Automation of university curriculum construction using didactic unit arrays

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Abstract. The article is devoted to new approach to the automated analysis and synthesis of university curriculum, based on the use of an array of didactic units from which are used to make educational chains. These chains are the base for educational disciplines. Thus, a "bottom-up" process is provided from didactic units through modules and training disciplines to a curriculum.

1. Introduction

Curricula are the basis of the educational process and contain a list of academic disciplines (AD) with an indication of the time limits for their teaching (number of semesters), types of classroom activities (lectures, practical and laboratory classes), types of independent work of students (course projects and works) allocated for this hours and credit units, types of control (exam, credit) [1, 2]. On the basis of the curriculum, the disciplines work programmes (DWP) are developed, which contain an exhaustive list of didactic units (DU). Nowadays, there several methods to develop curricula [3–5]. In addition, some e-courses could be used as a part of it [6].

At present, with the manual formation of the curricula a list of ADs is first created, then, based on expert assessments, they are distributed by semesters, and then the corresponding DWP are developed, which are filled with DU. Objectively, ADs are interconnected through the DU contained in them, but with manual formation of curricula, it often turns out that these connections are poorly aligned. Moreover, the limited time resources and the need to divide time between concurrently studied DWP are poorly taken into account. This is due to the fact that the DWP is developed by individual teachers who are not able to take into account the peculiarities of the DWP of other ADs [7].

At the same time, the emergence of new educational standards imposes additional requirements on the quality and speed of curricula development. First, the emphasis is placed on increasing the number of academic disciplines of choice. Secondly, the rapid development of all areas of knowledge involves frequent correction of AD. Thirdly, academic mobility, combined with the freedom to introduce academic disciplines decided by the university, means that students can study during the period of study in several curricula of various universities. Fourth, the deduction and recovery of students leads to the fact that they have to learn a lot of additional ADs. All this makes it very difficult manual formation of curricula.

Currently, the automated formation of curricula is rare, as evidenced by the abundance of teaching materials presented on the websites of universities, which contain recommendations for the manual

formation of curricula [8]. This means that the problem of automated synthesis of curricula remains relevant and requires the development of new ideas.

2. Curriculum Development

It is assumed that for each educational program specialization it is possible to form a common array of DUs, indicating the connection between them. A didactic unit (DU) is an element of competences that is indivisible within the framework of the educational process under consideration. Since competence is the unity of knowledge and skills, then DU can be of different kinds: knowledge DU, skills DU and ability DU. Within the framework of competences, knowledge, skills and abilities are combined into a system and receive the emergence property, i.e., their joint use has additional properties compared to the properties of individual components, which gives rise to a certain competence [9].

Usually, when automating analysis and synthesis of curricula, only DU of knowledge is taken into account, which are easily obtained from the content of the AD. DU of skills and abilities practically do not occur. There is a close relationship between the DU of knowledge, skills and abilities: the DU of knowledge is the basis for the DU of skills, which, in turn, are the basis for the DU of abilities. The same knowledge DU can generate several skills DU (for example, applying the same general method to different objects). Moreover, one DU of skill can be reflected in the practical field through several abilities DU (for example, text preparation abilities in different versions of MS Word). The basis of the total array of DU is the knowledge array of DU. This array is given in the form of a digraph, in which DU is represented by vertices. The edges of such a digraph have no informational meaning, except for designating the connection of some DU with others. Such a digraph can be represented by a matrix (a visual, but cumbersome form) or a list (a compact, but less visual form). The matrix representation of the array DU is table 1.

Table 1. Matrix representation of the array DU in general form

	→DU1	→ DU2	…	DUn
DU 1→	→ $d_{1,1}$	→ $d_{1,2}$	…	→ $d_{1,n}$
DU 2→	→ $d_{2,1}$	→ $d_{2,2}$		→ $d_{2,n}$
…	…	…	…	…
DUn→	→ $d_{n,1}$	→ $d_{n,2}$	…	→ $d_{n,n}$

The rows and columns contained DUs with the corresponding numbers in the same sequence. In the cells there are pointers to the connection of the outputs of the DU in the rows (in the left column) with the DU in the columns (in the upper line). If there is a connection, then 1 is stamped, if there is no connection, 0 (Table 2). The matrix is square, therefore it has a main diagonal. All 1 above the main diagonal show that the connection between the DU is left upwards. And all 1 below the main diagonal show that the connection between the DU is directed from the top to the left and is the reverse.

Table 2. Example of the matrix representation of the DU array

	→ DU1	→ DU2	→ DU3	→ DU4	→ DU5	→ DU6	→ DU7
DU1→	0	1	0	0	0	1	0
DU 2→	0	0	1	1	0	0	0
DU 3→	0	0	0	1	0	0	0
DU 4→	0	1	0	0	0	0	1
DU 5→	0	0	0	0	0	0	0
DU 6→	0	0	0	0	0	0	0
DU 7→	0	1	0	0	0	0	0

In well-constructed curricula there are no feedbacks, as they mean the study of DU based on the DU, which will be studied later. Thus, the study of the matrix type in Table 2 can give a lot of information about the structure of individual AD or the whole curricula.

DUs can be divided into two types:

1) elementary DU which is introduced in the process of learning;

2) composite DU which is formed on the basis of the previous DU.

Students get initial DUs at a previous level of education (for example, in high school). The combination of these initial elementary DUs generates new units of a more complex structure – composite units. For example, the DU from the course of elementary physics and algebra gives rise to the laws of Kirchhoff's electrical circuits in electrical engineering. In the process of learning by teachers, new elementary DUs are also introduced, which were not received at school and are not the result of a combination of already studied DUs. For example, in electronics transistors are studied that may not have been studied in school. In fact, any new knowledge is formed on the basis of previously obtained elements of knowledge. However in some cases, the general cultural training of the student is used to master the new DUs, in this case the DU is considered elementary.

In the formation of composite DU, both elementary and composite DU, obtained at earlier stages of study, are used. Each DU can be attributed to the time of its formation on the basis of other DU. Elementary D s do not have input DUs, and therefore the time of their study is determined by the DU itself. The constituent units have input units, therefore the time to study them is due to the interaction of all input units.

3. Results and Discussion

The basis of the general array of DUs are knowledge DUs. These DUs are used to receive an array of skills DUs associated with the relevant DU of knowledge. Each DU of skill can generate one or more DU of abilities. These units can also be elementary or composite. It is advisable to make notes for the corresponding form. Then, with automated analysis, it is possible to determine whether the knowledge gained is related to skills and abilities. The combination of these elements can be interpreted as a specific competence, which opens up the possibility of automated identification of competencies implemented in a particular discipline. However for this it is necessary to associate competence with a certain combination of knowledge and skills. On the basis of the matrix DU, the graph DU is formed in the form of parallel branches. Each branch can stand out in the form of academic discipline.

In the simplest case, the chain of didactic units is built as follows (Figure 1). The following notation is accepted: DU is didactic unit, C is compentency.
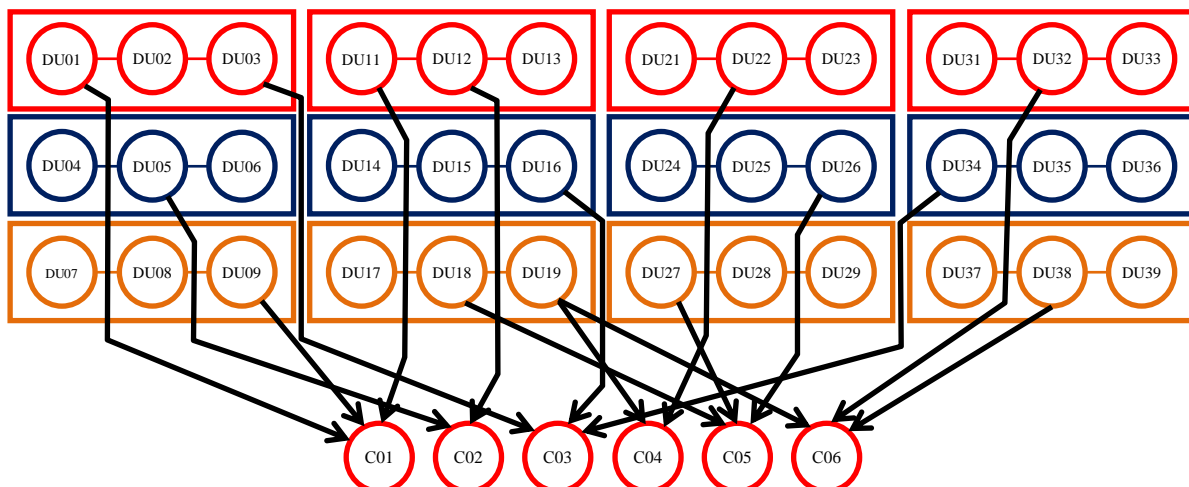
Figure 1. Formation of resulting competencies based on didactic units studied in various academic disciplines in different semesters

The authors considered 4 semesters. Each semester has 3 academic disciplines. Each discipline has 3 didactic units (in fact, there are many more). Some properties of these didactic units are included in the competence. These properties relate to knowledge and skills.

To build a tree of formation of the resulting competencies, it is necessary to set didactic units for each academic discipline (Figure 2). Each didactic unit must be labeled exactly what kind of knowledge, what skill and what ability it gives. Ideally, all didactic units should be studied in terms of knowledge and skills. However due to time constraints, this is not so: all didactic units give knowledge (knol.); some of them give skill; even fewer didactic units provide abilities.
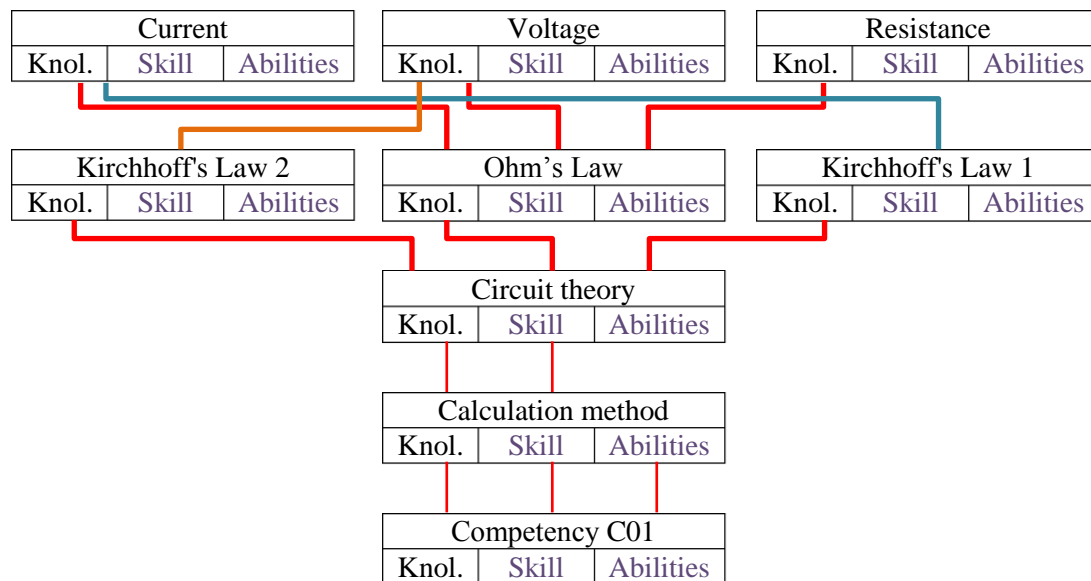
Figure 2. Tree of knowledge and skills for a certain competence

Knowing the period of time to study each DU, it is possible to determine the total time required to master the corresponding chain of DU. In the process of analysis, it is possible to formulate recommendations, which DUs should be studied audibly with a teacher, and which ones as part of the students' independent work. It is possible to determine the time required to study each chain, and place it in a given semester. It may turn out that after placing the AD there is free time. Therefore, it is possible to add a DU. If the chain of DUs goes beyond the semester, it is necessary to exclude some of the DUs. If at the stage of formation of the array DU specify their priority, then it is possible to perform this operation automatically. DUs will be removed, but then the curricula designer will have to check the correctness of the program.

The analysis of the curriculum is carried out "from top to bottom". This work can be done by starting with the traditional technology, in which the preliminary structuring of the educational process is performed with the release of enlarged academic disciplines (fields of knowledge). Then, for each academic discipline, the relevant experts (for example, teachers) form a local array of DUs. The rules for the formation of local arrays should be the same for all academic disciplines. As a result, local matrices of DU links appear, which are then combined into a common matrix according to the educational program specialization.

Combining private arrays of DUs provides for identifying the same DU and reducing them to a single DU with multiple entrances and exits. This will determine the presence of contours, which should then be converted to a linear structure.

4. Conclusion

The correction of curricula in this case is to replace a part of DUs with new ones in the framework of a new field of knowledge or taking into account changes already existing in curricula. After that, the

general array of DUs is reformed, new DU chains are lined up and, possibly, the content of individual ADs changes. At the same time, it is possible to automatically obtain the composition of the CU for each modified curricula, which greatly simplifies the processing of the DWP changing with the possibility of subsequent automation. The proposed approach is currently being implemented in the direction of a detailed analysis of the problems identified in the article, with the use of the considered solutions.

The novelty of the proposed approach lies in the fact that it was proposed to use an array of didactic units as the basis for synthesizing the curriculum, form a common array of didactic units from private arrays of didactic units according to areas of knowledge, form chains of didactic units, distribute them in time, and highlight educational disciplines (possibly with unconventional content and title), automatically form an array of didactic units for test and measurement materials. The creation of algorithms on this basis and their software implementation will allow automating the synthesis of curricula, including their adjustment when changing the composition of didactic units.

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