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Original article

Technology of Multilevel Interuniversity Indicators as a Factor for Increasing Academic Mobility. Experience Based on Russian Federal Educational Standards

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Abstract

Introduction. At the present time, more and more students are changing either their field of study or the university in the process of studying. This raises the problem of how to determine whether a student's level of knowledge meets the host institution's criteria. A simple comparison of competencies is not enough. Therefore, the authors propose a new system of comparing existing and required knowledge (competencies) at the new place of study. The purpose of this article is to present the results of research on the development and practical application of specific "competency trees" that allow for the automatic comparison and re-crediting of disciplines.

Materials and Methods. The research is based on the methods of system analysis for weakly formalized problems: the method of expert evaluations and the method of the goal tree. For direct development the method of construction of binary decision trees was used. To evaluate the effectiveness of the developed method, methods of observation and comparison were used.

Results. This article describes the specific steps for creating checklists based on multilevel competency indicator trees. The tables describe the four levels of competency acquisition. Based on the experiments carried out on the use of such tables for retake disciplines when transferring a student from one specialty to another, the following recommendations are made: if it is necessary to obtain a mark of the "Test" type in the Host University, the comparison is made according to the second level indicators; if it is necessary to obtain a mark of the type "Graded test/Test with a grade" in the Host University, the comparison is made according to the third level indicators; if it is necessary to obtain a mark of the "Exam" type in the Host University, the comparison is made according to the indicators of the deepest level for this indicator of the first level. The technique has been successfully tested for moving of a student within Kazan National Research Technical University named after A. N. Tupolev-KAI between the academic programs Aircraft Engineering and Applied Mathematics and Informatics.

Discussion and Conclusion. The proposed multilevel system of interuniversity indicators will significantly simplify the procedure for transferring subjects for students who are moved from one study program to another at any level – whether within one university, or between different universities of the Russian Federation. The use of an automated system for comparing the level of knowledge of a student when moving from one university to another will not only reduce the time of a student and teachers, but also eliminate the human factor, bias and subjectivity in the process of making decisions about transferring, and increase the transparency of this process. All this together will contribute to the development of academic mobility of students, increasing their competitiveness in the labor market and strengthening academic interuniversity relationships both in Russia and abroad.

Keywords: interuniversity indicators, multilevel competences, competence tree, academic mobility, professional competences, educational standards

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Научная статья

Технология многоуровневых межвузовских индикаторов как фактор повышения академической мобильности. Внутрироссийский опыт на основе федеральных государственных образовательных стандартов

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Аннотация

Введение. В настоящее время в процессе обучения все больше студентов меняют направление подготовки либо вуз. В связи с этим возникает проблема, как определить, соответствует ли уровень знаний студента критериям принимающего вуза. Простого сравнения компетенций бывает явно недостаточно. Поэтому авторы статьи предлагают новую систему сравнения имеющихся и требуемых на новом месте учебы знаний (компетенций). Цель статьи – представить результаты исследования по разработке и применению на практике специфических «деревьев компетенций», позволяющих производить сравнение и перезачет дисциплин автоматически.

Материалы и методы. В основе исследования лежат методы системного анализа для слабоформализуемых проблем: метод экспертных оценок и метод дерева целей. Для непосредственной разработки использован метод построения бинарных деревьев принятия решений. Для оценки эффективности разработанного метода использовались методы наблюдения и сравнения.

Результаты исследования. В статье описаны конкретные шаги по созданию специфических проверочных таблиц на основе многоуровневых деревьев индикаторов компетенций, в которых представлены четыре уровня приобретения компетенций. На основании проведенных экспериментов по использованию таких таблиц для пересдачи дисциплин при переводе студента с одной специальности на другую даются рекомендации. Методика прошла успешную апробацию при переводе студента в рамках Казанского национального исследовательского технического университета им. А. Н. Туполева-КАИ между образовательными программами «Самолетостроение» и «Прикладная математика и информатика».

Обсуждение и заключение. Сделанные авторами выводы будут способствовать развитию академической мобильности студентов, повышению их конкурентоспособности на рынке труда и укреплению академических межвузовских отношений как в Российской Федерации, так и во всем мире.

Ключевые слова: межвузовские индикаторы, многоуровневые компетенции, дерево компетенций, академическая мобильность, профессиональные компетенции, образовательный стандарт

Авторы заявляют об отсутствии конфликта интересов.

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Introduction

Academic mobility has become a characteristic feature of modern higher education. The mobility of students from one university to another, both nationally and internationally, is becoming commonplace. This trend, of course, carries many positive aspects, increasing the competitiveness of the students themselves, and providing the dynamically changing needs of the modern labor market[1] [1]. However, this sets new goals and objectives for higher education institutions, which were not relevant before Russia joined the Bologna process [2; 3].

Specialists of higher education know that the same educational programs in different universities are provided at times with a completely different set of studied modules [4; 5]. When moving from one university to another, even at the level of one region and within one study program, a student must, as it is commonly called, "cover the difference in plans" – what means that the student retakes at the host university those disciplines that he/she "has not studied" earlier. At the same time, the content of the module does not make a difference. If the name of the module is not included in the home university curriculum, this automatically requires that the mobile students have to retake this subject at the host university. Also, a student may find himself/herself in a similar situation if he/she substantially changes his/her study area moving to the next cycle of higher education, e.g. the postgraduate program , but some specific competencies have already been mastered by him/her during the undergraduate program [6; 7].

Even within the one university, the process of transition between related subject areas is associated with the need to retake a number of modules, often essentially identical. Let us give a typical example. KNRTU-KAI is a technical university that educates engineers for high-tech industries and the IT industry. In particular, education is underway in such undergraduate programs as Aircraft Engineering (subject area code 24.03.04), and Applied Mathematics and Informatics (subject area code 01.03.02), whose curricula are available on the university website[2]. According to the ideology of intra-university mobility implemented over the past 5 years, the curricula are built in such a way that during the first two years of study (Semesters 1-4), students have the opportunity to change the study program to another one, if budget places are available. Both of these subject areas require a strong mathematical background at the initial stage of training.

On the first program (24.03.04), within the framework of professional activity, specialists will build aircraft (Aviation Engineering), on the second (01.03.02), specialists will develop software (Software Engineering).

So, for the subject area 24.03.04, this is a three-semester course of Higher Mathematics, which includes such branches as Linear Algebra and Analytical Geometry, Mathematical Analysis, Differential Equations, Probability Theory and Mathematical Statistics, Equations of Mathematical Physics (Semester No. 1-3, Total Workload is 18 Credit Points)[3]. Within the framework of the subject area 01.03.02, students receive the same

[1] Zaydullin S., Novikova S. The Concept of International Educational Environment for Learning It-Specialists based on Requests of the Labour Market. *Uchenye zapiski Instituta sotsialnykh i gumanitarnykh znaniy* = Scientific Notes of the Institute of Social and Humanitarian Knowledge. 2016; (1):245-249. Available at: https://isgz.ru/images/ISGZ/UchZapiski/Arhiv/uz_1_16.pdf (accessed 01.08.2021). (In Russ., abstract in Eng.)

[2] [Curriculum of the Bachelor Program. Specialty 03.24.04 Aviation. Profile "Aircraft"] [Electronic resource]. Kazan: KNRTU-KAI; 2019. Available at: https://umk.kai.ru/2019_УП1_85_2_973180.pdf (accessed 10.07.2021). (In Russ.); [Curriculum of the Bachelor Program. Specialty 01.03.02 Applied Mathematics and Informatics. Profile "Mathematical and Software of Computers"]. [Electronic resource]. Kazan: KNRTU-KAI; 2019. Available at: https://umk.kai.ru/2019_%D0%A3%D0%9F1_85_2_973180.pdf (accessed 10.07.2021). (In Russ.)

[3] Anisimova I.V., Ignatiev V.N., Takseitov R.R. [Work Program of Discipline B1.O.07 "Higher Mathematics"] [Electronic resource]. Kazan: KNRTU-KAI; 2019. Available at: https://umk.kai.ru/2019_%D0%A0%D0%9F%D0%94_327_78_2_33786.pdf (accessed 10.07.2021). (In Russ.)

competencies from a wider set of disciplines. Some courses are studied separately, e.g. Linear Algebra and Analytical Geometry (Semester No. 1, 4 Cr. Points), Mathematical Analysis I-II-III (Semester No. 1-3, 16 Cr. Points), Differential Equations added with elements of equations of mathematical physics (Semester No. 4, 5 Cr. Points), Probability Theory and Mathematical Statistics (Semester No. 3-4, 7 Cr. Points)[4].

Even with a superficial comparison of the mathematical blocks of these two directions, a number of logical conclusions that are understandable to any teacher can be drawn:

– Despite the different names, the modules cover the same branches of Mathematics, and form essentially the same general professional competences called OPK-1 in the corresponding Federal State Educational Standard of Higher Education, which is also confirmed by the similarity of indicators for achieving these competencies. For example, for the disciplines of the theoretical mathematical block[5], and for the block of computational mathematical disciplines[6];

– Depth of mastering the branches in this two programs, however, is different, which is easy to see from the almost two-fold difference in the number of credits allocated for mastering the module[7];

– Students wishing to change the area of future professional activity from Software Engineering to Aviation Engineering, almost completely cover the mathematical block of the receiving subject area, and they do not need to retake the module "Higher Mathematics". This is explained by the complete alignment of the studied list of modules of the mathematical block for 01.03.02 subject area with the list of mathematical block for 24.03.04 subject area, while the workload of the mathematical block in the first program significantly exceeds the workload of the similar block in the second program;

– At first glance, students who change their activity from Aviation Engineering to Software Engineering also do not need to retake a number of modules of the receiving subject area, as they studied them as part of the generalized course of Higher Mathematics. However, due to the smaller number of hours allocated for each branch of Mathematics, the full mastery by the student of the competencies in accordance with the academic program of 01.03.02 subject area is not obvious and requires an in-depth study of this issue.

According to current practice, students of both directions, when changing their programs of study, are required to retake a full list of modules with clearly distinct names. This approach requires a lot of additional time from both the students and the teachers of the receiving subject area, which complicates the already difficult period of adaptation of the student to the new requirements and learning conditions on the one hand, and takes a lot of the teacher's time on the other.

The solution to the problem can be the creation of a system of multilevel indicators reflecting the mastering of certain clearly defined professional competencies. The indicators of the upper level will reflect the mastery of some sections of knowledge in general, with a decrease in the levels, the more precise details will be made. Thus, a tree of

[4] Emaletdinova L.Yu., Kabirova A.N. [Work Program of Discipline B1.O.07.01 Linear Algebra and Analytic Geometry] [Electronic resource]. Kazan: KNRTU-KAI; 2019. Available at: https://umk.kai.ru/2019_%D0%A0%D0%9F%D0%94_346_106_27_35864.pdf (accessed 10.07.2021). (In Russ.); Zabotin V.I. [Work Program of Discipline B1.O.07.02 Mathematical analysis I-III] [Electronic resource]. Kazan: KNRTU-KAI; 2019. Available at: https://umk.kai.ru/2019_%D0%A0%D0%9F%D0%94_346_5492_27_35865.pdf (accessed 10.07.2021). (In Russ.); Nesterova L.E. [Work Program of Discipline B1.O.17 Differential Equations] [Electronic resource]. Kazan: KNRTU-KAI; 2019. Available at: https://umk.kai.ru/2019_%D0%A0%D0%9F%D0%94_346_28_27_35881.pdf (accessed 10.07.2021). (In Russ.); Rodnischev N.E., Medvedeva S.N. [Work Program of Discipline B1.O.07.03 Probability Theory and Mathematical Statistics] [Electronic resource]. Kazan: KNRTU-KAI; 2019. Available at: https://umk.kai.ru/2019_%D0%A0%D0%9F%D0%94_346_319_27_35866.pdf (accessed 10.07.2021). (In Russ.)

[5] Anisimova I.V., Ignatiev V.N., Takseitov R.R. [Work Program of Discipline B1.O.07 "Higher Mathematics"]. (In Russ.); Emaletdinova L.Yu., Kabirova A.N. [Work Program of Discipline B1.O.07.01 Linear Algebra and Analytic Geometry]. (In Russ.); Zabotin V.I. [Work Program of Discipline B1.O.07.02 Mathematical analysis I-III]. (In Russ.)

[6] Nesterova L.E. [Work Program of Discipline B1.O.17 Differential Equations]. (In Russ.); Rodnischev N.E., Medvedeva S.N. [Work Program of Discipline B1.O.07.03 Probability Theory and Mathematical Statistics]. (In Russ.)

[7] [Curriculum of the Bachelor Program. Specialty 03.24.04 Aviation. Profile "Aircraft"]. (In Russ.); [Curriculum of the Bachelor Program. Specialty 01.03.02 Applied Mathematics and Informatics. Profile "Mathematical and Software of Computers"]. (In Russ.)

indicators, or competencies, will be built for each subject area. Each course studied within the framework of the academic program should be equipped with a similar tree, which will allow, when moving a student, to compare the levels of mastering competencies at a given level, and to reevaluate as a whole according to the mastered part of the curriculum without reference to the name of a specific module. This will significantly simplify the process of students' mobility between subject areas within one university, as well as from one university to another.

Literature Review

Thus, it is obvious that it is necessary to create a system that would make it possible, without additional checks of knowledge, to assess which sections of subjects have already been mastered by the student at his/her home university (institute, faculty), and which he needs to master additionally in order to bring his knowledge in line with the curriculum of the host university. To do this, it is initially necessary to determine what exactly will be an indicator of such an assessment. Here, in contrast to the point-rating system, we are not talking about the success of the student's mastering of competencies, but only about the very fact of studying the corresponding academic topic. The degree of success is expressed by the grade that the student has already received for a specific subject at home university [8–10].

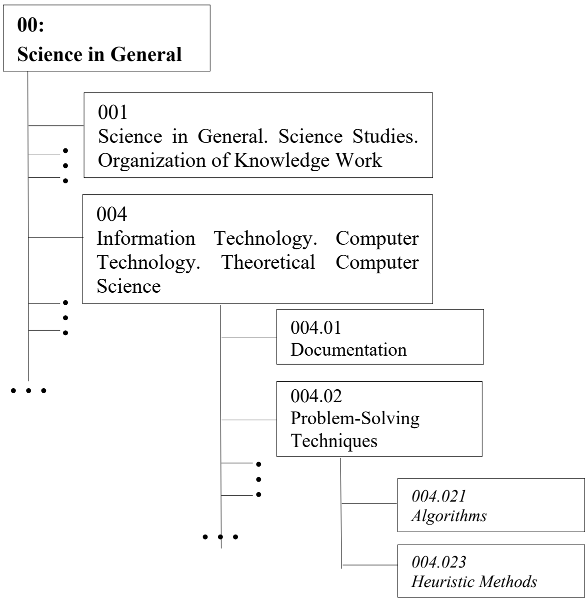
The indicator, therefore, has a binary character of the "Mastered/Not Mastered" type of specific subject and is assigned, therefore, to the subject itself or to its section. However, as it was shown earlier on the example of two training programs of KNRTU-KAI, what is a separate subject in one curriculum, in another can be only a part (section) of a subject with a different name. This circumstance dictates to us the need to create a tree of indicators, where each indicator of the upper level contains all the knowledge of the indicators of the lower level, described with a greater degree of specification.

According to this principle, for example, the UDC tree-classifier (Universal Decimal Classifier) is built – a system for organizing information used to systematize works of science, literature, periodicals, various types of documents, etc. The leaf (final top) of such a tree is a highly specialized section of scientific knowledge, for example, 004.023: "Heuristic Methods for Solving Problems". Intermediate nodes of the tree contain generalizing definitions of the vertices of the lower levels, for example, the above-mentioned section "Heuristic Methods" is combined with the top-leaf 004.021 "Algorithms" by the top-level top 004.02 "Methods for Solving Problems" (Fig. 1).

For the problem to be solved, the nodes of the tree must contain definitions of the acquired knowledge within the framework of the studied disciplines. The system of educational competencies in Russia is still rather poorly developed. Despite numerous attempts to modernize and concretize the content of competencies for each academic program, their description is still rather vague and allows for a variety of interpretations. An example is the already mentioned competences of the OPK-1 Aircraft Engineering and Applied Mathematics and Informatics. Also, many of the competencies that are present in modern educational standards in Russia practically do not lend themselves to an adequate generally recognized quantitative assessment.

In a sense, the classifiers that assess the depth of knowledge in a specific area include professional standards, the procedure for the development and approval of which is determined by the Decree of the Government of the Russian Federation dated January 22, 2013 No. 23 (as amended on September 02, 2018) "On the Rules for the Development and Approval of Professional Standards". The advantage of these standards should be considered the maximum compliance declared by their developers to the real needs of the labor market[8] [11]. However, the fact that standards can be freely developed

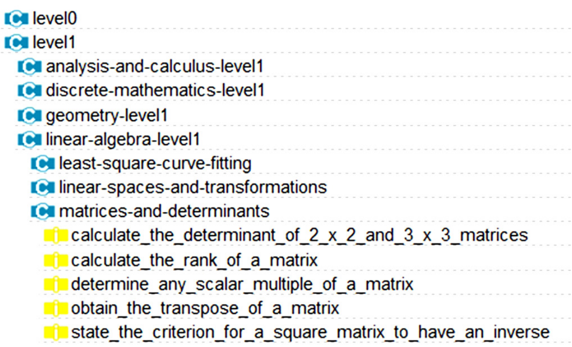
[8] Novikova S., Zaydullin S. The Implementation of a Flexible Educational Path for It-Specialists on the Basis of Cluster Approach to E-Learning. *Uchenye zapiski Instituta sotsialnykh i gumanitarnykh znaniy* = Scientific Notes of the Institute of Social and Humanitarian Knowledge. 2016; (1):423-427. Available at: https://www.isgz.ru/images/ISGZ/UchZapiski/Arhiv/uz_1_16.pdf (accessed 01.08.2021). (In Russ., abstract in Eng.)



F i g. 1. The Structure of the Classifier Tree of the UDC System (Fragment)

by any employers, both with the participation of educational organizations of professional education and without them, leads to the absence of a single unified classification scheme, which makes it impossible to apply this approach to the problem being solved.

In this sense, it is much more practical, for example, the standard created by the European Association for Engineering Education, known as the SEFI Standard. It describes the list of skills and knowledge that engineering students should have. SEFI covers basic mathematical parts (sections) studied in technical universities: Linear Algebra, Mathematical Analysis, Discrete Mathematics, Probability Theory, and some others [12; 13]. The standard contains a set of specific criteria. The standard at the top level contains sections of knowledge for each subject studied that must be mastered. For each section, a list of skills is given that derive from the knowledge of the upper level. The standard at the top level contains sections of knowledge for each subject studied that must be mastered. A list of skills is then given for each section that derives from the top-level knowledge. The criterion for grouping skills is the level of difficulty. Difficulty levels are basic (level 0), intermediate (level 1), advanced (level 2), and most difficult (level 3) (Fig. 2).



F i g. 2. Fragment of the Classifier Tree According to the SEFI Standard

Despite the apparent conformity of the SEFI Standard to the task at hand, it cannot be unconditionally accepted as a model for the system being developed, since the levels of the tree here are arranged according to the principle of the complexity of knowledge, and not according to sections and subsections of the module.

Materials and Methods

In the context of the problem being solved, professional competencies mean knowledge and skills in a specific given section from the knowledge area described [14; 15]. Binding to a specific module is not allowed. We offer a multi-level system of indicators based on the provisions of the Federal State Educational Standard:

The first (root) level of the classifier is a section of scientific knowledge according to the All-Russian classifier of specialties education (Classifier OK 009-2016). For example, "Higher Mathematics".

The second level is the classification of the designated scientific knowledge according to the principle of "Field of Knowledge as a Module". Unfortunately, it is impossible to rely on the current educational standards, so this classification is proposed to be carried out according to the educational standard[9]. So for Higher Mathematics, the standard defines the following sections: Mathematical Analysis, Algebra, Analytic Geometry, Linear Algebra and Geometry, Discrete Math, Mathematical Logic, Differential Equations, Differential Geometry, Difference Equations, Topology, Functional Analysis and Integral Equations, Theory of Functions of a Complex Variable, Partial Differential Equations (Methods of Mathematical Physics), Probability Theory, Math Statistics, Theory of Stochastic Processes, Calculus of Variations and Optimization Methods, Calculation Methods (Numerical Methods), Number Theory.

The third level assumes further specification of each of the selected sections. We will use the same standard[10], which also contains a complete list of requirements for the mandatory minimum content of the undergraduate program, which is, in fact, a list of sections for each discipline. Also, for each section, this standard also indicates subsections, which makes it possible to generate the fourth, last (leaf) level of the classifying tree.

So, for example, the module "Mathematical Analysis" contains 20 sections, including Theory of Limits, Continuous Functions, Differentials and Derivatives, Indefinite Integral, Definite Integral, and others.

Subsections of the section Differentials and Derivatives are Differentiability of a Function at a Point; Derivative at a Point, Differential and Their Geometric Meaning; Mechanical Meaning of the Derivative; Differentiation Rules; Derivatives and Differentials of Higher Orders; Leibniz Formula.

Not all knowledge areas contain the same number of nested sections and subsections. So, for example, according to[11] for the Philosophy knowledge area, not three, as for mathematics, will be defined, but two nested levels of the tree: the area includes 9 basic modules: Logic, Ontology and Theory of Knowledge, Social Philosophy, History of Foreign Philosophy, History of Russian Philosophy, Ethics, Aesthetics, Philosophy of Religion, Philosophy and Methodology of Science, each of which contains from 6 to 10 sections without subsections. For example, the module History of Russian Philosophy includes the following six sections:

– Subject of the Russian Philosophy History;
– Philosophical Thought of Russia in the 10^{th} – 17^{th} Centuries;
– Philosophy of the Enlightenment in Russia;
– Main Philosophical Trends of the 19^{th} Century;
– Philosophy of the Russian Diaspora;
– Russian Philosophy in the 20^{th} Century.

[9] [State Educational Standard of Higher Professional Education. Specialty 01.01.00 "Mathematics". Qualification "Mathematician". Ed by Lupanov O.B. Moscow; 2000. (In Russ.)
[10] Ibid.
[11] [State Educational Standard of Higher Professional Education. Specialty 02.01.00. "Philosophy". Qualification "Mathematician". Ed by Saletsky A.M. Moscow; 2000. (In Russ.)

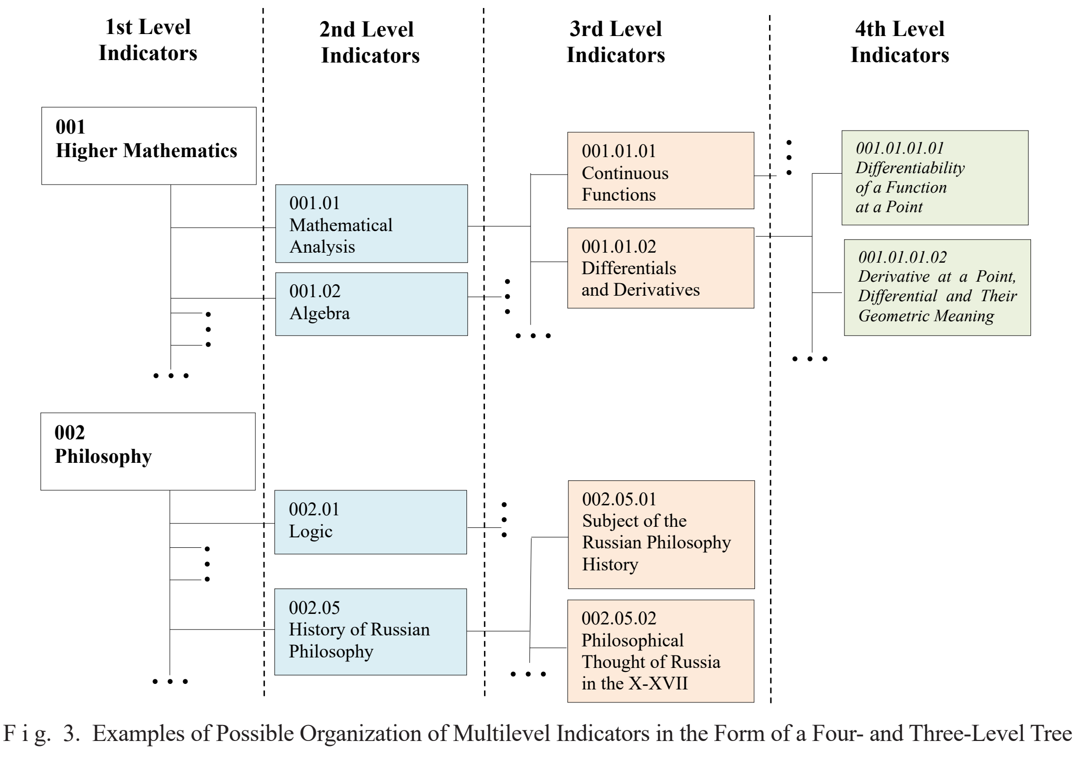
In this case, the classification tree will have three levels of detail.

The opposite situation is also possible, when the number of nesting levels of the classifier for a certain knowledge area will be more than four. According to the authors, one should confine oneself to a maximum of four levels, since with more detail the practical use of a multi-level system of indicators will become too complicated.

Thus, on the basis of the All-Russian Classifier of Education Specialties and State Educational Standards, a multilevel system of indicators for assessing the professional competencies achievement will be built in the form of a classifying tree. For the convenience of practical application, each node of the tree must be assigned an individual code by analogy with the UDC classification, which will allow "tracing" the succession of sections and subsections of knowledge (Fig. 3).

Results
A Way of Using Multilevel Indicators to Check the Compliance of the Student's Knowledge with the Requirements of the Host University

Formation of tables of indicators for the subsequent comparison of the practical competencies obtained. For the practical use of the proposed approach, it is necessary for each discipline studied as part of the curriculum to determine a table of indicators without reference to the name of the subject itself. The table should contain the numbers of the indicators according to the levels defined in the previous section. One of the possible options for the structure of such tables may be, for example, the following (Table 1).



F i g. 3. Examples of Possible Organization of Multilevel Indicators in the Form of a Four- and Three-Level Tree

T a b l e 1. **A Variant of the Structure of the Table of Indicators of the Curriculum**

Name of the Curriculum	Indicator Set for Level 1	Indicator Set for Level 2	Indicator Set for Level 3	Indicator Set for Level 4
	Set of indicators' codes "1" for level 1 of curriculum	Set of indicators' codes "1.2" for level 2 of each 1st level indicator	Set of indicators' codes "1.2.3" for level 3 of each 2nd level indicator	Set of indicators' codes "1.2.3.4" for level 4 of each 3rd level indicator

Such a structure represents the indicator tree proposed in the previous section in the form of a table and allows simple software implementation. This aspect is important, since in a modern university all documentation is kept in electronic form [16; 17], and information is stored in the form of databases, most often of a relational type [18; 19], focused on working with tables, not graphs. Therefore, the proposed structure for accounting indicators will not require global changes or modernization of the existing recording system at the university.

Initially, indicators should be indicated in each working program of the curriculum module. At KNRTU-KAI, working programs are created in a semi-automatic mode using special software that generates working programs. This generator can be easily updated by automatic switching on of indicators of the first, and for some disciplines and the second level (Fig. 4–5).

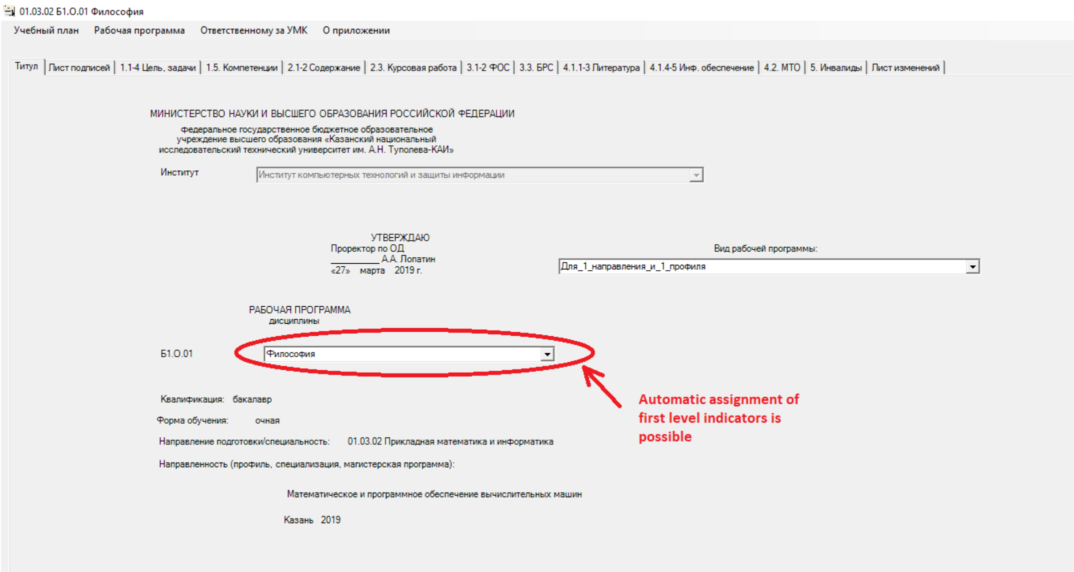
Indicators of lower levels can be added manually when further filling out the proposed forms (for example, in the form of a drop-down list) at the stage of filling in the content of working programs (Fig. 6).

The generated working programs are saved as xml files [20; 21], and then can be subjected to a special parsing procedure [22–24] to extract information about indicators, with further automatic filling of the final table, as in Table 1. For example, the summary table of indicators may look as follows (Table 2).

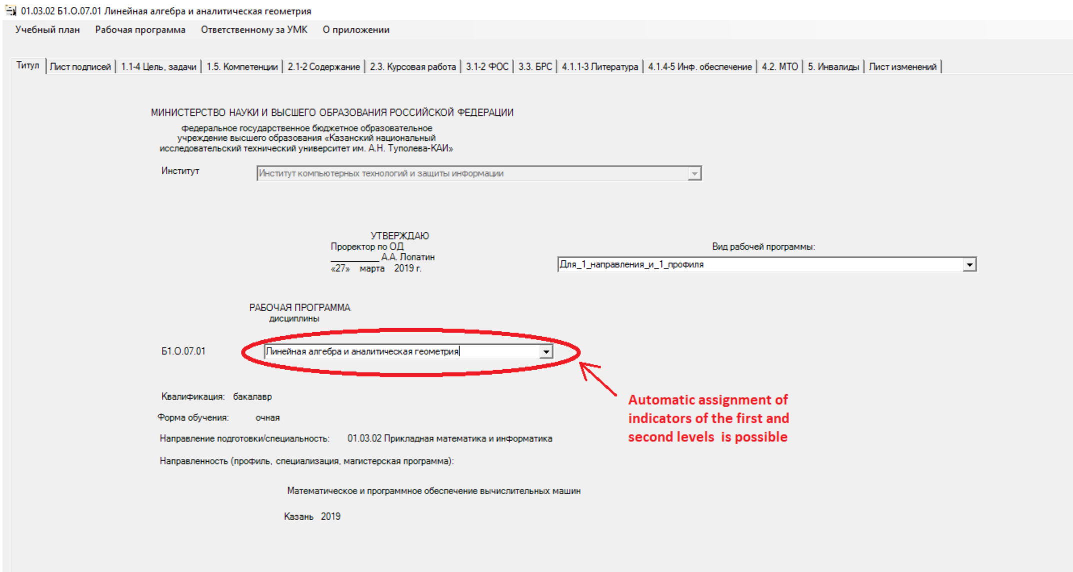
The process of checking the compliance of the student's knowledge with the requirements of the Host University according to the indicator tables. So, when moving to another university (faculty, area of study), each student will have a table of indicators of the knowledge received in the previous place of study in accordance with the curriculum adopted there. In the new university, this table should be compared with the table of indicators of the host university (faculty) curriculum. At the same time, the authors propose to choose the level of comparison of indicators according to the following principle:

– if it is necessary to obtain a mark of the "Test" type in the Host University, the comparison is made according to the second level indicators;

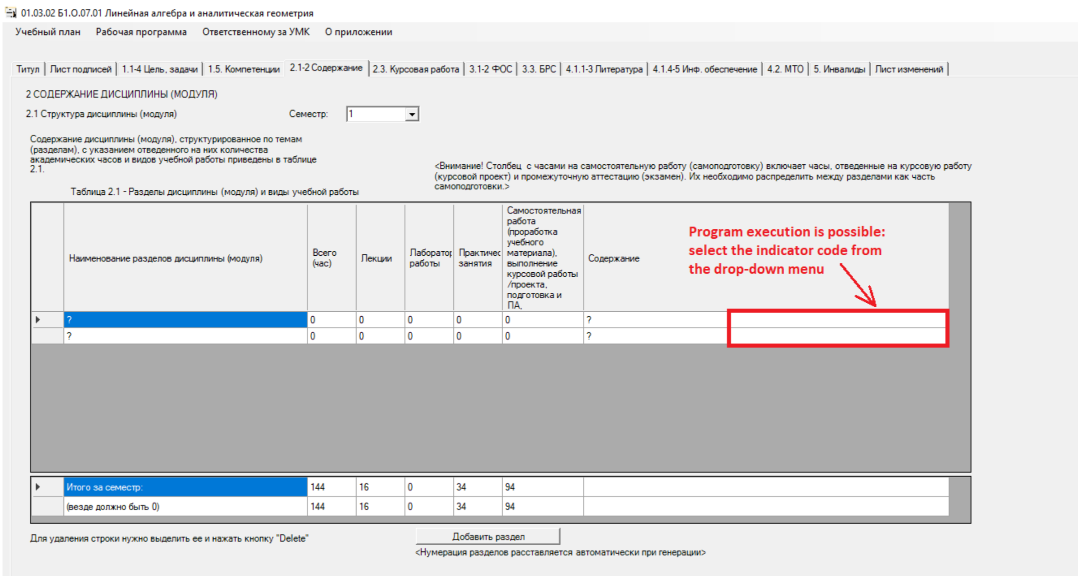
– if it is necessary to obtain a mark of the type "Graded test/Test with a grade" in the Host University, the comparison is made according to the third level indicators;



F i g. 4. Example of the Choice of Modules in the Automatic Generator of Working Programs with the Ability to Automatically Determine Indicators of the Same Level



F i g. 5. Example of the Choice of Modules in an Automatic Generator of Working Programs with the Ability to Automatically Determine Indicators of Two Levels



F i g. 6. Variant of the Form for Adding Specifying Indicators of 3 and 4 Levels when Filling Out the Content of the Module in the Generator of Working Programs

T a b l e 2. **Variant of the Final Form of the Table of Indicators (Fragment)**

<table>
<tr><td rowspan="13">Name of the Curriculum</td><td>Indicator Set for Level 1</td><td>Indicator Set for Level 2</td><td>Indicator Set for Level 3</td><td>Indicator Set for Level 4</td></tr>
<tr><td rowspan="8">001</td><td rowspan="3">001.03</td><td rowspan="2">001.03.01</td><td>001.03.07.02</td></tr>
<tr><td>001.03.07.04</td></tr>
<tr><td>001.03.07</td><td></td></tr>
<tr><td>001.04</td><td></td><td></td></tr>
<tr><td rowspan="3">001.08</td><td rowspan="3">001.08.03</td><td>001.08.03.01</td></tr>
<tr><td>001.08.03.02</td></tr>
<tr><td>001.08.03.07</td></tr>
<tr><td>....</td><td>....</td><td>....</td></tr>
<tr><td rowspan="4">002</td><td rowspan="2">002.01</td><td>002.01.01</td><td rowspan="4"></td></tr>
<tr><td>002.01.07</td></tr>
<tr><td>002.03</td><td>002.03.02</td></tr>
<tr><td>....</td><td>....</td></tr>
</table>

– if it is necessary to obtain a mark of the “Exam” type in the Host University, the comparison is made according to the indicators of the deepest level for this indicator of the first level.

Let us note that in each university, the principle of selecting the level of comparison of indicators can be determined independently, based on its own specifics and requirements [25–27].

If, when comparing tables according to the selected level of indicators, the codes of the Host University coincide with the codes of the tables of the Home University, a retake is not required. Otherwise, the student needs to retake only those sections of the selected modules that correspond to the uncovered indicators.

An Example of the Application of the Developed Multilevel Indicators for Automatic Transfer Credit

Let us consider the moving of a student within KNRTU-KAI between the academic programs Aircraft Engineering and Applied Mathematics and Informatics. For simplicity, we will restrict ourselves to the modules of the mathematical block listed above.

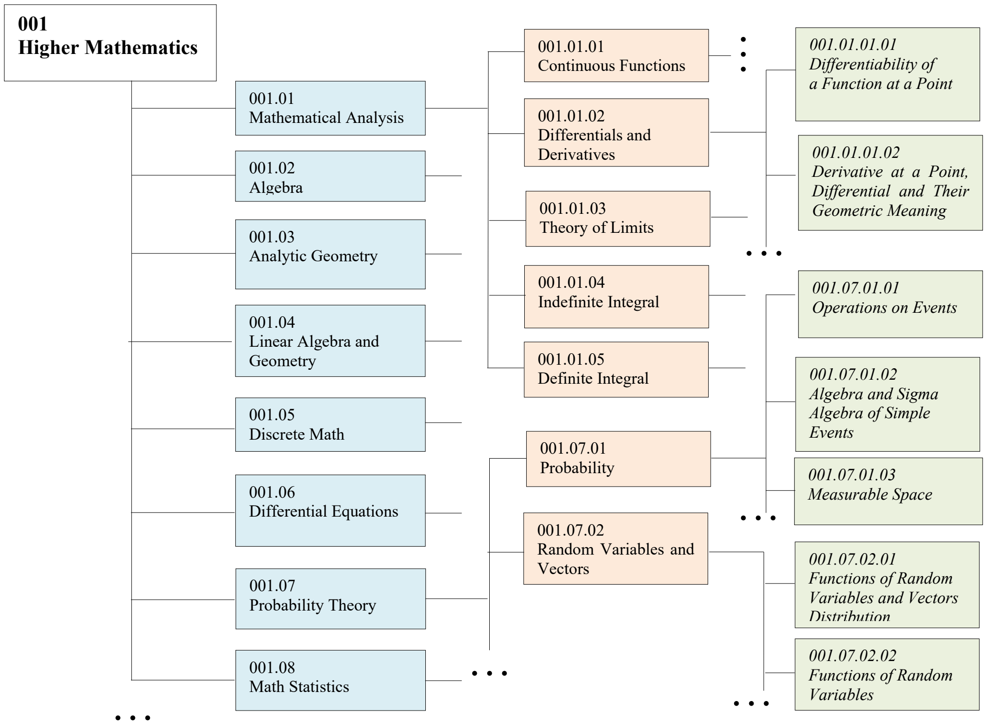
Consider the conditional assignment of codes (Fig. 7).

Initially on Aircraft Engineering program the student, we recall, has studied the module “Higher Mathematics” with the following sections: Linear Algebra and Analytical Geometry (code 001.04), Mathematical Analysis (code 001.01), Differential Equations (code 001.06), Probability Theory and Mathematical Statistics (codes 001.07 and 001.08) and Equations of Mathematical Physics (refers to section 001.06). Thus, a set of indicators of the second level, characterizing the development of knowledge in the section, has been determined. Indicators of deeper levels are determined based on the content of the working program of the modules. Suppose in the section “Mathematical Analysis” have been studied continuous functions with detailing subtopics, and the theory of limits without detailing. In the section “Probability Theory and Mathematical Statistics”, the topics “Random Variables and Vectors” have been studied with detail. Then you can create a layout of the indicator Table 3.

In the study program “Applied Mathematics and Informatics” students learn separate modules: Mathematical Analysis (code 001.01), Linear Algebra and Analytical Geometry (code 001.04), Differential Equations (code 001.06), Probability Theory and Mathematical Statistics (codes 001.07 and 001.08) with detail for all sections (topics) and subsections. Let us compose a conditional table of indicators for the mathematical block of this study program (Table 4).

After both tables have been drawn up, the decision on the need to retake or credit transfer of certain sections or modules is made as follows:

– in the case of final attestation in the form of “Test”, the moving to any of both study programs does not require an additional test of knowledge, since the list of second-level indicators in both tables is identical;



F i g. 7. Variant of Assigning Codes to the Indicator Tree of the Higher Mathematics Section (Fragment)

T a b l e 3. **A Variant of the Conditional Table of Indicators of the Mathematical Block of the Study Area 24.03.04 for the "Higher Mathematics" block**

	Indicator Set for Level 1	Indicator Set for Level 2	Indicator Set for Level 3	Indicator Set for Level 4
24.03.04-Aircraft Engineering	001	001.01	001.01.01	001.01.01.02
				001.01.01.05
			001.01.03	–
		001.04	…	…
		001.06	…	…
		001.07	001.07.02	001.07.02.01
				001.07.02.02
		001.08	…	

T a b l e 4. **A Variant of the Conditional Table of Indicators of the Mathematical Block of the Study Area 01.03.02**

	Indicator Set for Level 1	Indicator Set for Level 2	Indicator Set for Level 3	Indicator Set for Level 4
01.03.02-Applied Mathematics and Informatics	001	001.01	001.01.01	001.01.01.01
				001.01.01.02
				001.01.01.04
				001.01.01.05
			001.01.03	001.01.03.02
				001.01.03.05
		001.04	…	…
		001.06	…	…
		001.07	001.07.02	001.07.02.01
				001.07.02.02
				001.07.02.04
		001.08	…	…

– in the case of final attestation in the form of “Graded test/Test with a grade”, or at the discretion of the administration of the host educational institution, an additional test is also not required, since the indicators of the third level also coincide;

– in the case of final attestation in the form of an “Exam”, the situation differs depending on which study program the student is moved from. In the case of moving from the study program 01.03.02 to the program 24.03.04, a retake is not required, since all the indicators of the 4th level of the table for 24.03.04 are contained in the table of indicators of the same level of the table 01.03.02. In the case of a reverse moving, from the program 24.03.04 to the program 01.03.02, the student must confirm the knowledge of the module sections, the indicators of which have respectively the codes 001.01.01.01, 001.01.01.04, 001.01.03.02, 001.01.03.05, 001.07.02.04.

Discussion and Conclusion

The proposed multilevel system of inter-university indicators will significantly simplify the procedure for transferring subjects for students who are moved from one study program to another at any level – whether within one university or between different universities of the Russian Federation. The proposed methodology can be extended to foreign higher educational institutions. In this case, one of the systems of this territorial entity should be taken as indicators of achieving a certain level of knowledge. So for the universities of the European Union, such indicators can be taken from the system of standards of SEFI (European Society for Engineering Education), although not without reservations[12].

The use of an automated system for comparing the level of knowledge of a student when moving from one university to another will not only reduce the time of a student and teachers, but also eliminate the human factor, bias and subjectivity in the process of making decisions about transferring, and increase the transparency of this process.

Also, research can be expanded by creating a technology of multi-level indicators for the students transition from the bachelor level to the magister level. Such a indicators tree will allow bachelors to more adequately choose their direction of study in the magistracy.

All this together will contribute to the development of academic mobility of students, increasing their competitiveness in the labor market and strengthening academic interuniversity relationships both in Russia and abroad.

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S. V. Novikova – mathematical modeling; development of a theoretical framework.

N. L. Valitova – participated in the development and technical support of the pedagogical experiment.

E. S. Kremleva – participation in the implementation of multilevel indicators in the educational process.

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