALS technologies (Continuous Acquisition and Life-Cycle Support). CALS technologies are widely used for production [6, 7]. This article considers the application of CALS-technologies for the educational process.

2. Information model of the educational program
The educational process contains the three stages:

- designing the educational program;
- monitoring the implementation of the educational program;
- making a change in the educational program.

The design process includes several parts (figure 1).

![Diagram of designing educational program](image)

**Figure 1.** The process of designing the educational program.

Each part is based on the information model of the corresponding structural elements of the educational program (figure 2).

Each structure element of the educational program has its own information model. An information model is a set of parameters and their numerical values. The information model is placed in the database. In relational databases entities and attributes are distinguished. Each structural element has a relatively simple system of entities and attributes but within the framework of the entire educational program a complex system of cross-link is obtained. These links can be represented as a graph. The mathematical representation of a graph is a matrix.

Students are associated with a student group.
The student group is associated with the educational program and the year of study.
The teacher is associated with academic disciplines and departments.
The academic discipline is related to the classroom, training material and e-learning course.
The classroom is associated with the equipment.
All elements of the structure have the parameters:

- the educational program – the department to which the program is attached;
- the academic discipline – a semester, the number of credit units, the number of hours for lectures, laboratory classes, practical classes, course papers;
- the department – the number of teachers;
- the group – the actual number of students, the number of students on academic leave with a planned readmission;
- teachers – age, position, academic degree, basic diploma qualification, advanced professional training;
- a classroom – purpose (lecture, seminars, laboratory classes), number of seats for students, the equipment used;
- equipment – type of equipment (projection equipment, computers, computer network, laboratory facilities);
- a software – purpose, license;
- each type of equipment has its own characteristics, for example, computers – a processor, memory, monitor, a software.

The restrictions on the educational program parameters are as follows:

- the number of students in the program;
• the number of students in the group;
• the number of hours per teacher (separately for various posts);
• the proportion of teachers with the academic degree;
• the relationship of the teacher position and his/her academic degree with the academic discipline and the type of occupation;
• the ratio between the full-time teachers and teachers working part time;
• the positions of part-time teachers at the main workplace;
• the teachers’ work experience;
• the availability of teachers’ advanced professional training.

Some of these conditions are the parameters of the information model. The other part is calculated through the relevant parameters.

3. The process of designing the educational program
The educational program is designed taking into consideration the initial conditions: requirements and available resources. These conditions are used to record the objective function, optimality criterion and restrictions. Formally, this is an optimization problem.

The objective function and limitations include those parameters of the information model that are used to calculate the intermediate indicators. The problem to be solved is a multicriteria optimization problem. In this case it is usually not required to search for the minimum or maximum values of the optimality criterion. It is necessary to find such parameter values that correspond to the established restrictions. However, maximizing teachers’ salaries and at the same time minimizing the classroom workload can be chosen as the objective function. The indicators of these criteria are set for every teacher.

4. The process of monitoring the educational program implementation
Monitoring the educational program implementation is a constant check of compliance of the educational program indicators with the current conditions of regulatory documents. The educational program indicators are calculated applying the parameters of the resources used. At the beginning of implementation, the educational program fully complies with the current conditions as it is designed on their basis. But over time the parameters of the resources used are changed: the number of teachers, the number of students, equipment, software, etc. The conditions set by the regulatory documents are changed as well. It is required to identify the difference between necessary and real indicators.

5. The process of a new design of the educational program
Due to the monitoring result the deviation of real indicators from normative ones is revealed. After this it is required to formulate the proposals regarding changing the educational program. The changes can be structural and parametric.

   Structural changes are the changes in the curriculum and resources:
   • academic disciplines (semesters, types of classes, types of control);
   • the necessary material resources (students, departments, teachers, classrooms, equipment, software).

   Parametric changes are made for a fixed curriculum:
   • the consolidation of academic disciplines in the departments;
   • the workload distribution among the teachers;
   • the distribution of students in the groups;
   • the distribution of classrooms for academic disciplines (class schedule);
   • the creation of training materials and e-learning courses.
The changes can be divided into primary and secondary. Primary changes are the changes that are stipulated directly by the new conditions for the program’ implementation. Secondary changes are stipulated by the primary changes.

The structure of the educational program is reflected in the graph of academic disciplines. The graph is presented as the corresponding matrix (figure 3), where 1, 2, ... are the numbers of academic disciplines, and the «+» sign corresponds to the presence of a link between the left and upper disciplines. When creating a new curriculum structure, new disciplines are introduced in the matrix (figure 4), for example, 49, 50, 51, 52 and their links are indicated by a «+» sign. Then the new matrix (figure 4) is compared with the existing one (figure 3) and their inconsistencies are revealed.

![Figure 3. Fragment of an old curriculum matrix.](image1)

![Figure 4. Fragment of a new curriculum matrix.](image2)

The old matrix is transformed to a new matrix while maintaining the fixed position of the new academic disciplines. The structure of the old matrix should be kept as much as possible.

6. Conclusion
The presented technology for implementing the educational programs is based on the well-known CALS concept but is concretized for the considered subject area. In the future the theoretical provisions of this article will be realized as the automated decision support system.

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