Methods of Automated Analysis of Curricula According to the Higher Education Standard

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Abstract
The paper describes the new approaches to the automated analysis of curricula according to the higher education standard. The analysis process is proposed to carry out in two ways: (a) the analysis of completeness and sufficiency of curricula according to the standard of higher education; (b) the comparison of curricula of the same qualification and specialty. The problem of improving the quality of university students' training launches the process of monitoring and analyzing educational curricula and their correspondence to the higher education standard. We developed the rules and methods to compare curricula. In addition, we implemented the automated system of curricula comparison. The paper reveals the use of these methods based on the analysis of the curriculum bachelor level of higher education "Informatics", specialty "Computer science", at the Faculty of Computer Science and Cybernetics of the Taras Shevchenko National University of Kyiv. The findings put towards the idea that the implementation of developed methods as well as the automated system of curricula analysis will improve the educational services by higher education institutions.

Keywords:
Curricula, Higher Education Standard, Completeness and Sufficiency of Curricula, Rules and Methods to Curricula Comparing, Automated Analysis

1. Introduction

1.1. Problem Statement

In 2019, the accreditation procedure that the Ministry of Education and Science of Ukraine uses for the accreditation of curricula (educational programs) under-went significant changes [1]. This quality assurance procedure verifies the compliance of educational programs with the standards of higher education in the specialty, checks the provision of standard competencies and program outcomes with compulsory educational components, compares various educational programs, etc.

Educational programs designing, developing, and verification are an enormously complex and time-consuming processes, which requires additional time, as well as leads to the likelihood of errors. Since a plethora of spheres is increasingly adopting process automation to eliminate recurring tasks, in our opinion, the comparison and compliance analysis of educational programs can be also automated. The aforementioned determines the research relevance.

The study presents an innovative approach to the development and implementation of automated analysis of educational programs to check whether they meet the requirements of higher education standards. The analysis is proposed to be carried out in two ways: (a) compliance verification of the educational program with higher education standards; (b) comparison of educational programs of the same level in one specialty.

To test the developed methods, we selected the Bachelor's degree program "Informatics" [2], specialty 122 "Computer Science" [3], conferred by Faculty of Computer Science and Cybernetics of Taras Shevchenko National University of Kyiv (hereafter KNU-Informatics).

1.2 Related Works

The "Analysis of IT education in Ukrainian universities" [4] performed by the Better Regulation Delivery Office (BRDO) in February 2021 underlines the country's shortage of IT professionals. Indeed, the demand for qualified graduates in this field continues to grow and counts up to 30000-50000 per year, while higher education institutions annually produce an average of 16200 individuals with an IT Bachelor's degree.

At the same time, only 44% of Ukrainian university graduates get the job according to their qualifications [5], the rest do not meet the job requirements. It manifests certain IT training challenges faced by educators, in particular, the compliance of grad's

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professional training with the current needs of the IT industry. We strongly believe that high-quality analysis of "Computer Science" educational programs will much assist in reconfiguring and improving graduate programs to better prepare students for careers.

The given issue has received much attention in the past decade. For instance, [6-9] analyzed the questions of designing and developing standards of IT education-al and professional training.

In order to monitor KNU-Informatics, examine the experience of similar programs, and improve the quality of IT education, we found it necessary to compare the freely available "Computer Science" Bachelor's degree programs.

This comparison is based on the Law "On Higher Education" [10] and Higher education standard in the specialty 122 "Computer Science" for bachelor's degree, approved by the Order of the Ministry of Education and Science of Ukraine № 962 on July 10, 2019 [3].

It is worth noting that the higher education standard of the Bachelor's degree in Computer Science, which was approved in 2019, contains a technical error: Program result outcomes (PLO) 13 and PLO14 program outcomes coincide. It made it difficult to obtain valid results, as diverse educational programs took this error into account differently.

In 2019, the accreditation procedure that the Ministry of Education and Science of Ukraine uses for the accreditation.

2. Results of Investigation

2.1. Mathematical Model of Educational Program Analysis General Definitions

The analysis of educational programs will be conducted in two key directions:

(a) analysis of the educational program in terms of its completeness and sufficiency;

(b) comparative analysis of educational programs of the same level in a specialty.

For analysis, we introduce the following definitions [9]:

Set of specialties: $SP = \{sp_i \mid i=1..n\}$.

For each $sp \in SP$ let introduce the following concepts:

set of general competencies of the specialty: $ZK_{sp}=\{zk_i \mid i=1..z\}$;

set of professional competencies of the specialty: $FK_{sp}=\{fk_i \mid i=1..u\}$;

set of competencies of the specialty: $K_{sp}= ZK_{sp} \cup FK_{sp}$;

set of learning outcomes of the specialty: $LO_{sp}= \{lo_i \mid i=1..t\}$;

set of educational programs of the specialty: $OP_{sp}=\{op_i \mid j=1..m\}$.

For each $op \in OP_{sp}$ we introduce the concepts:

The set of mandatory educational components (courses) of the educational program:

$OK_{op[sp]} = \{ok_i \mid i=1..t\}$.

Predicate of covering competence by course:

$$Z_{op[sp]}\ (k_{sp}, ok_i) == \begin{cases} T, & \begin{array}{c} if\ in\ ok_i \in OK_{op[sp]}\ \&\ k_{sp} \in K_{sp} \\ \text{in } op \text{ there is a dependence between } k_{sp}, \text{ and } ok_i \\ \text{in the matrix of ensuring competencies } OKop[sp]. \end{array} \\ F. & \begin{array}{c} if\ in\ ok_i \in OK_{op[sp]}\ \&\ k_{sp} \in K_{sp} \\ \text{in } op \text{ is no dependence between } k_{sp}, \text{ and } ok_i \\ \text{in the matrix of ensuring competencies } OKop[sp]. \end{array} \\ \text{not specified}, & \text{for other cases} \end{cases}$$

For each course $ok \in OK_{op[sp]}$ let introduce the concept:

Set of competencies of the course: $K_{ok} = \{ k_{ok} \mid k_{ok} \in K_{sp}\ \&\ Z_{op[sp]}(k_{ok}, ok)\}$.

Number of competencies of the course $|K_{ok}|$.

Competency covering matrix:

For each course $ok \in OK_{op[sp]}$ we introduce the concept:

Set of learning outcomes of the course:

$LO_{ok} = \{ lo_{ok} \mid lo_{ok} \in LO_{sp}\ \&\ LOZ_{op[sp]}(lo_{ok}, ok)\}$.

Number of learning outcomes of the course $|LO_{ok}|$.

Predicate of ensuring competence by course:

$$LOZ_{op[sp]}\ (lo_{sp}, ok_i) == \begin{cases} T, & \text{if in } ok_i \in OK_{op[sp]}\ \&\ lo_{sp} \in LO_{sp} \\ & \text{in } op \text{ there is a dependence between } k_{sp}, \text{and } ok_i \\ & \text{in the matrix of learning outcomes } OKop[sp]. \\ F. & \text{if in } ok_i \in OK_{op[sp]}\ \&\ lo_{sp} \in LO_{sp} \\ & \text{in } op \text{ is no dependence between } lo_{sp}, \text{and } ok_i \\ & \text{in the matrix of learning outcomes } OKop[sp]. \\ \text{not specified}, & \text{for other cases} \end{cases}$$

Let's define a *set of different courses* on educational programs for one specialty:

$OKD_{[sp]} = \forall\ ok_{sp} \in OKD_{[sp]} \rightarrow (\exists\ op_{sp} \in OP_{sp}\ \&\ ok_{sp} \in OK_{op[sp]}) \& (\forall\ ok_1\ \forall\ ok_1\ (ok_1 \in OKD_{[sp]} \&\ ok_2 \in OKD_{[sp]}) \rightarrow ok_1 \neq ok_2)$.

Shared competences of the set of different courses on an educational programs of the specialty: $Spk(OKD_{[sp]})$:

$k_{sp} \in Spk(OKD_{[sp]}) \leftrightarrow k_{ok} \in K_{sp}\ \&$
$\forall\ ok_{sp} \in OKD_{[sp]}\ Z_{op[sp]}(k_{ok}, ok_{sp})\}$.

Number of shared competences of the set of different courses on an educational programs of the specialty: $|Spk(OKD_{[sp]})|$.

Let's call the educational program *op* in the specialty *sp* ***complete by competencies***, if there are no competencies defined by the *sp* standard that are not provided by any educational component (course) of this educational program.

Let's call the educational program *op* in the specialty sp ***complete by learning outcomes***, if there are no program learning outcomes defined by the standard *sp*, which are not provided by any educational component (course) of this educational program.

The educational program *op* in the specialty sp is called ***complete*** if it is complete in terms of competencies and complete in terms of learning outcomes.

An educational program *op* in specialty *sp* is called ***sufficient by competencies***, if there are no compulsory educational components (courses) defined by the educational program *op*, which do not provide any competence defined by the standard of specialty *sp*.

The educational program *op* in the specialty *sp* is called ***sufficient by learning outcomes***, if there are no compulsory educational components (courses) defined by the educational program *op*, which do not provide any program learning outcomes defined by the standard of specialty *sp*.

An educational program *op* in the specialty *sp* is called ***sufficient*** if it is sufficient in terms of competencies and sufficient in terms of learning outcomes.

It is obvious that the concepts of completeness and sufficiency of the educational program defined in this way are a necessary condition for its compliance with the Law of Ukraine "On Higher Education" [10]. Therefore, testing against these criteria is mandatory when analyzing the educational program.

2.2. Educational Programs Similarity by Competencies

Let's call *the coefficient of similarity by competencies of a pair of courses* in educational programs of one specialty:

$Pod_K(ok_{sp\ i}, ok_{sp\ j,}) = (Spk(\{ok_{sp\ i}, ok_{sp\ j,}\}) / |K_{ok\ i}| + Spk(\{ok_{sp\ i}, ok_{sp\ j,}\}) / |K_{ok\ j}|)/2$.

For Pod_K there are following properties:

$Pod_K(ok_{spi}, ok_{spi,})=1$ (the reflexivity of the coefficient of similarity by competences of the pair of courses);

$Pod_K(ok_{sp\ i}, ok_{sp\ j,}) = Pod_K(ok_{sp\ j}, ok_{sp\ i})$ (the symmetry of the coefficient of similarity by competences of the pair of courses).

The *set of all pairs of courses* from *op*1 and *op*2:

$Pairs(op_1[sp], op_2[sp]) = \{(ok_i, ok_j)|\ ok_i \in OK\ (op_1[sp]) \text{ and } ok_j \in OK\ (op_2[sp]) \text{ for } \forall i \in \{1, .. |OK\ (op_1[sp])|\ \forall j \in \{1, .. |OK\ (op_2[sp])|\}\}$

Metrics (coefficient) of similarity of the educational component in the educational program by competencies:

$$P_{comp}(ok, op) = max\{Pod_K(ok, ok_i)\ |\ |\ ok_i \in OK\ (op_1[sp])\}$$

Matrix of similarity of two educational programs $op_1[sp]$ and $op_2[sp]$ of one specialty *sp* by competencies:

$$P_{comp}(op_1[sp], op_2[sp]) = \left(\sum_{\forall | ok_i \in OK(op_1[sp])} P_{comp}(ok_i, op_2) \right) / |OK(op_1[sp])|$$

We will build a matrix of similarity of educational programs by competencies for the set of educational programs of the specialty $OP_{sp}=\{op_i \mid j=1..m\}$:

$$M_{P_{comp}(sp)} = \begin{pmatrix} P_{comp}(op_1[sp], op_1[sp]) & \dots & P_{comp}(op_1[sp], op_m[sp]) \\ \dots & \dots & \dots \\ P_{comp}(op_m[sp], op_1[sp]) & \dots & P_{comp}(op_m[sp], op_m[sp]) \end{pmatrix}$$

2.3. Educational Programs Similarity by PLO

Shared learning outcomes of the set of different courses in educational programs of one specialty: $Sp_{lo}(OKD_{[sp]})$:

$k_{sp} \in Sp_{lo}(OKD_{[sp]}) \leftrightarrow lo_{ok} \in LO_{sp}$ &

$\forall\ ok_{sp} \in OKD_{[sp]}\ LOZ_{op[sp]}(lo_{ok}, ok_{sp})\}$.

The number of shared learning outcomes of the set of pairs of different courses in educational programs of one specialty: $|Sp_{lo}(OKD_{[sp]})|$.

Let's call *the coefficient of similarity by learning outcomes of a pair* of courses from educational programs of one specialty:

$Pod_{lo}(ok_{sp\,i}, ok_{sp\,j}) = (Sp_{lo}(\{ok_{sp\,i}, ok_{sp\,j}\}) / |LO_{ok\,i}| + Sp_{lo}(\{ok_{sp\,i}, ok_{sp\,j}\}) / |LO_{ok\,j}|)/2$.

For Pod_{lo} there are following properties:

$Pod_{lo}(ok_{sp\,i}, ok_{sp\,i})=1$ (the reflexivity of the coefficient of similarity by *learning outcomes* of the pair of courses);

$Pod_{lo}(ok_{sp\,i}, ok_{sp\,j}) = Pod_{lo}(ok_{sp\,j}, ok_{sp\,i})$ (the symmetry of the coefficient of similarity by *learning outcomes* of the pair of courses).

Metrics of similarity of the educational component to the educational program by learning outcomes:

$$P_{lo}(op_1[sp], op_2[sp]) = \left(\sum_{\forall | ok_i \in OK(op_1[sp])} P_{lo}(ok_i, op_2) \right) / |OK(op_1[sp])|$$

For the set of educational programs of the specialty $OP_{sp}=\{op_i \mid j=1..m\}$ we can generate a similarity matrix of educational programs by learning outcomes:

$$M_{P_{lo}(sp)} = \begin{pmatrix} P_{lo}(op_1[sp], op_1[sp]) & \dots & P_{lo}(op_1[sp], op_m[sp]) \\ \dots & \dots & \dots \\ P_{lo}(op_m[sp], op_1[sp]) & \dots & P_{lo}(op_m[sp], op_m[sp]) \end{pmatrix}$$

2.4. Automating the Analysis of Educational Programs

MS SQL Server was chosen for data storage and analysis [11]. An EducationPrograms database was created for the study, which contains tables (see Figure 1):

- Universities ([PK] Id, Name, EDBO);
- Faculties ([PK] Id, Name, [FK] UniversityId);
- SpecialityCompetences ([PK] Id, Name, [FK] SpecialityId, [FK] CompetenceId);
- EdProgramsTypes ([PK] Id, TypeName);
- Specialisations ([PK] Id, Name);
- Competences ([PK] Id, Competence, [FK] CompetenceTypeId);
- EpSubjectCompetence ([PK] Id, [FK] SubjectId, [FK] SpecialityCompetenceId);

- Subjects ([PK] Id, Name, [FK] ERrogramId, Credit, [FK] ControlId);
- ControlTypes ([PK] Id, ControlTypeName);
- CompetencesTypes ([PK] Id, CompType);
- EpSubjectOutcomes ([PK] Id, [FK] SubjectId, [FK] LearningOutcomeId);
- EducationPrograms ([PK] Id, Name, [FK] SpecialityId, [FK] EdPrTypeId, EDBO, [FK] FacultyId, ImplementationDate);
- LearningOutcomes ([PK] Id, [FK] SpecialityId, LOName, LearningOutcome).

Currently the database contains the following data:
- one specialty (122 "Computer Science");
- 15 general competencies (GC), 16 special competencies (SC), and 17 of PLOs;
- 13 educational programs from 13 faculties of 12 different Ukrainian universities;
- 464 mandatory courses;
- 2759 covers of competencies by courses.
- 1061 covers of PLOs by courses.

The sample consisted of 107416 pairs of courses proposed by the aforementioned educational programs. 29500 pairs have common competencies. The next stage was to determine the competency-based coefficient of similarity for these pairs of courses.

It was found that 43751 pairs have common learning outcomes. Following this, we determined the learning outcome-based coefficient of similarity for these pairs of subjects.

2.5. Application of the Model for the Educational Program Analysis

The study investigates KNU-Informatics according to the above-described methods. The automated analysis of the given educational program demonstrated that:

(a) all competencies are provided by the courses;

(b) all courses provide competencies.

It means that KNU-Informatics meets certain completeness and sufficiency requirements.

Competency-Based Similarity of Educational Programs

As reported earlier, we have 107416 pairs of diverse courses, 29500 out of which provide common competencies.

Table 1, as well as Figure 1 and Figure 2, exemplify the calculation of the competency-based similarity coefficient of some KNU-Informatics courses concerning the courses of other educational programs.

The comparative Analysis used the following Educational Programs in the Specialty "Computer Science":

(1) Taras Shevchenko National University of Kyiv (Informatics) [2]; (2) Taras Shevchenko National University of Kyiv (Computer Science) [12]; (3) V.N. Karazin Kharkiv National University (Informatics) [13]; (4) Dnipro University of Technology (Computer Science) [14]; (5) Vinnytsia National Technical University (Computer Science) [15]; (6) Uzhhorod National University (Informatics) [16]; (7) Zaporizhzhia National University (Computer Science) [17]; (8) Lutsk National Technical University (Computer Science) [18]; (9) National University of life and environmental sciences of Ukraine (Computer Science) [19]; (10) National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" (Artificial Intelligence Systems) [20]; (11) Admiral Makarov National University of Shipbuilding (Computer Science) [21]; (12) Yuriy Fedkovych Chernivtsi National University (Algorithmic and Software of Computer Systems) [22].

Matrix of similarity of the educational programs by competencies is given in table (see Table 2).

Table 1. Competency Similarity for "Discrete Mathematics" and "Object-Oriented Programming" courses

KNU-Informatics	Discrete Math		Object-oriented programming	
	Subjects	**similarity coefficient by competences**	**Subjects**	**similarity coefficient by competences**
Dnipro University of Technology (Computer Science)	Discrete Math	0.5	Object-oriented programming	0.4167
Lutsk National Technical University (Computer Science)	Computer discrete mathematics	0.667	Object and cross-platform programming	0.5333

National University of life and environmental sciences of Ukraine (Computer Science)	Discrete Math	0.7	Object-oriented programming	0.5333
Taras Shevchenko National University of Kyiv (Computer Science)	Discrete structures	0.5	Object-oriented programming	0.4167
Uzhhorod National University (Informatics)	Discrete mathematics and theory of algorithms	0.643	Object-oriented programming	0.4242
V.N. Karazin Kharkiv National University (Informatics)	Discrete Math	0.7	Object-oriented programming (Java language)	0.4444
			Object-oriented programming (language C++)	0.4444
Vinnytsia National Technical University (Computer Science)	Discrete Math	0.611	Object-oriented programming	0.2167
Zaporizhzhia National University (Computer Science)	Discrete mathematics (for programmers)	0.4167	Object-oriented programming	0.4762

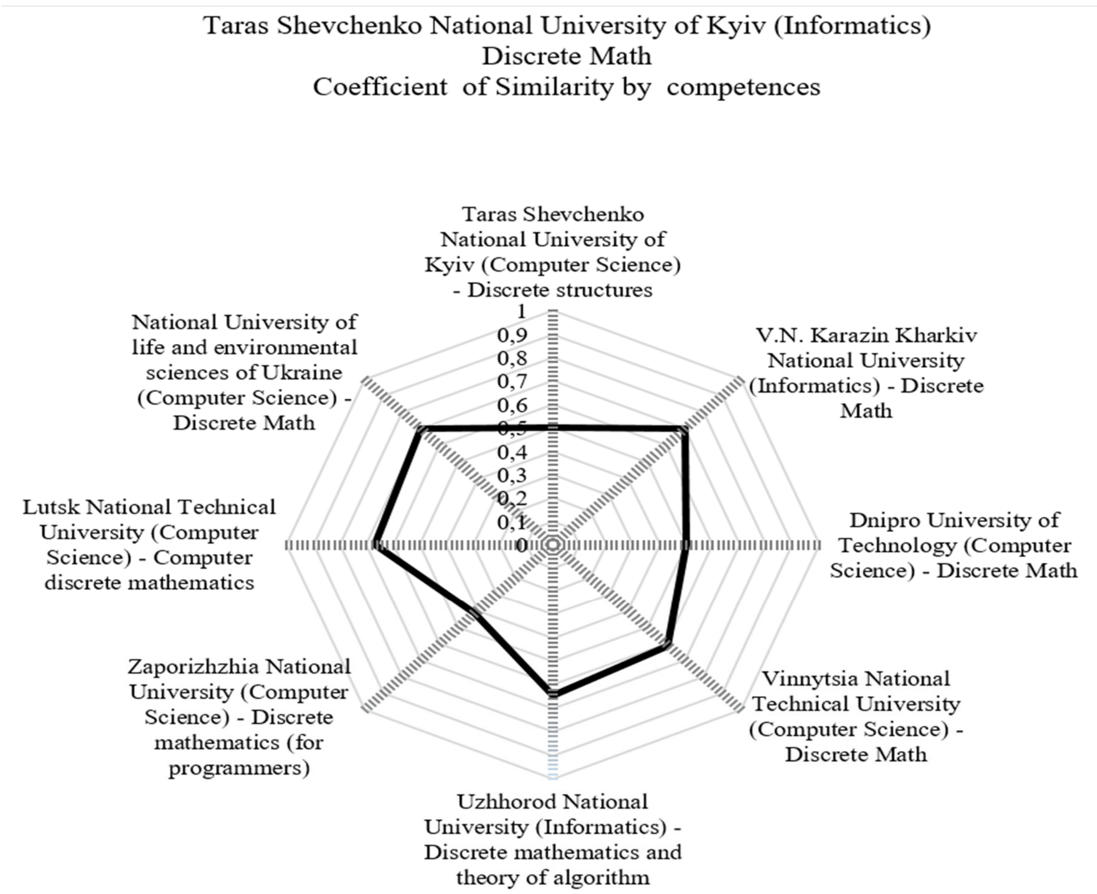

Fig. 1. Competency Similarity for "Discrete Mathematics" course

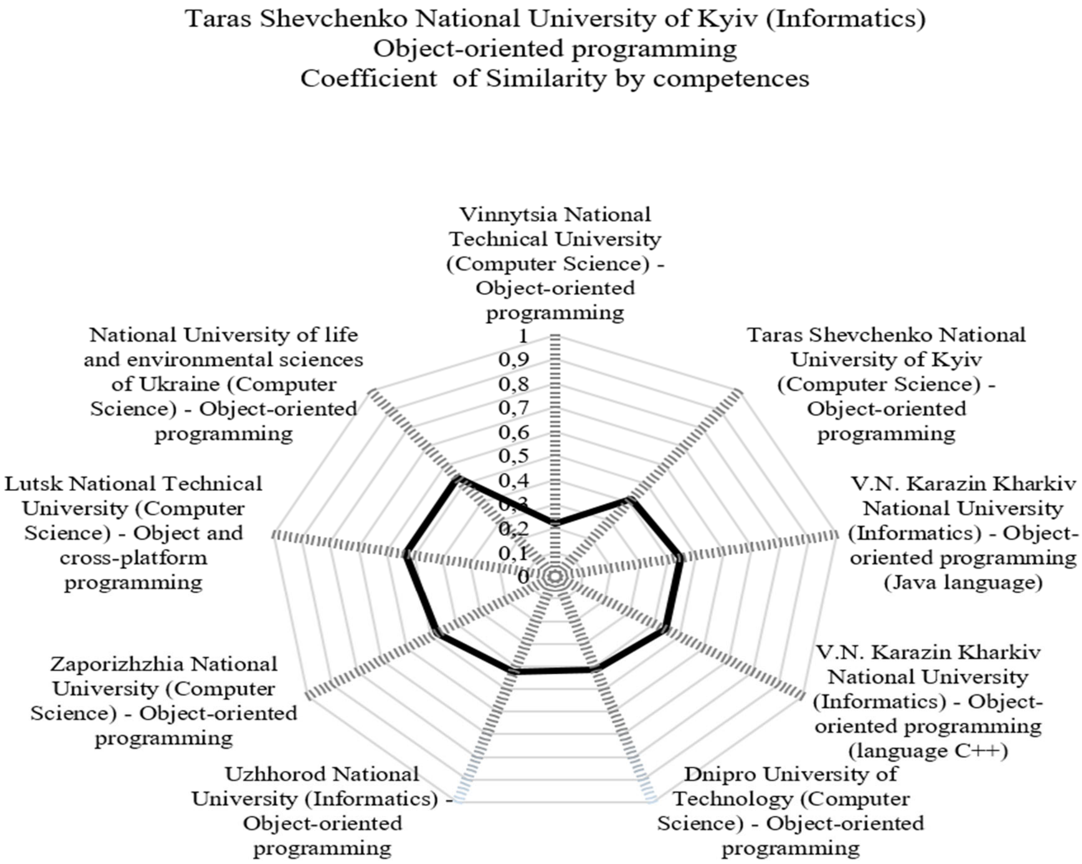

Fig. 2. Competency Similarity for "Object-Oriented Programming" course

Table 2. Matrix of similarity of the educational programs by competencies

	1	2	3	4	5	6	7	8	9	10	11	12
1	1,00	0,63	0,63	0,64	0,61	0,62	0,66	0,67	0,65	0,57	0,62	0,67
2	0,62	1,00	0,59	0,69	0,59	0,66	0,61	0,58	0,64	0,58	0,59	0,74
3	0,58	0,52	1,00	0,58	0,53	0,63	0,66	0,68	0,57	0,49	0,63	0,68
4	0,67	0,80	0,71	1,00	0,59	0,62	0,68	0,64	0,61	0,70	0,64	0,64
5	0,62	0,62	0,63	0,58	1,00	0,65	0,68	0,66	0,61	0,59	0,64	0,72
6	0,62	0,64	0,65	0,59	0,56	1,00	0,77	0,71	0,70	0,53	0,62	0,74
7	0,63	0,61	0,72	0,59	0,67	0,75	1,00	0,77	0,69	0,58	0,65	0,76
8	0,63	0,59	0,72	0,60	0,60	0,69	0,80	1,00	0,67	0,54	0,68	0,74
9	0,68	0,67	0,68	0,61	0,62	0,73	0,77	0,74	1,00	0,57	0,67	0,80
10	0,60	0,67	0,58	0,75	0,62	0,62	0,61	0,63	0,59	1,00	0,62	0,61
11	0,64	0,62	0,72	0,61	0,67	0,70	0,73	0,73	0,64	0,59	1,00	0,72
12	0,61	0,64	0,67	0,55	0,63	0,70	0,70	0,72	0,68	0,52	0,64	1,00

The analysis of the matrix made it possible to conclude that the given educational programs are characterized by an acceptable level of competency-based similarity.

Learning Outcome-Based Similarity of Educational Programs

Of 107416 pairs of subjects that were incorporated into the sample, 43751 have common learning outcomes.

The matrix of similarity of educational programs based on learning outcomes is given in Table 3.

Table 3. Matrix of similarity of the educational programs by competencies

	1	2	3	5	6	7	8	9	11	12
1	1,00	0,54	0,76	0,72	0,80	0,60	0,62	0,74	0,74	0,75
2	0,83	1,00	0,76	0,69	0,75	0,64	0,64	0,73	0,77	0,75
3	0,76	0,45	1,00	0,65	0,75	0,65	0,61	0,64	0,70	0,73
5	0,79	0,47	0,68	1,00	0,74	0,58	0,61	0,68	0,70	0,72
6	0,72	0,42	0,66	0,60	1,00	0,64	0,59	0,69	0,68	0,77
7	0,67	0,43	0,68	0,63	0,80	1,00	0,63	0,70	0,75	0,78
8	0,74	0,49	0,77	0,69	0,74	0,70	1,00	0,70	0,78	0,73
9	0,82	0,51	0,70	0,69	0,82	0,71	0,66	1,00	0,77	0,82
11	0,77	0,51	0,67	0,65	0,73	0,72	0,67	0,70	1,00	0,73
12	0,72	0,46	0,70	0,64	0,80	0,67	0,63	0,70	0,71	1,00

The result to emerge from the analysis of the matrix is that the considered educa-tional programs have an acceptable level of learning outcomes-based similarity.

Table 4 presents a summary matrix of similarity of the educational programs concerning the course similarities in terms of competencies and learning out-comes (see also Figure 3).

Table 4. Summary matrix of competency and PLO-based similarities of the educational programs

	1	2	3	5	6	7	8	9	11	12
1	1,00	0,58	0,70	0,67	0,71	0,63	0,64	0,70	0,68	0,71
2	0,73	1,00	0,67	0,64	0,71	0,63	0,61	0,68	0,68	0,75
3	0,67	0,49	1,00	0,59	0,69	0,65	0,65	0,61	0,66	0,70
5	0,71	0,54	0,65	1,00	0,69	0,63	0,63	0,64	0,67	0,72
6	0,67	0,53	0,66	0,58	1,00	0,70	0,65	0,70	0,65	0,76
7	0,65	0,52	0,70	0,65	0,77	1,00	0,70	0,70	0,70	0,77
8	0,69	0,54	0,74	0,64	0,71	0,75	1,00	0,69	0,73	0,73
9	0,75	0,59	0,69	0,66	0,78	0,74	0,70	1,00	0,72	0,81
11	0,70	0,56	0,69	0,66	0,72	0,72	0,70	0,67	1,00	0,72
12	0,67	0,55	0,69	0,64	0,75	0,69	0,67	0,69	0,68	1,00

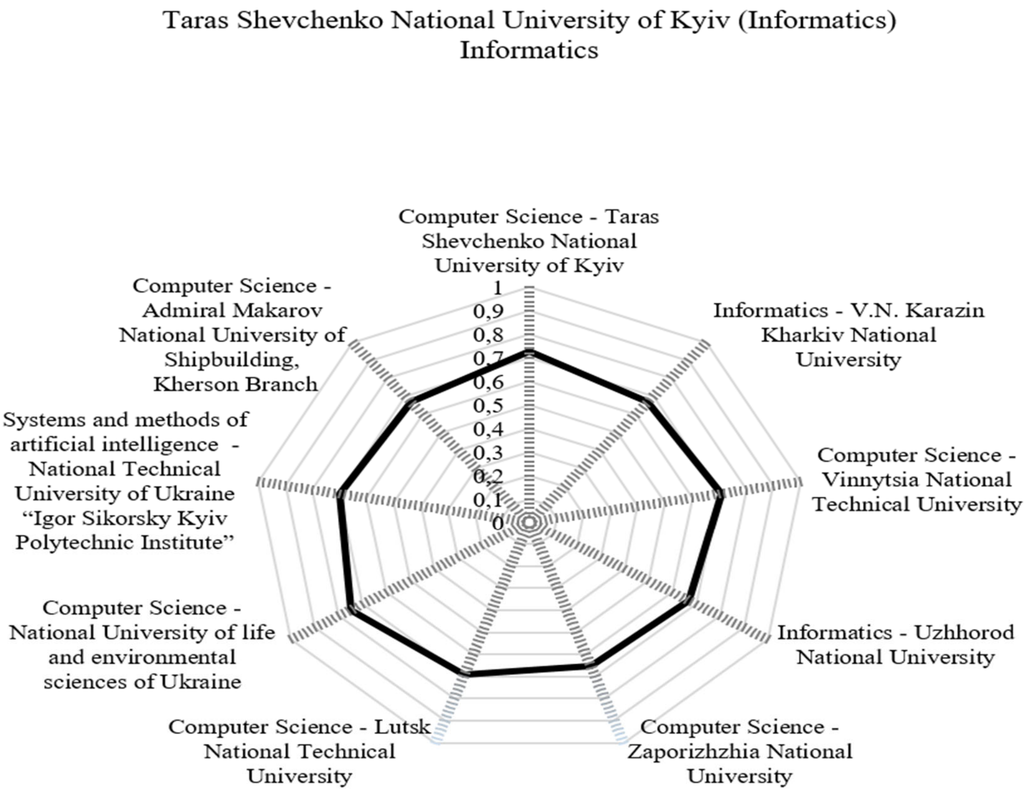

Fig. 3: Summary matrix of competency and PLO-based similarities of the educational programs

It is apparent from the matrix that all educational programs have an acceptable level of similarity. The coefficients can be exploited to determine the most and least similar educational programs.

3. Conclusions and future Perspective

This paper has stressed the importance of the mathematical model, which serves as the basis for automating the analysis of educational programs to verify whether they meet contemporary higher education standards. We succeeded in developing and implementing procedures and methods for comparing educational programs.

The application of these methods is demonstrated on the example of KNU-Informatics analysis.

These methods were employed to examine KNU-Informatics.

It is crucial to note that KNU-Informatics has neither the competencies, which are not provided by courses (program completeness) nor the courses, which do not provide competencies (program efficacy). This result has further strengthened our confidence in KNU-Informatics' complete compliance with Ukrainian legislation.

Besides, we focused on the relations between competencies and educational components in diverse educational programs, as well as carried out the comparative analysis of the courses included in educational programs.

The analysis of the course similarities shows that the content of identical courses at different universities in the specialty "Computer Science" provides the same competencies.

We strongly believe that our study will help to improve the quality of education of the IT Bachelor's degree program at the Faculty of Computer Science and Cybernetics of Taras Shevchenko National University of Kyiv.

The proposed methods and the automated system for curricula analysis is a powerful tool for increasing the provision of educational services by higher education institutions.

Our model is a precise metric to compare different educational programs by individual and general criteria, which is an excellent initial step toward automation and future areas of research that include:

- studying the dynamics of individual educational programs and the dynamics of similarity of various curricula;
- metricizing and automating comparison of related specialties standards (within the same industry and related ones);
- comparing related specialties standards in different countries;
- developing methods for analyzing the relations between educational components and assessing the adequacy of educational programs and their projects based on the matrix of compliance by using graph theory, statistical analysis, and machine learning methods;
- developing expert assessment methods for scrutinizing current higher education standards and their projects.

We are in the process of investigating the aforementioned issues.

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