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THE METHODOLOGY OF CREATING AN INTELLECTUAL ENVIRONMENT OF INCREASING THE COMPETENCE OF STUDENTS BASED ON A BAYESIAN APPROACH

Abstract. Artificial intelligence is widely used in solving various problems in various fields of science. The actual use of artificial intelligence methods to create an intellectual environment to improve the competence of the student. Recently, research into the most popular use of artificial intelligence has been the use of Bayesian network apparatus. When creating an intellectual environment for improving the competence of a student, the Bayesian approach is promising. At present, the theory of Bayesian networks is used in various fields of science and production in solving various applied problems. There is a fairly large number of software products for working with Bayesian networks. These products are divided into commercial and free. To implement the mathematical ideas of the Bayesian network, the BayesiaLab application software package is well applied and is one of the high-quality software products that specializes in artificial intelligence technologies. With the help of the package BayesiaLab, you can explore, edit, analyze and determine the model of the Bayesian network. This article provides definitions of various scientists to the term "competence" and explores the possibilities of using Bayesian networks in the formation of students' competence in the direction of information technology. For the formation of students' competencies in the field of information technology, a generalized algorithm and a general architecture of the intellectual environment have been developed. In order to improve professional competence in education, it leads to an increase in the competitiveness of specialists, an improvement in the content, methodology, and updating of the corresponding educational environment. In the formation of competence, a number of technologies are applied: cognitive-oriented, activity-oriented, personality-oriented. The approach used in the formation of competencies is used to simulate the quality of student knowledge. The level of competence depends on the method chosen.

Keywords. Bayesian network, student competencies, knowledge mobility, method flexibility, critical thinking, BayesiaLab software package.

1 Introduction

The development of modern information technologies allows to determine the competence of students in the educational system through information means. This includes the creation of an intellectual environment for the formation of students' competence.

VM Shepel introduces knowledge, skills, theoretical training to competence [1]. Definitions for other competences (V.Landscheer, P.Simonov, M.A.Choshanov) do not contradict this. For example, Landshereer understood the competence as a combination of in-depth knowledge and ability to fulfill the task [2]. P.V. Simonov's commitment to the task, M.A.Choshanov pays attention to the content (knowledge) and procedural components of competence [3].

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

Table 1 - An example of a set of questions for competence assessment and competency assessment is given to the students.

Levels of competence determination	To be competent	Sample questions for the assessment
Mobility of knowledge	Being able to find the information you need and to be able to explain the information. This allows the student to be knowledgeable and to explain, to be able to convey his 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	It should be able to use information in various situations. That is, the student's flexibility, the ability to adapt quickly to any situation increases.	(... 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	They should be able to convert information, find arguments, interact with the game, and make decisions. Through these qualities, the student's confidence in himself, his courage, and his ability to be courageous increases.	(... find the error, because ... what are the criteria, what are the advantages and disadvantages, ... hypothesis, support arguments, or counter arguments), 21 - 30 questions.

Currently, Bayes' approach is a promising aspect in solving applied problems in various research areas as well as deep neural networks [4,5]. 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 [6].

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

The following structure of the article is proposed: the second chapter provides a literary review of the application of the Bayesian approach in various fields of study. The third chapter defines the problem statement. The fourth chapter describes the architecture of the intellectual environment of improving the competence of the student in the field of IT based on the Bayesian approach. The fifth chapter describes the methods and results of the study. The sixth chapter is devoted to the discussion of the findings. At the end of the article, a conclusion is given and a list of references is given.

2 Literature Review

The actual use of artificial intelligence methods in various fields of research [7]. 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. It contains fairly 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, in the course of working with the system [8].

The first models of students were described in the works of P.L.Brusilovsky [9], V.A. Petrushina [10] and others. In these works, it was shown that knowledge support is needed to support learning, about learning strategies and methods, and learning about learners. A large number of approaches, specific models and formalisms were proposed for the model representations that are used in organizing the learning process. In [11], it is noted that measuring the level of students' competence with the help of their answers to test tasks is a typical problem of probabilistic reasoning. The two most frequent cases, in view of which uncertainty arises, are called in the foreign literature the terms miss and otgadka. Students may randomly answer the wrong question, the answer to which they know - this situation is called a miss. Also, students may randomly guess the correct answer or write off a task. Such a case is called a clue.

The article [12] describes the general scheme of work with a list of competencies that are formulated in the standard of training. Examples of assessing the level of competence formation are considered.

Bayesian networks are a handy tool for describing fairly 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, the mathematical apparatus of probability theory is used. 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 network is a model for representing probabilistic dependencies, as well as the absence of these dependencies [13].

To describe the Bayesian network, it is necessary to determine the structure of the graph and the parameters of each node [14]. This information can be obtained directly from the data or from expert assessments. Such a procedure is called learning the Bayesian network [15].

As noted in [16], the Bayesian network 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 networks have been actively used in the development of computer-aided learning tools [17].

The structure of the Bayesian network reflects the structure of students' knowledge, and is a tool with which you can make judgments and assessments regarding the level of student readiness, as well as make decisions [16].

In [18], Bayesian approaches to building student models 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 lies in their high performance, as well as in an intuitive representation in the form of a graph [19].

In [20], the problem of knowledge modeling with adaptive testing of students in a given discipline is considered. The structure of the training course involves the division of discipline into chapters, and each of the chapters, in 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 turn, the possession of each of the concepts may be necessary to perform one or several test tasks. This work uses a Bayesian network with binary variables, associated disciplines, topics, concepts, and questions (assignments). Conditional probabilities for variables are set by the teacher.

In article [21], the Bayesian network was used to describe the fuzzy connection between the student's achievements and their competences. The structure of the Bayesian network reflects the structure of students' knowledge and is a tool with which you can make judgments and assessments regarding the level of student readiness.

In the study [22], the relationship between test problem sets and the rules for solving them is modeled on the basis of the Bayesian network. [21] described methods and algorithms for learning the structure of a Bayesian network with hidden nodes based on the available training data.

3. Task setting

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.

When solving such problems, which require the consideration of uncertainty, the Bayesian approach is promising.

The Bayesian approach is based on the Bayes theorem, which is described as follows [23]:

$$P(A \mid B) = \frac{P(B \mid A)P(A)}{P(B)}$$

where, P (A) is the a priori probability of hypothesis A; $P(A|B)$ - the probability of hypothesis A when an event B occurs; $P(B|A)$ - probability of occurrence of event B with the validity of hypothesis A; $P(B)$ - the total probability of an event B.

Using the Bayes formula, you can more accurately recalculate the probability, based on previously known information and new observations.

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 creates mobility

of knowledge. Flexible method organization of information usage in different situations. Transforming information, finding evidence, and making decisions form critical thinking[24].

4 Architecture of the intellectual environment for improving the competence of the student in the directionof IT basedon the Bayesianapproach

The overall architecture of the Intelligent Environment is shown in Figure 1 below. Our main goal in creating such an environment is to educate IT students about the course and bring them to some competence. We used a bundle to determine competence. We have designed competencies based on three criteria and developed a system of questions on each criterion. We determine the competence of the student through this system of questions. These criteria are closely interconnected.

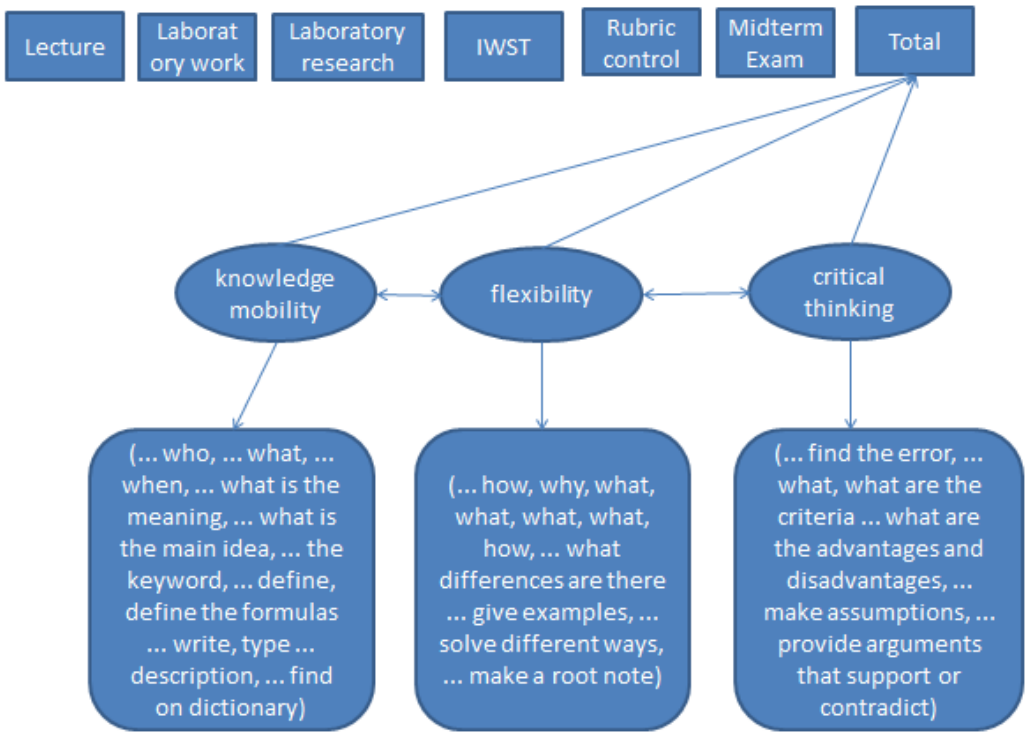

Figure 1 - Intellectual environment architecture

Advantages of the Intellectual Environment:
- It helps to define the competence of students.
- Many visual aids for teachers are offered in English.
- Allows you to study at any convenient location and at any time.
- Efficiently combines learning and new technologies.
- Makes everyone equal opportunities for quality education.

5 Research methods and results

For the solution of the report, we build a network of partners within the framework of the report. For variables and probability links, we will use experts for individual points.

BayesiaLab [25] A very powerful system has been working for about 20 years. Today BayesiaLab'sBayesia is the software market leader for working with Bayes networks. You can work with the Bayesia Engine API (Java Application Library). The disadvantage of this complex is very expensive, but you can download a 30-day free version (you can not save a network).

The accounting net is shown below.

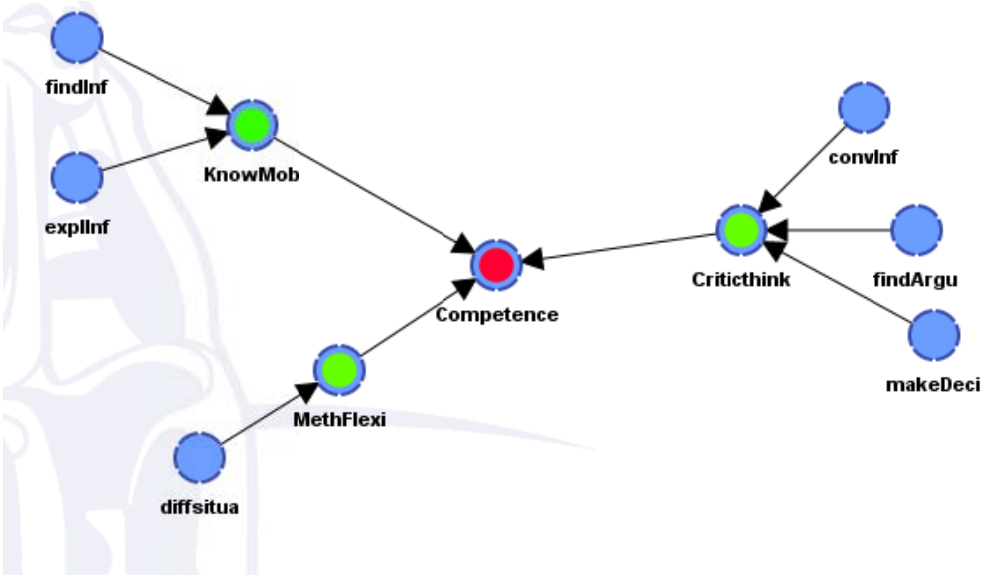

Figure 2 - Bayesian network

Bayesian networks are one type of probabilistic graphical models. A graphical probabilistic model is a probabilistic model, in which the graphs show the dependencies between random variables [26].

The Bayesian Faith Line is a probabilistic-graphic model (that is, not directed to cycles without directed cycles), which is a cyclically oriented graph, the vertices of which are random elements, and the boundary between the edges is the conditional dependence. Each random element is characterized by the probability distribution function, random elements of binary, can be multidimensional and continuous [27].

The mathematical apparatus of Bayesian networks was proposed in the mid-1980s by the American scientist J. Pearl. Methods for computing, learning Bayesian trust networks are developed in the works [21,24,28-31].

From a mathematical point of view, the Bayesian network is a model for the representation of probabilistic dependencies, as well as the absence of these dependencies [31].

We define competencies based on three criteria. They include knowledge mobility, flexibility, and critical thinking. These 3 criteria are closely interconnected.

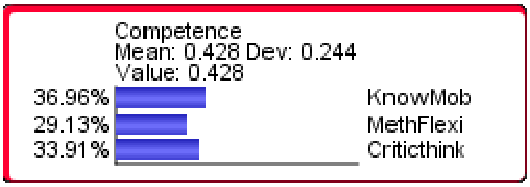

Figure 3 - Determination of competencies by 3 criteria

Let's define the competence of random students to the subjects of information technology. We do not know that this student has the ability to study information technology, and in many cases have the ability to use information and explain information. In this case, high probability - 3%.

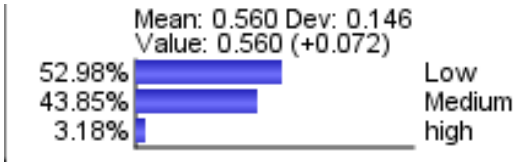

Figure 4 - Determination of competence of random student to discipline

We are aware that the student has the ability to study information technology, to have the ability to access information and explain information in various situations, and to have the ability to transform information, find evidence and make decisions. In this case, we see that high probability - 63%.

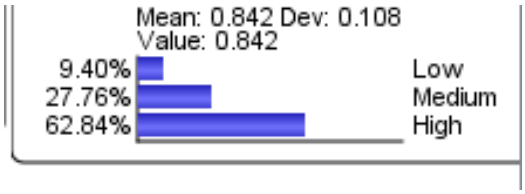

Figure 5 - Definition of competence of the special student for discipline

When determining the competence of the mobility, we pay attention to the ability to find the necessary information and to explain the information.

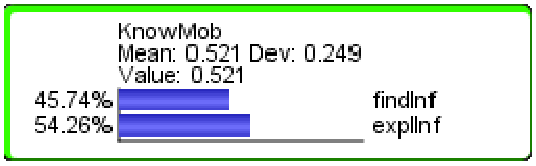

Figure 6 - Definition of mobility competence of knowledge

When considering the competence through flexibility, we consider the ability to use information in different ways.

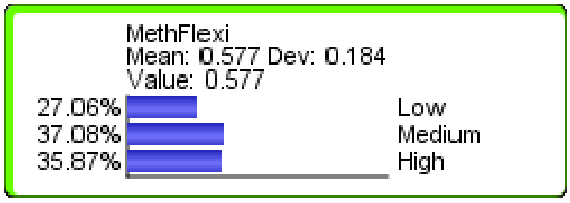

Figure 7 - Determine the competence by using a flexible method

When determining competence by critical thinking, we pay close attention to modifying information, finding arguments, and making decisions.

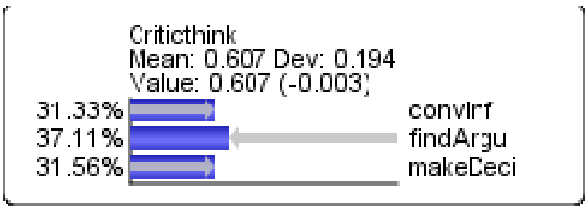

Figure 8 - Determination of Critical Thinking Competence

The following enlarged algorithm of forming the competence of a teacher in the direction of IT has been developed.

Step 1. We define the criteria for the competence of students.

Step 2. Build up the 3 criteria for competence build up.

Step 3. We build a network of 3 by the criteria. We use the BayesiaLab package to build bayes network. Variables and Probability We use experts for individual relationships. (Fig.1)

Step 4. We define individual competencies on each criterion. That is, knowledge mobility, flexibility, critical thinking. (Fig.5-7)

Step 5. Total 3 criteria and their items are interconnected. Under these 3 criteria, we determine the overall competence of IT-trainees. (Fig.2)

6. Discussions

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 the trainee in the intellectual system is based on three main criteria: mobility of knowledge, flexibility of the method and critical thinking boyish zhetiledi. 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 get this knowledge. Thirdly, 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.Conclusions

Thus, a methodology has been developed for creating an intellectual environment for improving the competence of a student in the field of IT based on the Bayesian approach. As a result of the study: a literature review was conducted on this issue, an architecture of the intellectual environment was created, and an integrated algorithm was developed to form the competence of a teacher in IT.

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БАЙЕС ТӘСІЛІНЕ НЕГІЗДЕЛГЕН АҚПАРАТТЫҚ ТЕХНОЛОГИЯЛАР БАҒЫТЫНДА БІЛІМ АЛУШЫЛАРДЫҢ ҚҰЗЫРЕТТІЛІГІН АРТТЫРУ ҮШІН ЗИЯТКЕРЛІК ОРТАНЫ ҚҰРУ ӘДІСТЕМЕСІ

Аннотация. Жасанды интеллект ғылымның түрлі салаларында әртүрлі мәселелерді шешуде кеңінен қолданылады. Студенттің құзыреттілігін арттыру үшін зияткерлік ортаны құру үшін жасанды интеллект әдістерін пайдалану өзекті. Соңғы уақыттарда жасанды интеллекте ең танымал қолданудың зерттеулері Байес желілік аппаратын пайдалану болып табылады. Студенттің құзыреттілігін арттыру үшін интеллектуалды ортаны құруда Байес тәсілінің келешегі зор. Қазіргі уақытта Байес желілерінің теориясы түрлі қолданбалы мәселелерді шешуде ғылым мен өндірістің әр түрлі салаларында қолданылады. Байес желілерімен жұмыс істеуге арналған бағдарламалық өнімдердің жеткілікті саны бар. Бұл өнімдер коммерциялық және тегін бөлінеді. Байес желісінің математикалық идеяларын жүзеге асыру үшін BayesiaLab қосымшасының бағдарламалық пакеті жақсы қолданылған және жасанды интеллект технологияларына маманданған жоғары сапалы бағдарламалық өнімдердің бірі болып табылады. BayesiaLab пакетінің көмегімен Байес желісінің моделін зерттеу, өңдеу, талдау және анықтауға болады. Бұл мақалада «құзыреттілік» терминіне әртүрлі ғалымдардың анықтамалары берілген және ақпараттық технологиялар

бағытында студенттердің құзыреттілігін қалыптастыруда Байестік желілерді пайдалану мүмкіндіктері зерттелді. Ақпараттық технологиялар саласында студенттердің құзыреттілігін қалыптастыру үшін интеллектуалды орта ортақ алгоритмі және жалпы архитектурасы жасалды. Білім берудегі кәсіби құзыреттілігін арттыру үшін мамандардың бәсекеге қабілеттілігін арттыру, жақсартылған мазмұн, әдіснамасын жетілдіруге және тиісті білім беру ортасын жаңартуға алып келеді. Құзыреттілікті қалыптастыру кезінде бірқатар технологиялар қолданылады: когнитивтік-бағдарланған, қызметке бағытталған, тұлғалық-бағдарланған. Құзыреттілікті қалыптастыруда қолданылатын тәсіл студенттердің білім сапасын модельдеу үшін қолданылады. Құзыреттілік деңгейі таңдалған әдіске байланысты.

Түйін сөздер: Байестік желілер, білім алушылардың құзыреттілігі, білімнің ұтқырлығы, икемділік әдісі, сын тұрғысынан ойлау, BayesiaLab қолданбалы бағдарлама пакеті.

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МЕТОДОЛОГИЯ СОЗДАНИЯ ИНТЕЛЛЕКТУАЛЬНОЙ СРЕДЫ ПОВЫШЕНИЯ КОМПЕТЕНТНОСТИ ОБУЧАЮЩЕГОСЯ ПО НАПРАВЛЕНИЮ IT НА ОСНОВЕ БАЙЕСОВСКОГО ПОДХОДА

Аннотация. Искусственный интеллект широко используется при решении различных проблем в различных областях науки. Актуально применение методов искусственного интеллекта для создания интеллектуальной среды повышения компетентности обучающегося. Последнее время в исследованиях наиболее популярным направлением использования искусственного интеллекта стало применение аппарата байесовских сетей. При создании интеллектуальной среды повышения компетентности обучающегося перспективно применение байесовского подхода. В настоящее время теория байесовских сетей используется в различных областях науки и производства при решении различных прикладных задач. Существует достаточно большое количество программных продуктов для работы с байесовскими сетями. Данные продукты деляться на коммерческие и бесплатные. Для реализации математические идеи байесовской сети хорошо применяется пакет прикладных программ BayesiaLab и является одним из высококачественных программных продуктов, который специализируется на технологиях искусственного интеллекта. С помощью пакета BayesiaLab можно исследовать, редактировать, анализировать и определить модель байесовской сети. В данной статье даны определения различных ученых термину «компетенция» и исследованы возможности использования байесовских сетей при формировании компетенции обучающихся по направлению информационных технологий. Для формирования компетенций обучающихся по направлению информационных технологий разработан обобщенный алгоритм и общая архитектура интеллектуальной среды. Для совершенствования профессиональной компетентности в образовании приводит к повышению конкурентоспособности специалистов, улучшению содержания, методологию и обновлению соответствующей образовательной среды. При формировании компетентности применяются ряд технологий: когнитивно-ориентированная, деятельностно-ориентированная, личностно-ориентированная. Подход используемый при формирований компетенций используется для моделирования качества знаний студента. Уровенькомпетентности зависит от выбранного метода.

Ключевые слова: Байесовские сети, компетентность обучающегося, мобильность знаний, гибкость метода, критичность мышления, пакет прикладных программ BayesiaLab.

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REFERENCES

[1] Shepel V.M. Management anthropology. Human competence manager. M.

[2] Landsheer V. The concept of "minimal competence" / V. Landsheer // Perspectives. Issues of education. 1988.

[3] Choshanov M.A. Flexible technology of problem-modular learning: a manual / M.A. Choshanov. M .: Public education, 1996. 160 p.

[4] Mamyrbayev O., Turdalyuly M., Mekebayev N., Alimhan K.,Kydyrbekova A., Turdalykyzy T. Automatic Recognition of Kazakh Speech Using Deep Neural Networks // Lecture Notes in Computer Science,2019. Vol. 11432 LNAI, 2019, P. 465-474.

[5] 5.MamyrbayevO.Zh.,Kunanbayeva M.M.,Sadybekov K.S.,Kalyzhanova A.U. One of the methods of segmentation of speech signal on syllables // Bulletin of the National Academy of Sciences of the Republic of Kazakhstan, 2015. Vol. 2. P. 286-290.

[6] V.M. Trembach. Intellectual information system of formation of competencies for the implementation of the model of continuous education. Open Education, 2010 (4), C. 79-91.

[7] Kalimoldayev M. N., Pak I. T., Baipakbayeva S. T., Mun G. A., Shaltykova D. B., Suleimenov I. E. Methodological basis for the development strategy of artificial intelligence systems in the Republic of Kazakhstan in the message of the president of the Republic of Kazakhstan dated October // N E W S OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN SERIES OF GEOLOGY AND TECHNICAL SCIENCES, 2018. Vol. 6(432). P. 47–54. https://doi.org/10.32014/2018.2518-170X.34

[8] Bul' E.E. Obzor modelej studenta dlja komp'juternyh system obuchenija // Obrazovatel'nye tehnologii i obshhestvo (Educational Technology & Society). 2003. Tom. 6, № 4. S. 245-250. Rezhimdostupa: http://ifets.ieee.org/russian/depository/v6_i4/html/G.html (data obrashhenija 01.07.2014)

[9] Brusilovskij P.L. Intellektual'nye obuchajushhie sistemy // Informatika. Informacionnye tehnologii. Sredstvaisistemy. 1990. №2. S.3-22.

[10] Petrushin V.A. Jekspertno-obuchajushhiesistemy. K.: Naukovadumka, 1992. 196 s.

[11] Bidjuk P.I., Terent'ev A.N. Postroenie i metody obuchenija bajesovskih setej // Tavrijs'kij visnik informatiki i matematiki, №2/2004. s. 139-154.

[12] Neapoliltan RE. Learning Bayesian Networks. NJ: Prentice Hall, 2004. 704 p.

[13] Liu, C. A simulation-based experience in learning structures of Bayesian networks to represent how students learn composite concepts / C. Liu // International Journal of Artificial Intelligence in Education. 2008. V. 8, N. 3. P. 237–285.

[14] Litvinenko A.,MamyrbayevO., Litvinenko N., Shayakhmetova A.,Kotyra A.Application of bayesian networks for estimation of individual psychological characteristics // PRZEGLAD ELEKTROTECHNICZNY, 2019. Vol. 5 (95). P. 92-97.

[15] Villano, M. (1992) Probabilistic student models: Bayesian belief networks and knowledge space theory. In C.Frasson, C. Gauthier, & G. McCalla (Eds.) Intelligent Tutoring Systems, Proceeding of the Second International Conference, ITS'92, Montreal, Canada (pp. 491-498). Berlin: Springer-Verlag.

[16] Mayo, M., &Mitrovic, A. (2001). Optimising ITS behavior with Bayesian networks and decision theory. International Journal of Artificial Intelligence in Education, 12, 124–153.

[17] Desmarais, M. C., & Baker, R. S. (2012). A review of recent advances in learner and skill modeling in intelligent learning environments. User Modeling and User-Adapted Interaction, 22(1–2), 9–38.

[18] Millán E. A Bayesian Diagnostic Algorithm for Student Modeling and its Evaluation / E. Millán, J. L. Pérez-de-la-Cruz // User Modeling and User-Adapted Interaction. 2002. N. 12. P. 281–330.

[19] VanLehn, K. Student modeling from conventional test data: a Bayesian approach without priors / K. VanLehn, Z. Niu, S. Siler, A. Gertner // Proc. of 4th Int. Conf. ITS'96. 1996. P. 29–47.

[20] Reye, J. Student Modelling based on Belief Networks / J. Reye // International Journal of Artificial Intelligence in Education. 2004. N. 14. P. 1–33.

[21] Jensen F. V. Bayesian Networks and Decision Graphs. NY: Springer-Verlag, 2001. 268 p.

[22] VanLehn K., Niu Z., Siler S., Gertner A. Student modeling from conventional test data: a Bayesian approach without priors // Intelligent Tutoring Systems, Proceedings of 4th International Conference ITS'96. 1996. pp. 29–47.

[23] Neapoliltan R.E. Learning Bayesian Networks. NJ: Prentice Hall, 2004. 704 p.

[24] Sologub, G. B. Development of mathematical methods and complex software simulation of knowledge based on semantic models: Dis. Cand. f.-m. Sciences: 05.13.18, 05.13.11 / G.B.Sologub. Moscow, 2013. 134 p.

[25] Koller D., Friedman N. Probabilistic Graphical Models. Massachusetts: MIT Press, 2009. 1208 p.

[26] Khlopotov M.V. The use of the Bayesian network in building models of students to assess the level of formation of competencies. Internet journal "SCIENCE" http://naukovedenie.ru Issue 5 (24), 2014.

[27] Pearl J. Probabilistic Reasoning in Expert Systems: Networks of Plausible Inference. San Francisco: Morgan Kaufmann, 1988. 552 p.

[28] Heckerman D. A tutorial on learning with Bayesian networks / M.I. Jordan (ed.). Dordrecht: Kluwer Academic, 1998. 57 p.

[29] Tulupyev, AL, Nikolenko, S.I., Sirotkin, AV Bayesian trust networks: logical-probabilistic inference in acyclic directed graphs. - SPb .: Publishing house of S.-Petersburg. University, 2009. 400 p.

[30] Darwiche A. Modeling and Reasoning with Bayesian Networks. Cambridge University Press, 2009. 526 p.

[31] Bidyuk P.I., Terentyev A.N. Construction and teaching methods of Bayesian networks // Tavreysky Informatics i Mathematics, №2. 2004. p. 139-154.