

BAYESIAN APPROACH FOR COMPETENCE FORMATION FOR STUDENTS OF IT-SPECIALTY

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ABSTRACT

The Bayesian networks theory has recently become very popular in solving various applied problems in multiple fields of science and industry. For the practical application of the Bayesian approach, a high quality software product that implements the mathematical theory of Bayesian networks is required. The Bayesian approach is a promising approach for creating an intelligent environment to enhance student competence. To implement Bayesian networks, the BayesiaLab application software package is well suited and is one of the high-quality software products, which is specialised in artificial intelligence technologies. With the help of the BayesiaLab package, various models of Bayesian networks can be created, explored, edited and analysed. This article introduces student competences and explores the possibilities of using Bayesian networks in the formation of the competences of information technology (IT) students and for this purpose, a general algorithm and a specific architecture of the intellectual environment have been developed. It is a known fact that improved professional competence in education increases the competitiveness of specialists and updates the corresponding educational environment.

Keywords: *Bayesian approach, competence formation, IT students, education, BayesiaLab package*

1. INTRODUCTION

In modern pedagogical literature, the categories competence and competence are widespread [1]. The analysis of a number of scientists' works allows us to pick out several approaches to the definition of the concepts competence and competence.

In the papers T.E. Isaeva, N.T. Pechenyuk, N.F. Talyzinoy, A.V. Khutorskoy, K.V. Shaposhnikova et al [2] competence is understood as a set of interrelated personality traits such as knowledge, skills, abilities, and ways of doing things. Competence is understood as the possession of a person with relevant competence. In their opinion, a competent person has the relevant knowledge and abilities that enable him to reasonably judge such field.

The analysis of psychological and pedagogical literature allows us to give a generalized definition of the term competence (as obtained as a result of training in the university a knowledge, skills,

abilities and ways of activity aimed at successful professional self-realization) and competence (the ability and willingness to use the competences acquired and developed at the university to solve educational and professional problems).

Competence means to be able to accumulate and apply its knowledge, skills, experience, that is, to focus on the real situation and engage in action. At the same time, the nature of competence and competence emerged, and education in the field of education is double-edged. First of all, it depends on social and individual reasons (individuality). It opens opportunities for people to achieve goals and personality. Then, depending on the goals of the educational wor. The purpose of the higher education institution is to train professionals with a psychological readiness to work in the labour market.

It is necessary to take into account the following criteria for competence development: mobility, flexibility and critical thinking. Finding the right information and explaining the

information create a mobility of knowledge. Flexibility is the organization of the use of information in different ways. Transforming information, finding evidence and making decisions form a critical thinking. By building these skills we will reach the required competence.

Currently, Bayes' approach is a perspective aspect for solving applied problems in various research areas. Mathematical methods and computer technologies are widely used in biology, technology and medicine. The technique of a monotheist gives precise solutions and theoretical development of these sciences [1].

The method of monotheism is not only rapidly developing in the field of science and technology, but also in the field of education. The method of education is used to determine the quality of students' education of in education system, testing systems and competence of students.

2. LITERATURE REVIEW

Recently, the Bayesian approach has become a promising direction in solving applied problems in various fields of research. Mathematical methods and computer technologies are widely used in biology and medicine. Bayesian methods are used in the possibility of obtaining more accurate solutions and in the theoretical development of these Sciences [3]. [4] describes a program that determines the risk of clinical manifestation of caries. It is calculated by a computer program using Bayes' theorem. The developed diagnostic algorithm is a quick and easy way to clinically determine caries in children at an early stage.

The possibilities of artificial intelligence (AI) have been widely used in practical medicine [5]. In this work, a model based on the Bayesian network has been developed. This model is used for initial diagnosis of diseases that are manifested by high blood pressure. The structure and parameters of the model at this stage are determined by literary information on the significance of complaints, symptoms and other signs as indicators of the diagnosed disease. The publication [6] discusses a method of predicting breast cancer outcomes by using Bayesian networks built on the basis of a database of patients with a verified diagnosis of breast cancer. This work differs from other works in that it uses naive Bayesian networks. Using significant parameters of a particular patient, based on the conditional probability of the corresponding outcome obtained in the Bayesian network survey, this patient is assigned to one of the risk groups and the obtained value is used to determine the

prognosis, i.e. progression or death, using the absolute probability risk histograms.

Bayesian approaches have received good use in the field of bioinformatics. [7] discusses the problem of recognizing the secondary structure of proteins using Bayesian procedures. An empirical Bayesian network has been built that surpasses other methods in prediction accuracy.

The article [8] describes the models of assessing the intensity of socially significant behavior of students' research projects using the Bayesian trust network.

The Bayesian approach is also used in solving many statistical problems, in economic analysis, in statistical estimation [9]. The main difference between the Bayesian approach and other approaches is that before data is obtained, the decision maker considers the extent of his confidence in possible models and presents them as probabilities. Once the data is obtained, Bayes' theorem allows to calculate a new set of probabilities.

Today, the application of the Bayesian approach in the definitions of the student model is well developed and is one of the main components of intelligent computer systems. The study [10] describes the process of building a Bayesian network for modeling learners. The main steps in this process include identifying variables, defining structure, and defining parameters. Calculations are performed using the built Bayesian network. [11] presents a new approach to diagnostics in student modeling, based on Bayesian networks and computer adaptive tests. A new integrated student Bayesian model is defined and combined with an adaptive testing algorithm. The advantage of the proposed structural model is the ability to detail students at different levels, which makes it possible to significantly simplify the determination of parameters (conditional probabilities) for building a Bayesian network that describes the student's model and supports the adaptive diagnostic algorithm. The validity of the approach is verified using the student model. The results show that the student's Bayesian model is accurate and efficient.

In [12], an expert system of assessing the professional competence of future IT specialists has been developed. This system is implemented based on the Bayesian inference model.

In paper [13] discusses one new cycle, which will help students get more information about mathematical modeling. Using IBM SPSS Modeler will help students deeply understand the basics of the modeling process. Students will better understand the real problem, analyze the correlation

of data, use software for building models, and present the results in the form of tables or graphs.

In paper [14] was created a common model for Computerized Adaptive Testing (CAT). This model was created by three different types of models. In the future, we will focus on the BN models, because the models we experimented with Bayes Network gave the best potential.

The article [15] proposes a methodology in which the process of collecting and preprocessing data was initially carried out, and then at the second stage, students were grouped with similar performance models. At the next stage, on the basis of the revealed patterns under observation was chosen the most appropriate learning algorithm, and then the experimental process was conducted. The results showed the effectiveness of machine learning methods for predicting student performance.

The only way to define competence is to build a student model. The student model can be based on different approaches (neural networks, neuro-fuzzy logic, fuzzy logic, Bayes Networks). The student model is one of the basic components of intelligent computer learning systems, and it contains sufficiently complete information about the student: his level of knowledge, skills and abilities, ability to learn, ability to perform tasks, personal characteristics and other parameters. The student model is dynamic, i.e. changes during the course and while working with the system [16,17].

The article [18] describes the general scheme of work with a list of competencies that is formulated in the education standard. Considered examples of assessing the level of competence formation.

Bayesian approaches are easy tool for describing sufficiently complex processes and events with uncertainties. The basic idea of building a network is the decomposition of a complex system into simple elements. To integrate individual elements into a system is used the mathematical apparatus of probability theory. This approach provides the ability to build models with many interacting variables for the subsequent development of efficient data processing and decision-making algorithms. From a mathematical point of view, the Bayesian approach is a model for representing probabilistic dependencies, as well as the absence of these dependencies [19].

To describe the Bayesian approach, it is necessary to determine the structure of the graph and the parameters of each node. This information can be obtained directly from the data or from expert assessments. Such a procedure is called learning the Bayesian approach [20].

As noticed in [21], the Bayesian approach is a common choice of researchers for describing the fuzzy connection between student achievements and their competences in many research projects. Since the late 90s of the last century, models based on Bayesian approaches have been actively used in the development of computer-aided learning tools [22].

The structure of the Bayesian approach reflects the structure of students' knowledge, and it can be a tool with which we can make judgments and assessments regarding the level of student readiness, as well as make decisions [21].

In paper [23] Bayesian approaches were classified into three types. The first type of models in which experts determine the network structure, as well as initial and conditional probabilities. The second type is models aimed at maximizing efficiency by limiting the structure of the network. The third type is data-based models that use data from previous experiments to generate a network structure and probability values.

The attractiveness of Bayesian models are in their high performance, as well as in an intuitive representation in the form of a graph [24].

Paper [25] considers the problem of knowledge modeling with adaptive testing of students in a given discipline. The structure of the training course involves the division of discipline into chapters, and each of the chapters, in its turn, corresponds to a set of concepts. Testing includes a set of test items, each of which may require ownership of one or more concepts. In its turn, the possession of each of the concepts may be necessary to perform one or several test tasks. This work uses a Bayesian approach with binary variables, associated disciplines, topics, concepts, and questions (assignments). Conditional probabilities for variables are set by the teacher.

The article [26] describes models for assessing the intensity of socially significant behavior of students' research projects using the Bayesian approach of trust.

The Bayesian approach is also used to solve many statistical problems, economic analysis, and statistical estimation [27]. The main difference between the Bayesian approach and other approaches is that the decision maker considers his confidence in possible models and presents them in the form of probabilities before the data are received. Once data is obtained, Bayes theorem allows to calculate a new set of probabilities.

Presently, the use of the Bayesian approach to the definitions of a student model is well developed and one of the main components of intelligent

computer systems. The paper [28] describes the process of building a Bayesian approach for student modeling. The main stages of this process include the identification of variables, the definition of structure and the definition of parameters. Calculations are carried out using the Bayesian approach.

Table 1: Examples of techniques for transport data processing

3 STATEMENT OF THE PROBLEM.

The statement of the problem is formed as follows: it is necessary to create a methodology for the formation of the student’s competence in an IT specialty based on the Bayesian approach.

The task definition is formed as follows: it is necessary to form the competence of the student in the direction of IT using the Bayesian approach.

While solving such problems, which require the consideration of uncertainty, the Bayesian approach is perspective.

The Bayesian approach is based on the Bayes theorem, which is described as follows [29]:

$$P(A_i|B) = \frac{P(B|A_i)P(A_i)}{P(B)}$$

(i=1,2,...,n).

where, $P(A_i)$ is the a priori probability of hypothesis A_i ;

$P(A_i|B)$ - the probability of hypothesis A when an event B occurs;

$P(B|A_i)$ - probability of occurrence of event B with the validity of hypothesis A_i ;

$P(B) = \sum_{i=1}^n P(A_i)P(B|A_i)$ - the total probability of an event B.

A probability model for a classifier is a conditional model $P(C | X_1, \dots, X_n)$ over a dependent

class variable C with a small number of classes or outcomes conditional on a number of variables (X_1, \dots, X_n) . For an instance to be classified, the Naive Bayes Classifier (NBC) uses the Bayesian formula to calculate the probability of each class

C given the values X_i of all the attributes. Assuming conditional independence of the attributes: X_i is conditionally independent of every other attribute X_j for $j \neq i$. The joint model can be expressed as:

$$P(C | X_1, \dots, X_n) = P(C) \prod_i^n P(X_i | C).$$

The NBC combines this model and the decision rule. The most common rule is the hypothesis that is most probable known as maximum a posteriori. The corresponding classifier is the function classify defined as classify

$$(f_1, \dots, f_n) = \arg_c \max P(X = x) \prod_{i=1}^n P(X_i = x_i | C = C).$$

Today, when determining the competence of a student, it is important to use the Bayesian approach. Bayesian approach clearly and clearly displays the results of the study.

Using the Bayes formula, we can more accurately recalculate the probability, based on previously known information and new observations [26].

To form the competence of the students, it is necessary to consider the following: mobility, flexibility and critical thinking factors. Finding the right information and explaining the information create mobility of knowledge. The information conversion, the search for evidence and decision-making form the critical thinking [30].

Today, when determining the competence of a student, it is important to use the Bayesian approach. Bayesian approach clearly displays the results of the study.

Once a Bayesian approach has been constructed, it is ready for inference. The logical inference commences by computing the probability of each state of each variable in the network. After introducing some observations (evidence) the posterior probabilities are computed. Those probabilities can then be used to determine the most likely causes of a certain event or a set of events or to predict the results of a test or a set of tests.

To build competence, we built a 3 element bayes network. We have divided into several levels these built-in elements. These elements and element levels are closely interconnected. We believe that each student can demonstrate very high, high, medium and low results in accordance with the knowledge, skills, abilities and potential elements. We have already discussed these levels of assessment.

In the Bayesian approach competence-oriented tasks are connected by ribs with those

competencies, which they check up [31-35]. At this situation knowledge mobility, method flexibility, critical thinking are competencies, edges are associated with these competencies are competence-oriented tasks. Several competence-oriented tasks can be associated with one competence. At the same time, the number of such tasks should not be less than the number of predetermined levels of competence.

creating such an environment - to educate IT specialty students and lead them to some competence. We used a package (software) to determine competence. We have designed competencies based on three criteria and developed a system of questions on each criterion. We determined the competence of the student through this system of questions. These criteria are closely interconnected.

4 INTELLECTUAL ENVIRONMENT ARCHITECTURE

The overall architecture of the Intelligent Environment is shown in Figure 1. Our main goal is

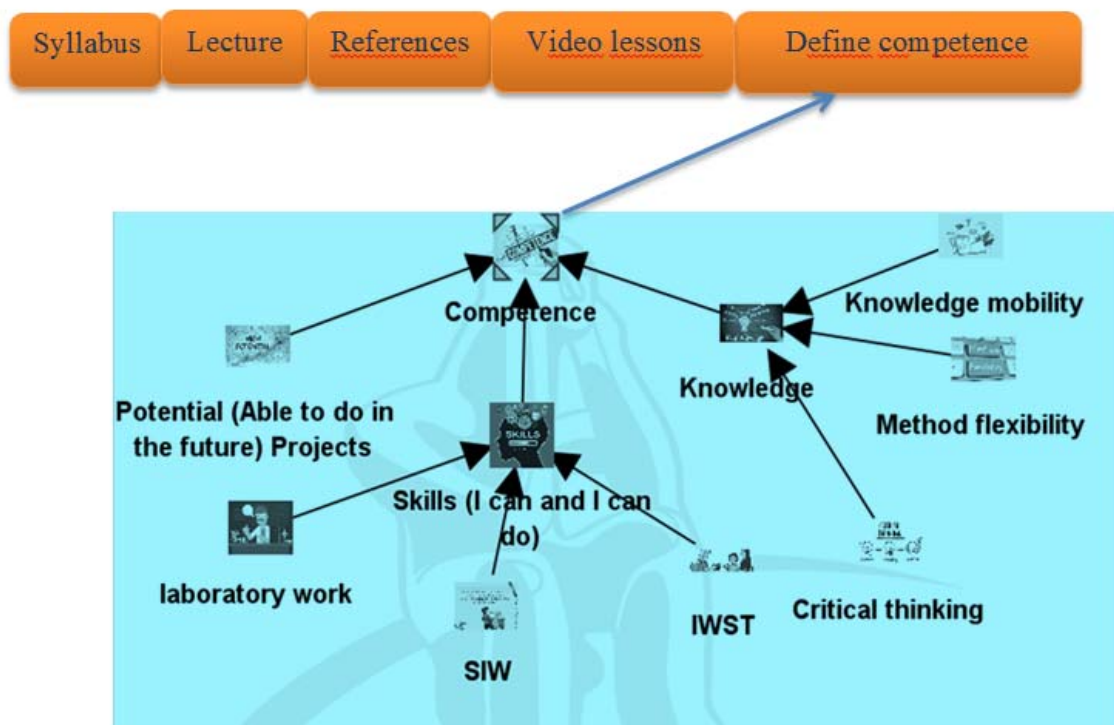


Fig.1. Intellectual environment architecture

Advantages of the Intellectual Environment:

- Helps to define the competence of students.
- Many visual aids for teachers are offered in English.
- Allows to study at any convenient location and at any time.
- Efficiently combines learning and new technologies.
- Presets everyone equal opportunities for quality education.

5 MATERIALS AND METHODS

5.1. Structure of the Bayesian network

Students' competence model was invented for testing software products using Bayesian networks. The model is in no way connected with any real task. Matches can only be random. We describe this model.

- It is required to determine the possibility of building a student's competence.
- This requires the determination of competency elements and its levels of competency definition

- For simplicity of the model, we assume that the student’s formation depends on three elements: knowledge, skill and potential

Also, for simplicity, we assume that knowledge depends on its levels: the mobility of knowledge (being able to find the necessary information), the flexibility of the method (the ability to use information in various situations), critical thinking (transforming information, finding arguments, making decisions, acting in changing conditions).

- We assume that the skill depends on the student’s independent work, laboratory work and the student’s independent work with teachers.

- We assume that the student’s potential is determined by his ability to develop and with the development direction.

Bayesian network consists of nine nodes and ten interconnections (arcs) between nodes. Bayesian network corresponding to this model is shown in Figure 2.

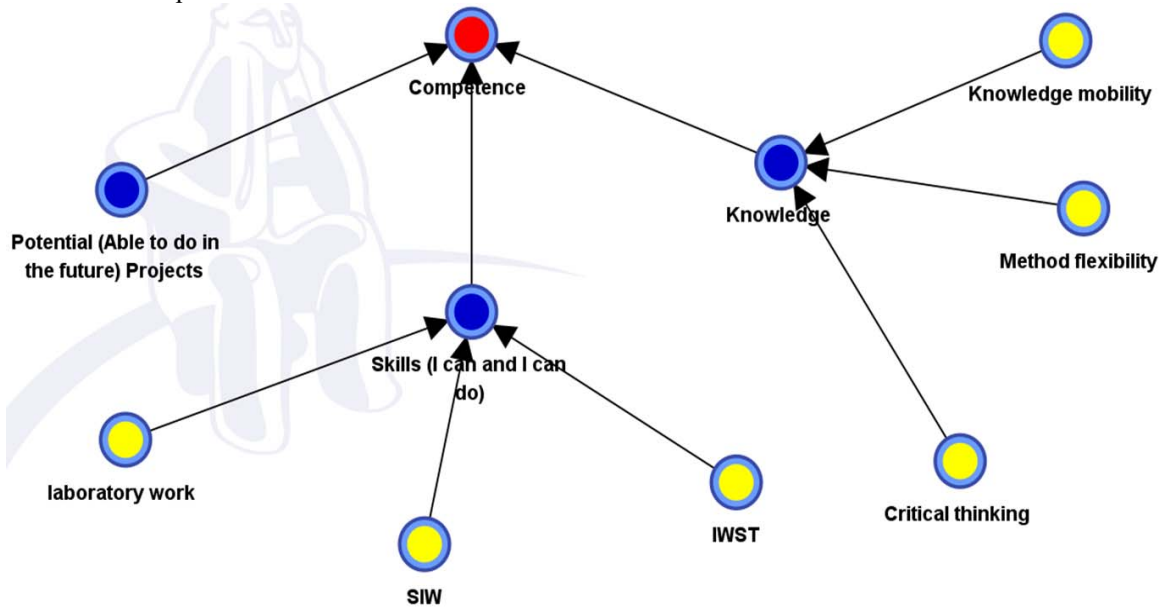


Fig 2. An example of Bayesian network

A priori for nodes of this network is known (Figure 3)

- A priori, we assume that approximately 63.47% of students possess knowledge mobility as a false answer, 36.53% have knowledge mobility as a true answer.

- A priori, we assume that approximately 41.60% of students have the flexibility of a false answer method, 58.40% have the flexibility of a true answer method.

- A priori, we assume that approximately 56.01% of students have critical thinking with a false answer; 43.99% have critical thinking with a true answer.

- A priori, we assume that approximately 72.28% of students did not do the student’s independent work with teachers, 27.72% did the student’s independent work with teachers.

- A priori, we assume that approximately 50.61% of students did not perform the student’s independent work, 49.39% did the student’s independent work.

- A priori, we assume that approximately 40.26% of students did not perform laboratory work, 59.74% did laboratory work.

- A priori, we assume that approximately 98.31% of the students did not defend the project, 1.69% passed the project.

- A priori, we assume that approximately 63.62% of students do not have skill, 36.38% possess skill.

- A priori, we assume that approximately 24.10% of students have a low level of knowledge in this field, 26.71% have an average level of knowledge, 25.82% have a good level of knowledge and 23.36% have a high level of knowledge.

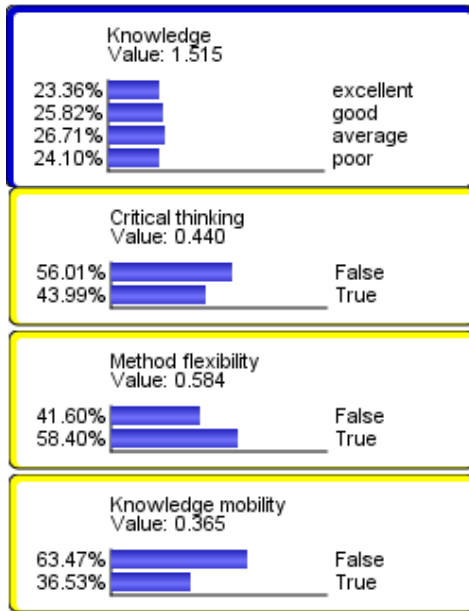


Fig 3. Determine the learning element by 3 criteria

We classify the element of competence and skill to build competencies according to their own criteria (Figure 4). They appreciate the proper work done or not performed on laboratory work, the student's individual work (SIW), and the individual work student's with teacher (IWST).

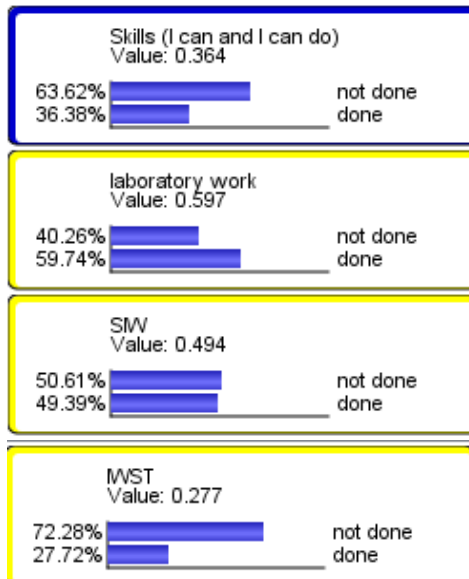


Fig 4. Determining the competence of a student for the discipline on the element of skill and skill

We evaluate the potential component for creating competencies in the future (Figure 5). Potential is

the expansion of the ability of the student to develop and develop oriented. Determines the ability to work as a competent professional in the future.

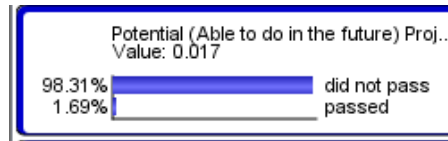


Fig 5. Determining the competence of the trainee by the element of potential

In Figure 3 we show an educational element to the lowed, average, good, very good evaluation, highlighting levels. We have described the following levels of assessment:

low level - indicates the lack of information competence of students studying in the direction of IT;

medium level - fragmented: the knowledge shown by the student at this level is incomplete, unstructured, and therefore there are errors in the performance of the IWS, IWST and laboratory work, the lack of logic. The average level of information competence is characterized by a lack of fundamental knowledge in the subjects on which the competence of those engaged in IT is formed and developed.

high level - this is sufficient level to perform the basic educational tasks that are pursued within the framework of of Information Communication Technologies (ICT) disciplines. At the same time, it should be noted that students with a high level of competence are not initiative in their activities, although they have a fairly good command of computer technology; previously acquired skills in non-standard situations are practically not used.

A very high level is that the student is able to apply the knowledge and skills acquired in the training sessions in future professional activities. This level is also characterized by extensive theoretical knowledge and practical skills in academic disciplines, in the process of studying

which develops the competence of those who are engaged in IT; the ability to use the acquired knowledge and skills in new non-standard educational and professional situations, as well as the constant desire to expand and deepen existing knowledge and skills.

Various methods exist to determine the competence of a student. In our work, we used the Bayesian method. This method is well used in handling uncertainties. The step-by-step action is described in the competence formation algorithm.

5.2 Algorithm for competence formation

While implementing the methodology for developing a student's competence in IT specialty using the Bayesian approach the following algorithm was developed:

1. Define the elements for the formation of students' competencies.
2. Make up to 3 items for competencies.
3. Build a network of 3 elements. We use the BayesiaLab package to build Bayes network. Use experts for individual variables and probability links to separate points (Figure 1).
4. There are 3 elements and their items are closely linked. For these 3 elements we define the overall competence of IT specialty students.

5. Define competencies on each element: knowledge, skills, skills and abilities.
 6. Classify the element of knowledge for competence based on the following criteria: knowledge mobility, flexibility, and critical thinking.
 7. Classify the element of competence and skill to build competencies according to their own criteria. They are evaluated by laboratory work, student self-study, and collaborative work (Figure 3).
 8. Determine the potential for the capacity building based on the future project design.
 9. Obtain the result from the built-in network of elements designed forming the competence of students.
- Then, created a table with examples of questions set for competence assessment.

TABLE 1: Levels of knowledge competence.

Competence	Competence element	Content and Key Meaning	Levels of competence determination	To be competent
	Knowledge	Systematic theoretical information about a specific type of activity and an algorithm for its implementation. "I know what, why and how to do"	Mobility of knowledge	(... who, ... what, ... when, ... what is the meaning, ... what is the main idea, ... the keyword, ... define, define the formulas ... write, type ... description, find dictionary ...), 1 - 10 questions.
			Flexible method	(... how, why, what, what, what, what, how, ... what differences are there ... give examples, ... solve different ways, ... make a root brief), 11 - 20 questions.
			Critical Thinking	(... find the error, because ... what are the criteria, what are the advantages and disadvantages, ... hypothesis, support arguments, or counter arguments), 21 - 30 questions.
	Skill	Acquired in the process of performing activities ability to perform the necessary sequence of actions. "I can and can do"	Laboratory work	
			Independent work student with teacher (IWST)	
	Potential	Borders of empowerment, developmental ability and direction of development. "May do in the future"	Independence work student (IWS)	
			(able to do in the future) projects	

A modern future student should not only possess the amount of knowledge necessary for professional activities, but also be able to use them creatively in educational activities: to determine the goals of cognitive activity; find the best ways to achieve your goals; use a variety of information sources; search and find the necessary information, evaluate the results; organize activities; collaborate with the trainees.

We have classification for 3 elements. We divided these 3 elements into competency levels. For

example, we classify the element by levels of knowledge: learning mobility, flexibility, and critical thinking levels into a special quiz template. The second element is skills: we have prepared specific tasks for laboratory work, individual work of student, individual work of student with teacher. Third element is potential. Under this element, students are required to prepare a project and put it on the system through their competencies. We will identify and evaluate students' competencies in the subject through these elements of competence. We

have created a network of Bayes to identify competencies. It is shown in Figure 5 above.

6. RESULT AND DISCUSSIONS

Today, when determining the competence of a student, it is important to use the Bayesian network technique. Bayesian network displays the results of the study.

Once a BN has been constructed, it is ready for inference. The inference commences by computing

the probability of each state of each variable in the network. After some observations (evidence) are introduced, posterior probabilities are computed. Those probabilities can then be used to determine the most likely causes of a certain event or a set of events or to predict the results of a test or a set of tests.

The structure of the Bayesian approach constructed on the elements for the competence formation of students is given below (Figure 6).

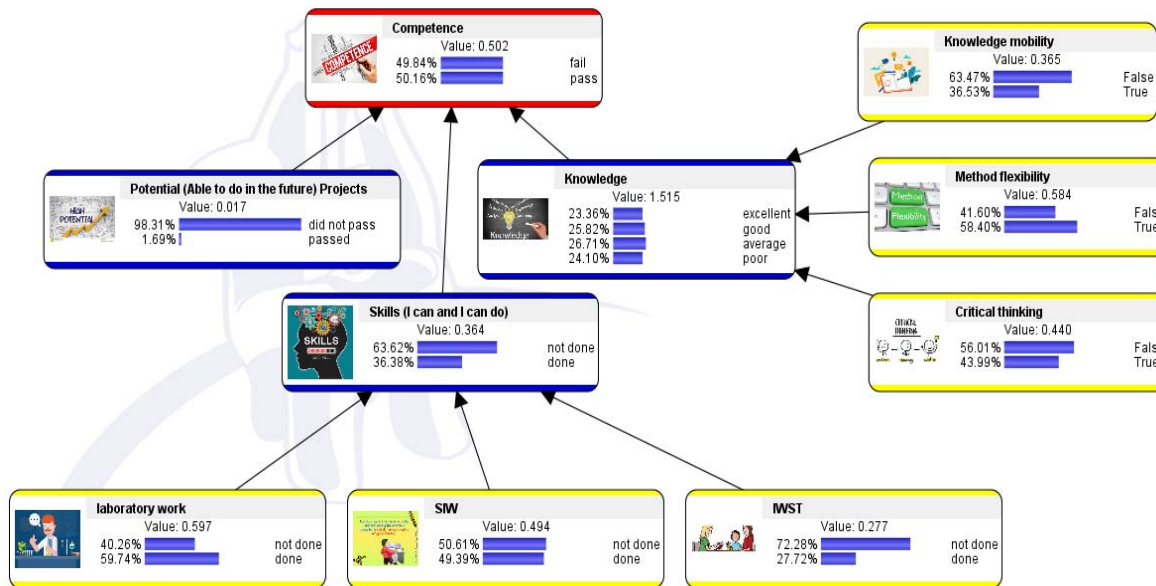


Figure 6: Bayesian approach built on the elements for the competence formation of students

The student's competence was formed using three main criteria: knowledge mobility, method flexibility, and critical thinking. This competence is determined based on one of the methods of artificial intelligence-the Bayesian approach. The data obtained with the help of this approach allows not only to record the level of competence of students, but also to identify the factors that influence it, as well as the dynamics of its formation when conducting research. Studies based on six different samples have confirmed a number of its The results of this approach contribute to the effective selection of educational resource s and the selection of an individual learning path.

The data for the nodes will accept the following values:

- probability of 1.69%, students defended the project.
- probability of 36.38%, students have the ability.

- probability of 23.36%, students with a high level of knowledge

- probability of 49.84%, the competence of students is formed

We create a sophisticated network with competency-building elements and consider elements of competence to be divided into knowledge, skills, and potential.

Knowledge is the systematic theoretical information about certain types of activities and the algorithm of its implementation. "I know what, why, and how to do it."

Skill - the abilities that have been gained through the implementation of the activities, and the algorithm of necessary actions. "I Can Do It"

Potential is the expansion of opportunities for development and orientation. "I can do it in the future"

Conducted research and numerous publications on this topic prove the relevance of applying the

Bayesian approach in the formation of students' competence.

The competence of a student in the intellectual system is based on three main criteria: knowledge, skills and potential. Proceeding from this, one can come to the conclusion that, first, knowledge, not just information, is rapidly changing, dynamic, varied, which needs to be able to be found, separated from unnecessary, translated into the experience of one's own activity. Secondly, the ability to use this knowledge in a particular situation; understanding how to obtain this knowledge. Third, an adequate assessment of oneself, the world, one's place in the world, specific knowledge, their necessity or uselessness for their activities, as well as their method of obtaining or use. This competence is determined on the basis of one of the methods of the artificial intelligence of the Bayesian approach. The results of this approach contributes to the effective selection of educational resources, choose an individual learning path.

7. CONCLUSION

Bayesian approaches are easy tool for describing sufficiently complex processes and events with uncertainties. To describe the Bayesian approach, it is necessary to determine the structure of the graph and the parameters of each node. In this work we developed a Bayesian network modeling student's competencies. The structure of the Bayesian approach shows the structure of the student's competencies in his formations in professional activities. Among the advantages of the proposed model, we can distinguish clarity and ease of interpretation, as well as detail and formal rigor, and diagnostic accuracy.

- The project of architecture of the Intellectual environment was created;
- Criteria for forming competencies have been identified;
- Network was created using Bayes method;
- An algorithm for elaborating competencies has been developed.

Prospects for further research are related to the expansion of the intellectual environment in the field of information technology, for example, more in-depth studies on the application of the developed method and Bayesian approach algorithm for the formation of students' IT competence.

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