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REFLECTION PAPER

AN INVESTIGATION OF THE EDUCATIONAL CURRICULUM WITH USE OF FORMAL CONCEPT ANALYSIS

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ABSTRACT

An educational curriculum is a path of learning that students should follow in their study. It consists of learning modules aimed at mastering skills and developing the necessary competencies within the qualification framework. Each module is logically completed and contains a set of related disciplines which responsible for certain group of competencies. Modularity is an attractive approach to organization of study since it provides variability and flexibility of a learning path. However, modularity significantly complicates the process of curriculum planning and developing. The goal of this work is to propose an efficient tool for planning and analysis of educational curricula, based on the mathematical apparatus of the lattice theory. We use formal lattices as a method of studying the consistency and coherence of an educational curriculum. The advantages of this method are clear algorithmization, restrictions on the inclusion of new entities and concepts, automated construction of the hierarchy of relations, analysis of collisions.

KEYWORDS

Formal Concept Analysis, Lattice Theory, Educational Curriculum

1. INTRODUCTION

The algebraic theory of lattices dealing with partial ordering relations has numerous applications in the fields of artificial intelligence such as conceptual modeling, ontology engineering and data mining. Particularly, one of the popular applications of the lattice theory is formal concept analysis – a method which allows to form hierarchies of domain concepts based on input sets of data presented in an object-feature form (Ganter and Wille 2012; Poelmans et al 2013). The concepts are defined as units of knowledge having a certain volume and content. The volume of concept (extensional) is expressed through a set of features describing the covered objects. Relations between objects and features describing them are expressed through a formal context. In this work we use formal concept analysis for investigation of university curricula.

According to the definition of UNESCO, a curriculum is a systematized purposeful set of competences (i.e. knowledge, skills and judgments supported by assessments), which can be acquired by students through the learning process taking place in both formal and informal situation (UNESCO 2017). In modular building of a curriculum, the learning process is broken into a number of stages called modules each of which contains a holistic limited set of interrelated academic disciplines. Part of modules is invariant, i.e. compulsory for learning, and part of them is variable, i.e. replaceable. The diversity and variability of the learning modules are designed to provide formation of versatile competences of students and thereby contribute to maximum full achievement of the training goals. At the same time, modularity of the curriculum seriously complicates the process of curriculum planning and development, transfers it to a multilink and multiply connected system, the assessment of the consistency and balance of which requires special tools.

Thus, the goal of this work is to develop tools for analysis of a curriculum based on the mathematical apparatus of the lattice theory. According to the set up goal, the structure of this work is as follows. In Section 2, we present some related papers. In Section 3, we provide the necessary input information from the formal concept analysis. In Section 4, we model a formal context of a curriculum and use the formal concept analysis to investigate its structure and content. In Section 5, we formulate the conclusions and plan of the further work.

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2. RELATED WORK

The problem of analysis and development of educational curricula using advanced computer tools and methods is a very popular theme among researchers. We can point out a quite great branching tree in this field. Especially popular is the so-called integrated approach which allows to consider planning and development of a curriculum in complex, on the basis of common methodology which integrates all steps from setting high-level learning goals to visualizing the learning outcomes for students.

The integrated approach to curriculum planning and development "combines both pedagogical and organizational change strategies" (Hubball and Burt 2004). There are a lot of studies which analyze these strategies. For example, authors of the just cited work associate these strategies to certain stages of curriculum design and describe each stage in a detailed manner, e.g. "During the awareness stage, curriculum leaders (Deans, committee personnel) across campus were exposed to a wide range of resources … about the benefits of learning centered curricula". Malik and Malik (2011) analyze the strategies by concerning with real cases (e.g. staff development, establishing working groups, organizing teaching materials, etc.). All such studies are helpful when getting started.

Some works are devoted to more thorough investigation of the issue of curriculum integration. For example, Drake and Burns (2004) present the methodological foundation of the process and formulates the basics of good curriculum design. All such studies are useful methodologically. Some works advocate the use of integrated curriculum on their own experience (Van Tassel-Baska and Wood 2010; McKimm 2010; Jacobs and Jacobs 2003). Such studies are useful practically.

There are a number of works focused on technological or modelling aspects. For example, Monette et al (2007), Hnich et al (2002), Chiarandini et al (2012), Ünal and Uysal (2014) investigate the problem of curriculum balancing, which is, in general, related to the aim of our work. The last paper we want to mention is (Škopljanac-Mačina and Blašković 2014). They, as we, use formal concept analysis in the field of teaching. The difference is that they provide subsequent analysis of the examination tasks whereas we investigate a curriculum structure.

3. FORMAL CONCEPT ANALYSIS. BRIEF INFORMATION

A formal context is a triple $K = \langle G, M, I \rangle$, where G is a set of objects, M is a set of features, I is a correspondence between G and M: gIm means that object $g \in G$ possesses an feature $m \in M$. For arbitrary subsets $A \subseteq G$ and $B \subseteq M$, we introduce Galois operators: $A' = \{m \in M | \forall g \in A\ gIm\}$, i.e. A' is a set of features which refer to all objects from A; $B' = \{g \in G | \forall m \in B\ gIm\}$, i.e. B' is a set of objects which possess all features from B.

Let us explain concepts of a formal context and Galois operators on the example of a set of natural numbers from 1 to 9 and three features of evenness, oddness and primality. We have a set of objects $G = \{1, 2, \ldots, 9\}$, a set of features $M = \{\text{odd}, \text{even}, \text{prime}\}$. A formal context can be presented in the form of an object-feature binary matrix: if a number from G possesses an feature from M, we put 1(check) at the intersection of the corresponding row and column of the matrix, otherwise 0 (see Table 1). For a subset $A = \{1,2,3\}$ we have $A' = \{\text{prime}\}$ and for subset $B = \{\text{prime}\}$ we have $B' = \{1,2,3,5,7\}$. As we see, though $A' = B$, however, $B' \neq A$.

A formal concept of a context K is called a pair of the form (A, B), $A \subseteq G$ and $B \subseteq M$ such that $A' = B$ and $B' = A$. As is mentioned above, set A is called a concept volume and B – its content. The two concepts (A_1, B_1) and (A_2, B_2) are called partially ordered $(A_1, B_1) \leq (A_2, B_2)$, if the volume of the first concept enters (inclosed) into the volume of the second one $A_1 \subseteq A_2$. A set of all concepts of a context K ordered by insertion of their volumes is called a concept lattice.

Table 1. An Example of a Formal Context Given in the Form of a Binary Matrix

A	B	C	D
	Odd	Even	Prime
1	X		X
2		X	X
3	X		X
4		X	
5	X		X
6		X	
7	X		X
8		X	
9	X		

In the above considered example, a pair "object-feature" $(A_1 = \{1,3,5,7\}, B_1 = \{\text{uneven}, \text{prime}\})$ forms a concept "a prime odd number", and a pair $(A_2 = \{1,2,3,5,7\}, B_2 = \{\text{prime}\})$ forms a wider concept "a prime number". In the mentioned context of 9 numbers and 3 features we can highlight 7 concepts: a number, an even number, an uneven number, a prime number, a prime even number, a prime uneven number and an empty concept corresponding to the number simultaneously even and uneven (see Figure 1).

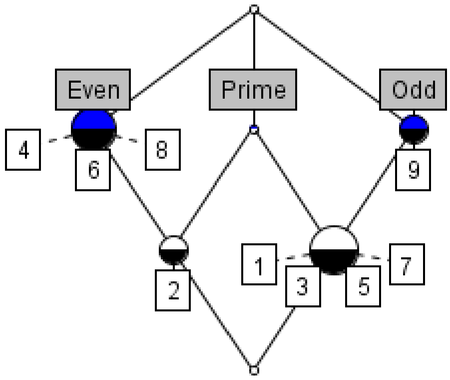

Figure 1. An Example of a Formal Context Given in the Form of a Lattice

A feature implication $B_1 \rightarrow B_2$ is the dependence of features $B_1, B_2 \subseteq M$ such that all objects possessing all features from B_1 also possess all features from B_2. That is, $B_1 \rightarrow B_2$ is an feature implication if and only if $B_1{}' \subseteq B_2{}'$. Feature implications satisfy axioms of reflexivity$(X \rightarrow X)$, augmentation (if $X \rightarrow Y$, then $X \cup Z \rightarrow Y$) and transitivity (if $X \rightarrow Y$ and $Y \cup Z \rightarrow W$, then $X \cup Z \rightarrow W$) which are also known as Armstrong's rules [1]. An implications basis is a minimum set of implications from which all other implications can be derived by Armstrong's rules.

In the above considered example, a formal context does not allow to determine any feature implication. If a number is prime, it is not necessarily even (numbers 1, 3, 5, 7) and not necessarily uneven (number 2); if a number is uneven, it is not necessarily prime (number 9) and so on. If we extend the considered context by a new feature "square of the number is divisible by 4", we will at once have two feature implications: if the number is even, the square of the number is divisible by 4; if the square of the number is divisible by 4, the number is even. It should be noted that introduction of such feature does not increase the number of context concepts.

The concept of implication in the lattice theory is closely related with the concept of association rule in the data mining. Implication is an association rule the reliability of which is equal to 1(100%) (Bazin and Ganascia, 2012). In the considered by us example one can define the following association rule: if the number is prime, it is uneven. The reliability of this rule is 80%, that is the rule works in 80% of cases (numbers 1, 3, 5, 7) and does not work in 20% of cases (number 2).

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4. INVESTIGATION OF THE STRUCTURE OF UNIVERSITY CURRICULUM WITH THE HELP OF FORMAL CONCEPT ANALYSIS

Due to the complexity of the curriculum structure, its formal context can be determined not by a single way. Everything depends on how it is necessary to analyze a curriculum. For example, if we choose academic disciplines as objects of formal context, we must indicate competences developed by these disciplines, terms when they are studies or the expected learning outcomes as features. If the matrix is to be transposed, the objects will be competences, terms or outcomes and features will be disciplines.

Let us consider a competencies distribution matrix in academic disciplines as a formal context. Table 2 presents an example of such context the prototype of which was a competencies matrix of the “Information systems and computer modelling” curriculum developed in one of Kazakhstani universities. The proposed matrix is created by Concept Explorer and describes distribution of the next general professional competencies (PC):

PC1 – students are able to perceive and apply mathematical, professional knowledge;

PC2 – students are able to reason analytically, to make judgments under incomplete information;

PC3 – students are able to analyze and assess the levels of their competencies, to self-learn;

PC4 – student are able to communicate in English, to use professional terminology;

PC5 – student are able to use methods of information collecting, storing, processing, and transporting.

PC6 – student are able to analyze and structure professional information, to highlight trends and core information, formalize and represent information in the form of review, to resume.

The lattice of concepts built on the basis of this formal context allows to assess the competencies matrix visually. So, for example, it is seen in the lattice presented in Figure 2 that competences PC1 and PC6 (formed by 8 disciplines) have the greatest weight.

Table 2. A Sample of a Formal Context for an Educational Curriculum

A	B	C	D	E	F	G
	PC1	PC2	PC3	PC4	PC5	PC6
Decision theory	X	X				X
CAD	X	X			X	X
Requirements analysis	X					X
Intelligent systems	X	X		X		X
Data Mining	X	X			X	X
Experimental data procecing	X	X	X		X	
Control theory	X	X			X	X
Designing of intelligent systems	X	X			X	
Special chapters of math			X			X
Information processes modelling					X	X

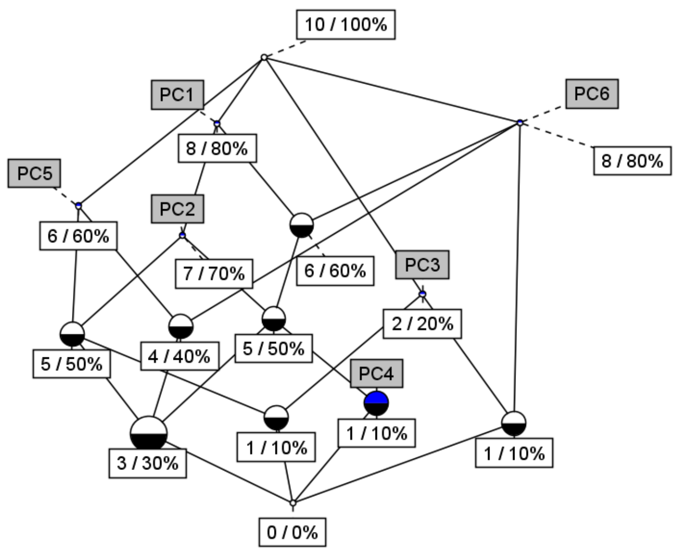

Figure 2. A Lattice of Competencies

On the basis of the lattice, Concept Explorer forms 5 feature implications which characterize interrelations between competencies:

1 < 7 > PC2 ==> PC1;

2 < 5 > PC1 PC5 ==> PC2;

3 < 1 > PC1 PC3 ==> PC2 PC5;

4 < 1 > PC3 PC5 ==> PC1 PC2;

5 < 1 > PC4 ==> PC1 PC2 PC6;

Implication 1 shows that in 7 disciplines the presence of competency PC2 involves the presence of competency PC1, i.e. competency PC1 (ability to perceive and use knowledge) is likely to enter into the composition of competence PC2 (ability to reason). Correspondingly, we can formulate the following rule which we will call the rule of competency absorptions. If in several cases there takes place implication X2→X1, it is probable that competency X1 is not independent but is a part of a more general competency X2. Thus, it is necessary to perform the further analysis whether competency X1 can be excluded from the list of basic competencies and, correspondingly, reduce their redundancy. Anyway, we can assert that competency X2 is deeper than competency X1.

Implication 2 indicates the fact that if a discipline forms competency PC1 (ability to perceive and use knowledge) and PC5 (ability to work with information), then competency PC2 (reasoning ability) is necessarily formed. This indicates that ability to draw conclusions PC2 is part of a more complex competence, which based both on the ability to use knowledge PC1, and on the ability to obtain and process new information PC5. It will be efficient to present all three competencies as components of stronger one which can be treated as soft skills competency. Therefore, we can formulate the following rule which we call the rule of complex competency. If in several cases there takes place implication X2, X3→X1 under the implication X2→X1, it is probable that competencies X1, X2 and X3 are parts of a more complex competency.

Implications 5 shows that if a discipline form competency PC4 (ability to communicate in English for professional purpose), then competencies PC1 (ability to understand), PC2 (ability to reason) and PC6 (ability to conclude and present results) should be necessarily formed. Hence, there is a probability that competencies PC1, PC2 and PC6 are necessary but not sufficient to form one competency PC4. Thus, we can formulate a rule which we will call the rule of necessary competencies. If in several cases there takes place implication X1→X2, X3,..., XN, then it is probable that competency X1 is based on the competencies X2,.., XN.

Reasoning similarly, we can develop a whole number of rules which would allow to reduce redundancy, red rid of circles and duplicates, analyze collisions in the structure of curricula. All this allows us to speak about prospects of the apparatus of formal lattices as a tool of studying the consistency and coherence of curricula. Its advantages are clear algorithmization, strict discipline when introducing new entities and concepts, automated construction of the hierarchy of relations, and also analysis of collisions. In our case we have no collisions but we suppose that the simultaneous presence of two implications of the form X2→X1 and X1→X2 can alert that competencies X1 and X2 duplicate each other (different names of one ability). Also in favor of collisions can indicate the simultaneous implications X2, X3→X1 and X1, X3→X2, which alerting to the presence of methodological problems in the educational program. All this requires further careful analysis, and allows a certain degree of optimism speak about the prospects of development of expert system for the analysis of educational programs on the basis of the proposed apparatus of formal lattices.

As feature implications satisfy axioms of reflexivity($X \rightarrow X$), augmentation (if $X \rightarrow Y$, then $X \cup Z \rightarrow Y$) and transitivity (if $X \rightarrow Y$ and $Y \cup Z \rightarrow W$, then $X \cup Z \rightarrow W$), which are also known as Armstrong's rules, we can determine the basis of implications from which all the other implications will be derived by Armstrong's rules.

5. CONCLUSION

According to the predictions of the World Bank, the structure of the national wealth of the countries in which a smart-society is formed will look like as follows: 5% of it will consist of natural resources, 18 % – of material production capital, 77 % – of knowledge and skills of people which become truly valuable and will determine their future. Correspondingly, the most important question is training of personnel who can create a “smart” environment, produce new values performing "smart" work.

Analysis of formal lattices and all directions of the promising fields such as Data Mining and Text Mining are exactly those smart tools with the help of which a person forms an intellectual space around him. Our subsequent works will be related to the further investigations on the listed tools for analysis of curricula.

REFERENCES

Ganter B., Wille R. (2012). Formal concept analysis: mathematical foundations. Springer Science & Business Media.

Poelmans, J. et al. (2013). Formal concept analysis in knowledge processing: A survey on applications. Expert systems with applications, 40(16), pp. 6538-6560.

UNESCO, 2017. UNESCO. Education: Curriculum. [reviewed 22 March 2017]. Available from http://www.unesco.org/new/en/education/themes/strengthening-education-systems/quality-framework/core-resources/curriculum/

Bazin, A. and Ganascia, J.-G. (2012). Completing terminological axioms with formal concept analysis. In ICFCA, pp. 29-40.

Hubball H. and Burt H. (2004). An integrated approach to developing and implementing learning-centered curricula. International journal for academic development, 9(1), 51-65.

Malik A., Malik R. (2011). Twelve tips for developing an integrated curriculum. Medical teacher, 33(2), pp. 99-104.

Drake S. M., Burns R. C. (2004). Meeting standards through integrated curriculum. ASCD.

Van Tassel-Baska, J., Wood, S. (2010). The integrated curriculum model (ICM). Learning and individual differences, 20(4), pp. 345-357.

McKimm, J. (2010). Current trends in undergraduate medical education: program and curriculum design. Samoa Medical Journal, 1(2), pp. 40-48.

Jacobs, C. and Jacobs, K. (2003). An integrated approach to curriculum at foundation level. Journal of Engineering, Design and Technology, 1(1), pp. 89-101.

Monette, J.et al. (2007). A CP approach to the balanced academic curriculum problem. In 7th International Workshop on Symmetry and Constraint Satisfaction Problems, Vol. 7.

Hnich, B. et al. (2002). Modeling a balanced academic curriculum problem. In Proceedings of CP-AI-OR-2002.

Chiarandini, M. et al. (2012). The balanced academic curriculum problem revisited. Journal of Heuristics, 18(1), pp. 119-148.

Ünal, Y. and Uysal, Ö. (2014). A new mixed integer programming model for curriculum balancing: Application to a Turkish university. European Journal of Operational Research, 238(1), pp. 339-347.

Škopljanac-Mačina, F. and Blašković, B. (2014). Formal concept analysis–overview and applications. Procedia Engineering, 69, pp. 1258-1267.