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INTELLIGENT TRAINING PROCESS MANAGEMENT

The article discusses the development of an intelligent training system (ITS), types of technologies in ITS and their use in intelligent management of the learning process. The article gives the examples of models and describes an overlay fuzzy model of a student's knowledge based on the concept of a didactic unit.

The research methods include a systematic approach to the development of the ITS concept and knowledge processing models based on the use of adaptive testing theories, fuzzy logic, artificial intelligence.

The proposed concept of building an ITS using an overlay fuzzy model of the student's knowledge will determine the degree of mastering the didactic units and competencies of the student. The results obtained are of interest in building an intelligent training systems and training complexes, which, in turn, help to increase the efficiency of training due to the openness, multifunctionality and adaptability of intelligent training systems.

In connection with the growing interest in the design of intelligent training systems, there are many ambiguities in the interpretation of the types of learner models in ITS. However, since new directions in the modeling of ITS for trainees have appeared, innovative technologies of the learning process itself have been developed. This article is relevant in this regard, especially if we consider the application of theoretical ideas into practice and use of ITS in the intelligent management of education.

This article discusses the concept of building an ITS in the Nova KakhovkaInstrument Making Applied College. The one of the tasks of ITS should be dynamic adaptation of educational material to the level of student knowledge. The training model proposed in the article allows: to adjust the learning goals set by teachers to the goals of students, to increase the independence of learning, responsibility and conscientiousness of students, to increase the share and quality of independent learning, to ensure the unity of training and educational processes.

Key words: intellectual training system, competencies, student overlay model, didactic unit.

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ІНТЕЛЕКТУАЛЬНЕ УПРАВЛІННЯ ПРОЦЕСОМ НАВЧАННЯ

У статті розглядається питання розробки інтелектуальної навчальної системи (ІОС). Види технологій в ІОС та їх використання в інтелектуальному управлінні процесом навчання. Наводяться приклади моделей учня. Описується оверлейна нечітка модель знань учня, яка заснована на понятті дидактичної одиниці.

Методи дослідження базуються на системному підході до розробки концепції ІОС та моделей обробки знань, що базуються на використанні теорій адаптивного тестування, нечіткої логіки, штучного інтелекту.

Запропонована концепція побудови ІОС з використанням оверлейної нечіткої моделі знань учня дозволить визначити ступінь освоєння дидактичних одиниць і компетенцій учня. Отримані результати мають застосування при побудові інтелектуальних навчальних систем і тренажерних комплексів, які в свою чергу допомагають підвищити ефективність навчання за рахунок відкритості, багатофункціональності та адаптивності інтелектуальних навчальних систем.

В зв'язку з дедалі більшим інтересом до проектування інтелектуальних навчальних систем виникає багато непорозумінь в трактуванні видів моделей, яких навчають в ІОС. Однак, з'явилися нові напрямки в будуванні моделі учнів, розроблені інноваційні технології самого процесу навчання. Запропонована стаття в цьому сенсі актуальна, якщо розглядати застосування теоретичних ідей в практичному проектуванні і використанні інтелектуальних навчальних систем при інтелектуальному управлінні освітою.

В статті розглядається концепція побудови ІОС в Новокаховському приладобудівному фаховому коледжі. Одним із завдань ІОС є здійснення динамічної адаптації навчального матеріалу до рівня знань студентів. Застосування запропонованої в статті оверлейної моделі учня дозволяє: узгодити поставлені викладачами цілі навчання з цілями студентів, підвищити якість отриманих знань та навичок, самостійність, відповідальність і сумлінність студентів.

Ключові слова: інтелектуальна навчальна система, компетенції, оверлейна модель учня, дидактична одиниця.

The problem or the research

Currently, the development of information technology has led to dramatic changes in society, but in the field of education, these changes have just begun. Dynamic processes in all areas of human activity require a professional to use modern and relevant knowledge and skills. The acquisition of knowledge on classical technologies is often delayed that does not provide a competitive advantage to the trainees. Therefore, development of competencies that meet modern requirements must be carried out using intelligent training systems (ITS), which:

-   provide personalized learning environment;
-   take into account the current competencies of the student;
-   provide timely adjustment of the learner's model;
-   dynamically adapt the presentation of training material;
-   provide contextual help at the level of hints, examples or explanations;
-   is effective in group and joint learning, etc. [1, c.3-53].

In special cases, ITS allow building individual learning paths to focus on a narrow specialization; the learning objectives can be adapted to the individual qualities of the student and can quickly change in the learning process.

The basis of modern ITS includes: a domain model (DM), a learner's model (LM), a training process model and a result control model [1, c. 3-53].

The ITS algorithm (fig.1) can be described as follows: until the specified learning goal is achieved, the ITS, based on the current state of the student's model, selects and provides him with the next fragment of training information from the DM, then monitors the assimilation of this fragment and, based on the control results, corrects the student's model and the trainingprocess model [2, c. 210].

A sequence of pieces of teachingmaterial can be formed as **active** (according to a given curriculum) or **reactive** (based on control results) [3, c. 35].

Active sequencing implies explicit learning objectives, which are described as a set of necessary and sufficient competencies (knowledge and skills). This technology will provide the trainee with an individually designed training course designed precisely for the trainee.

Passive (corrective) sequencing is a closed-loop technique with no explicit learning goal. The feedback that updates the learner's model is usually an intelligent analyzer of the learner's performance – the technology that is able to determine whether the answer proposed by the student is correct, to analyze the mistakes and completeness. It is also possible to identify the missing knowledge that led to the error.

Interactive problem solving support is a technology that allows helping a student at every stage of solving a task.

The technology of support in **solving**tasks**from example** is based on the experience of solving tasks by students: it allows solving new problems based on examples from previously solved ones.

In general, the structure of knowledge used by the DM ITS and the type the sequence largely determines its architectural features.
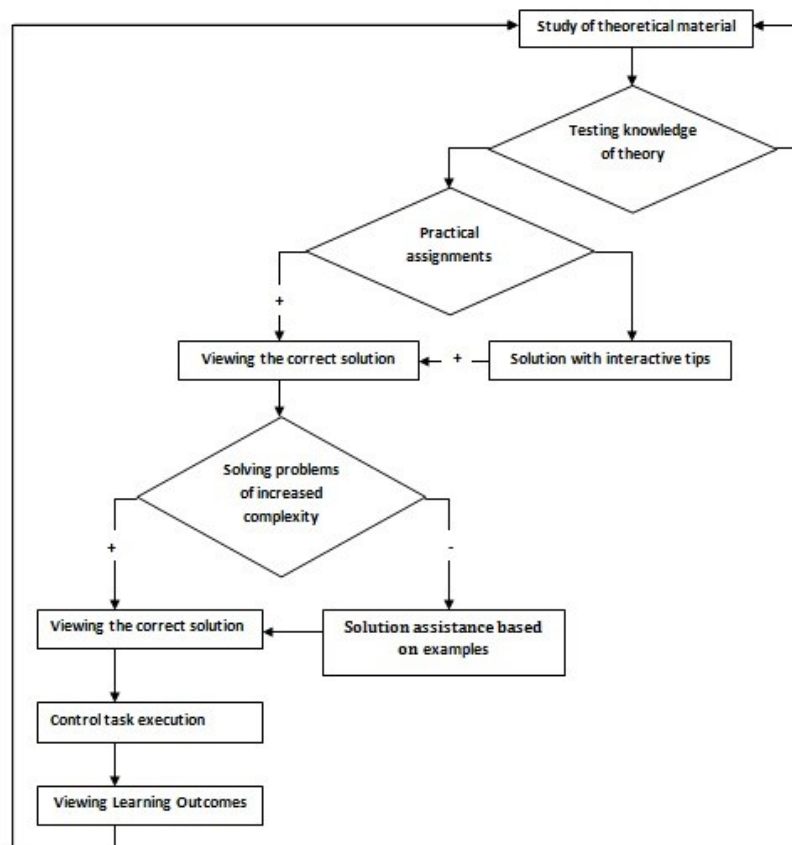

Fig. 1. Algorithm of the training process

Analysis of recent research and publications

Thus, summarizing the definitions proposed by various researchers, we can say that an intelligent training system (ITS) is an e-learning system that includes elements of artificial intelligence (AI) and allows solving tasks in the most suitable sequence for the student, adapting the course to knowledge or other characteristics of the student, intelligent analysis of performance, assisting in assignments and intelligent monitoring of the learning process [4-7,12].

An overview of modern ITS of various classes is presented in research papers[7-10]. It is customary to distinguish such types of ITS as information and reference, consulting, intellectual-trainers (expert-trainers), managers and accompanying ITS.

The type of intelligent training systems considered in the article differs significantly from other types of ITS. The type of intelligently training ITS is focused ondeveloping a system of skills and abilities in trainees and implies that the student has a sufficient level of knowledge, while ITS of other types make a system of competencies in the form of knowledge.

Aim of the study. The aim of the study is to describe the concept of a model of an intelligent training system according to a competency-based approach. We will consider a student model for use in ITS, designed to assess the competencies of students, when the acquisition of a certain piece of knowledge, skills and abilities is aimed at developing certain competencies in the student, otherwise he/she cannot go to the next level of training.

Presentation of the research

This article discusses the concept of building an ITS in the Nova KakhovkaVocational Instrument Making Applied College (Ukraine). The ITS of the College will include the following technologies: building the sequence of the curriculum, intelligent analysis of the student's performance, interactive support in solving tasks, assistance in solving tasks from examples. And, since one of the ITS's tasks is to implement the dynamic adaptation of learning/teaching material to the level of studentknowledge, it is necessary that the ITS includes such a student model that would reflect his/her existing and missing knowledge. To date, in the College, only a few of the listed technologies have been implemented and are used.

There are various classifications of learner models in ITS. Different types of models can cover such parameters as the level of knowledge, psychological characteristics, pace and style of learning, percentage of assignments done, chosen teaching technique /strategy [11, c.155], etc.

Another way to make a training program intelligent is to use **learner models** [12, c.167].

The student's knowledge model identifies the level of knowledge in the studied course or subject. Models are divided into **scalar** and **overlay** ones. When using the scalar model, the student's level of knowledge is assessed through some integral assessment, for example, by a point on a point scale.

The overlay model, in turn, shows what exactly the learner knows and does not know. In it, the student's knowledge is a subset of the expert's knowledge, that is, the DM. Moreover, the level of mastering each of the units of knowledge can be estimated by a *Boolean* data type of *1 or 0* (that is, «knows» or «does not know»), a percentage («as far as he/she knows») or a probability coefficient («what is the probability that he/she knows»).

The student model, designed to build an ITS for assessing the competencies of college students, should be based on the DM of ITS. Several levels of hierarchy can be distinguished in the domain model. The didactic unit (DE) acts as the minimum structural unit of the educational material - a logically independent part of the educational material, for example, a concept, theory, law, etc. [13, c. 377].Each of the ITS levels corresponds to the level of the student's knowledge model. For example, at the lowest level of the hierarchy, there are many didactic units DUE - Didactic Units in Expert model. It corresponds to the set of mastered didactic units of the DUS - Didactic Units in Student model. Taking into account that the student may not fully know any didactic unit, the following formula can be proposed (using the theory of fuzzy sets):

$$DUS = \{(due, \mu_{dus}(due))| due \in DUE\}, \tag{1}$$

whereDUS - fuzzy set of didactic units of a student's knowledge model;

DUE - set of didactic units of the domain model;

due - elements of the set DUE;

$\mu_{dus}(due)$- membership function indicating the extent to which the due element belongs to the fuzzy set DUS.

In this case, three types can be distinguished:

$\mu_{dus}(due)$=1, means the complete belonging of the element due to the fuzzy set $DUS(due \in DUS)$, that is, the student has completely mastered this didactic unit;

$\mu_{dus}(due)$=0, means that the due element does not belong to the fuzzy set $DUS(due \notin DUS)$, that is, the student has not mastered this didactic unit at all;

$0 < \mu_{dus}(due) < 1$, means the partial belonging of the element due to the fuzzy set DUS, that is, the student has not fully mastered this didactic unit.

Since the membership function for a fuzzy set can take any values in the interval [0,1], and not just the values 0 or 1, the degree of mastering a didactic unit can be represented as a decimal fraction in the range from 0 to 1. Table 1 shows the results of the intermediate knowledge control of students in Object-Oriented programming, on the topic "Methods (functions) of the String class for working with strings in C #", where the didactic units are functions of the String class.

Table 1

Degrees of mastering didactic units

Didactic Units	Mastering degrees
1. IsNullOrEmpty()	1
2. IsNullOrWhiteSpace()	0.8
3. Insert()	1
4. ToUpper() & ToLower()	0.5
5. Contains()	0,6
6. IndexOf()	0,5
7. StartsWith() & EndsWith()	0,7
8. Compare()	0,3

Figure 2 shows an example of what the *DUS* fuzzy set pie chart looks like for eight didactic units mastered with varying degrees. *DUS* ideal is a set of didactic units of the student's knowledge model when fully mastered ($\mu_{dus}(due)$=1for all didactic units).

The degree of mastering a didactic unit is calculated based on the results of laboratory and practical work related to this didactic unit. If all tasks are completed successfully, then it is considered that $\mu_{dus}(due) = 1$. Otherwise, the membership function can be calculated using the following formula:

$$\mu_{dus}(due) = \sum_{i=1}^{N} q_i / N, \tag{2}$$

where $\mu_{dus}(due)$ - membership function;

i - the serial number of the task associated with this didactic unit;

N - the number of tasks to check this didactic unit;

qi– the result of the i-th task (equal to 1 if the task was successfully completed, and 0 if the task was not completed or was not completed correctly).
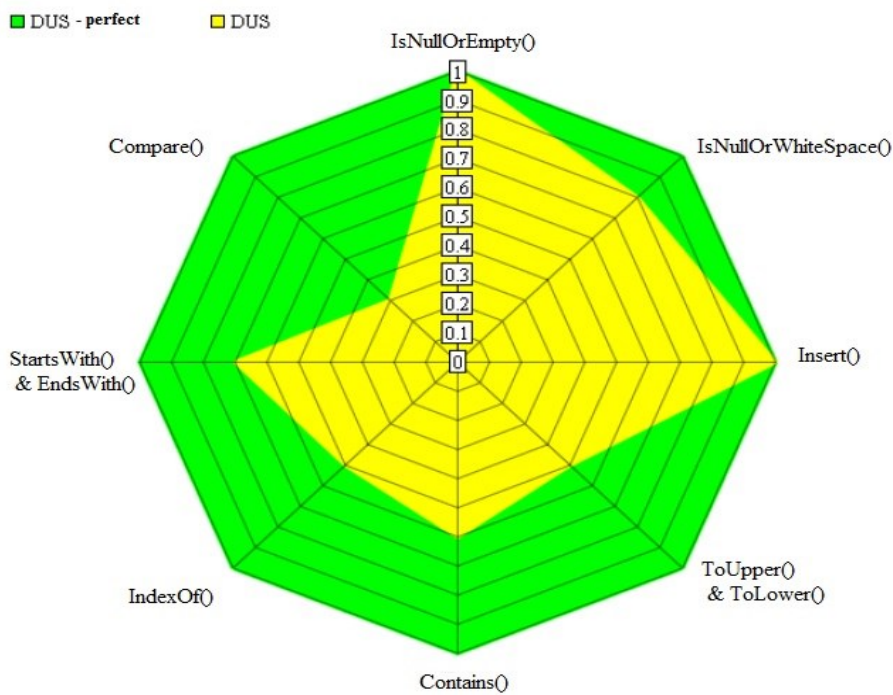

Fig.2 - The pie chart of the fuzzy set *DUS-ideal*

Assessment of the degree of mastering the subject as a whole is based on information about the degree of mastering didactic units and can be done in several ways. In the simplest case, in the ITS, by default, certain parameters are set that are the same for all didactic units. For example, for all due, where G is the degree of mastering the subject:

IF($\mu_{dus}(due) < 0{,}5$), THEN G = «not mastered»;

IF($0{,}5 \leq \mu_{dus}(due) < 0{,}8$), THEN G = «partially mastered»;

IF($0{,}8 \leq \mu_{dus}(due) < 1$), THEN G = «mastered enough»;

IF($\mu_{dus}(due) = 1$), THEN G = «fully mastered».

Also, the above criteria for assessing the degree of mastering the subject can be set differently for each of the didactic units using the methods of expert assessments. So, Figure 3 shows a diagram of the criteria for assessing the degree of mastering a subject consisting of the above-mentioned didactic units.

The diagram shows four zones of the degree of mastery of the topic. If the degree of mastering by a student of each of the didactic units falls, for example, in the "partially mastered" zone, then it is considered that the student has partially mastered the whole topic.

However, in practice, the degree of mastering by students of didactic units rarely strictly correspond to one of the zones, more often they fall into several zones at once, as in Figure 4.

In this example, the student twice achieved the best result, that is, he mastered the use of the IsNullOrEmpty () and Insert () functions completely. Once his result fell into the zone of "mastered enough", that is, in writing programs of the IsNullOrWhiteSpace () function, he "mastered partially" four functions and "did not master" the use of the Compare () function.
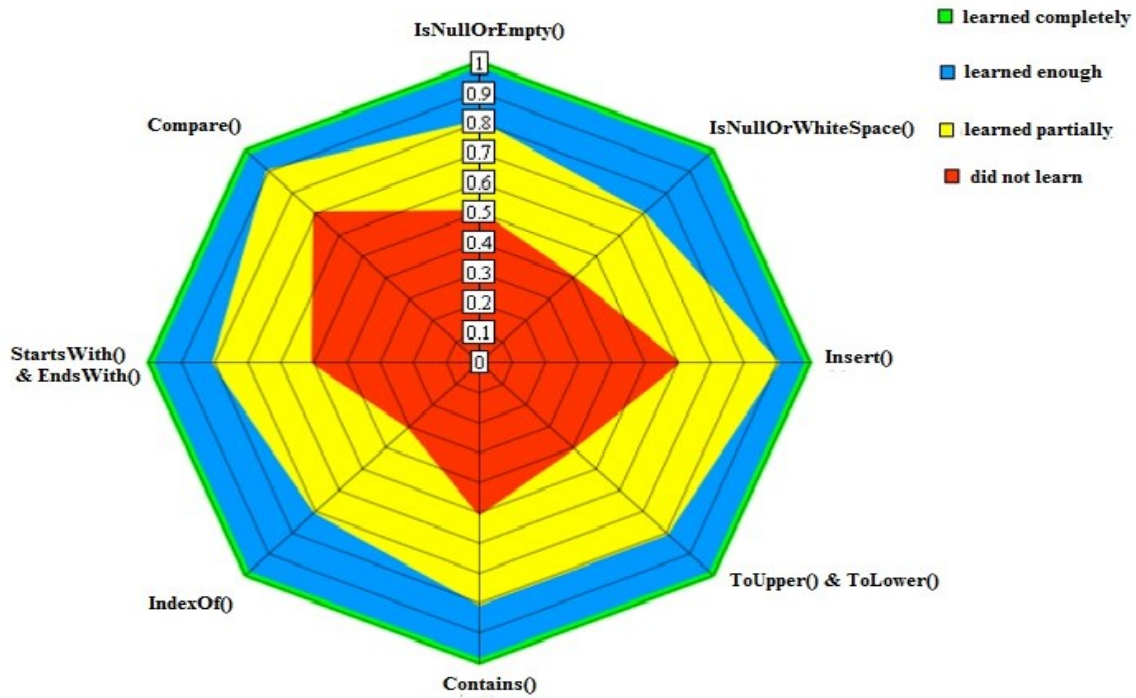
Fig. 3 Pie chart of the criteria for the degree of mastering the subject

Based on this, it is possible to calculate the membership measures (μ_i) of the degree of mastering the topic by students in four zones:

    1. Zone «notmastered» – $\mu_1 = 1/8 = 0{,}125$;
    2. Zone «partiallymastered» – $\mu_2 = 4/8 = 0{,}5$;
    3. Zone «masteredenough» – $\mu_3 = 1/8 = 0{,}125$;
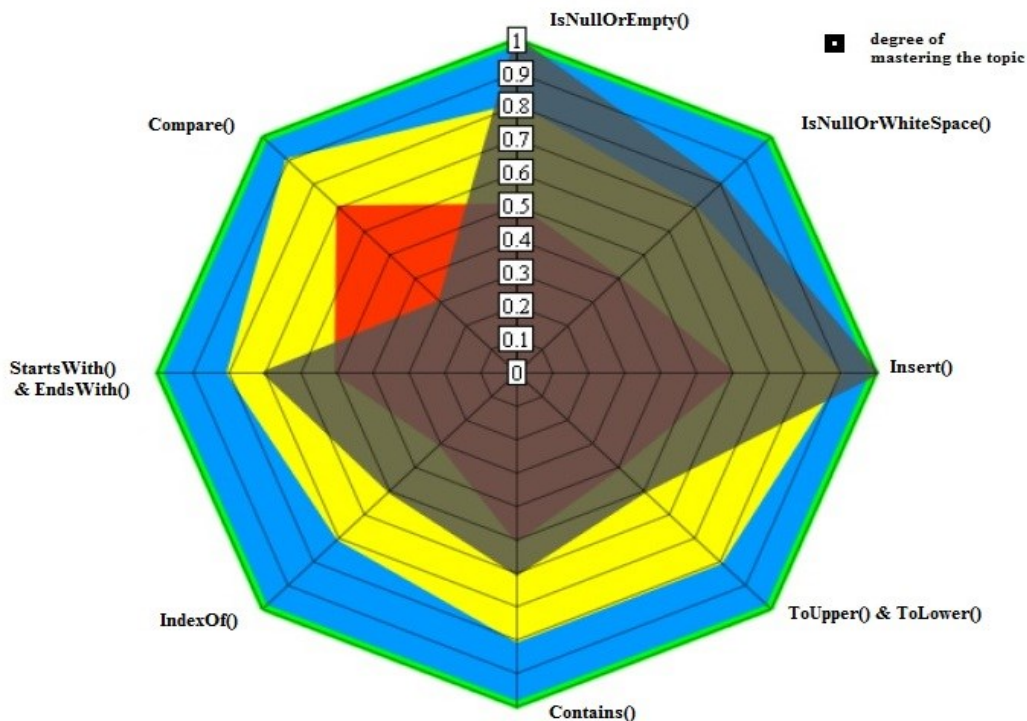   4. Zone «mastered fully» – $\mu_4 = 2/8 = 0{,}25$.

Fig. 4 - Pie chart of the degree of mastering the topic by students

We select the maximum of the obtained values (μ_2) of the degree of mastering the topic by the student and we conclude that in this example the student has mastered this topic partially.

The belonging (μ_i) of the degree of mastering the topic to the four zones can be calculated using the following formula:

$$\mu_i = \frac{Q_i}{M}, \tag{3}$$

where i– serial number of the zone (from 1 to 4);

Q_i– number of didactic units, the degree of mastering of which by the students falls into the i-th zone;

M – number of didactic units.

Knowing the measure of membership(μ_i), the degree of mastering the subject (G) can be identified as follows:

IF($\mu_1 = max(\mu_1, \mu_2, \mu_3, \mu_4)$), THEN (G = «not mastered»);

IF($\mu_2 = max(\mu_1, \mu_2, \mu_3, \mu_4)$), THEN (G = «partially mastered»);

IF($\mu_3 = max(\mu_1, \mu_2, \mu_3, \mu_4)$), THEN (G = «mastered enough»);

IF($\mu_4 = max(\mu_1, \mu_2, \mu_3, \mu_4)$),THEN (G = «mastered fully»).

In general terms, this can be written as follows:

IF($\mu_i = max(\mu_1, \mu_2, \mu_3, \mu_4)$), THEN($G = g_i$).

Similarly, it is possible to assess the degree of mastering a competence based on information about the degree of mastering the entire subject.

In addition to the knowledge model, the student model should also store information about his activity in the system. Statistics on the activity of work in the system (time, date and duration of studying, taking tests, etc.) can be used to assess the conscientiousness, responsibility, independence of work and the pace of learning, which, in turn, can be used by the ITS recommendation subsystem or college teachers. These statistics can be stored in the student's user activity model and taken into account when assessing the acquired competencies.

Thus, a student's model, consisting of a student's knowledge model and a student's user activity model, can be used not only for effective assistance to the student in the learning process, but also for the most complete assessment of his knowledge, skills, abilities, learning ability, ability to use the information received, personal characteristics, etc.

Further developing the ITS of the College, it is proposed to use a precedent approach to accumulate the experience of teachers. In the process of learning with the help of ITS, a knowledge base of precedents is accumulated. At the first address of the student to the ITS, his personal characteristics will be saved and stored. This information in the future will make it possible to draw up the most suitable and successful methods of learning/teaching. It is planned to develop an ontology of techniques and methods used by a teacher in teaching a subject, taking into account the individual abilities of students. When referring to this knowledge base, the teacher will be able to choose the optimal learning model.

Conclusions

Thus, an intelligent training system (ITS) should provide an interactive dialogue with the student as well as the operational control function allows the system to respond quickly and adjust for a more effective learning/teaching process. Within the framework of the ITS, an individual training and testing strategy should be built, based on the level of individual knowledge, abilities and skills. In addition, ITS is also focused on the teacher, so it is necessary to have an intuitive interface that helps create, add, change educational material, and analyze learning outcomes. The use of ITS will improve the efficiency of the learning process, make it more interactive and individual.

Moreover, the competence-based approach on which the proposed model is based will minimize the lag of education from the dynamically changing needs of the national economy.

References

1. Brusilovsky P. The Adaptive Web / P. Brusilovsky, E. Millán. – Springer-Verlag Berlin Heidelberg, 2007. – 190 s.

2. Zhou L. A Network Based Intelligent Training System of Internet Marketing for SMEs / L. Zhou., X. Feng // International Conference on Future Computer Supported Education. – 2012. – №2. – S. 209-214.

3. Khoroshkova O. Implementation of an individually oriented approach for trained programming based on a competent approach / O. Khoroshkova // Naukovi zapysky Natsionalnoho universytetu «Ostrozkaakademiia». Seriia: Pedahohika. – 2019. – № 3 (47). – S. 33-38.

4. Bespalko O. Personalization training based on piece intelligence / O. Bespalko // Visnyk Chernihivskoho natsionalnoho pedahohichnoh ouniversytetu imeni T. H. Shevchenko. – № 170 (1). – S. 83-89.

5. Danyliuk O. Special orientations of LED in the system of higher lighting based on the technologies of piece intelligence / O. Danyliuk // Osvita ta rozvytok obdarovanoi osobystosti. – 2019. – №12 (31). – S. 31-36. [In Ukrainian]

6. Hutsol S. Use of artificial intelligence technologies in education / S. Hutsol, V. Khoroshkevych // Skhidnoievropeiskyi zhurnal peredovykh tekhnolohii. – 2019. – № 4 (10). – S. 20-25.

7. Okhten O. Intelligent tutoring system based on the scenarized approach to knowledge representation / O. Okhten, A. Gromovoy // Proceedings of the 2017 IEEE First International Conference on Data Stream Mining & Processing (DSMP). – 2017. – S. 120-124.

8. Varchenko-Trotsenko L. Scenarization of the educational process: A new vector of development of modern pedagogy / L. Varchenko-Trotsenko, N. Derkach // Proceedings of the 2019 IEEE First International Conference on Advanced Information and Communication Technologies (AICT). – 2017. – S. 254-259.

9. Voronenko Y. Scenario-based learning environment for the basics of computer programming / Y. Voronenko, I. Kovtun // Proceedings of the 2017 IEEE First International Conference on Data Stream Mining & Processing (DSMP). – 2017. – S. 111-115.

10. Fari A. Intelligent tutoring systems: A comprehensive survey / A. Faria, P. Martins, D. Carneiro// Artificial Intelligence Review. – 2017. – № 47 (2). – S. 147-165.

11. Woolf B.P. Building intelligent interactive tutors: student-centered strategies for revolutionizing e-learning / B.P. Woolf . – Morgan Kaufmann, 2017. – 120 s.

12. Randler C. Didactic units on genetics: Their effects on students' interest and conceptual understanding / C. Randler, C. Vollmer // Journal of Biological Education. – 2017. – № 53 (4). – S. 376-388.

Література

1. Brusilovsky P. The Adaptive Web / P. Brusilovsky, E. Millán. – Springer-Verlag Berlin Heidelberg, 2007. – 190 s.

2. Zhou L. A Network Based Intelligent Training System of Internet Marketing for SMEs / L. Zhou., X. Feng // International Conference on Future Computer Supported Education. – 2012. – №2. – S. 209-214.

3. Хорошкова О. Реалізація індивідуально-орієнтованого підходу у навчанні програмування на основі компетентнісного підходу / О. Хорошкова // Наукові записки Національного університету «Острозька академія». Серія: Педагогіка. – 2019. – № 3 (47). – С. 33-38.

4. Беспалько О. Персоналізація навчання на основі штучного інтелекту / О. Беспалько // Вісник Чернігівського національного педагогічного університету імені Т. Г. Шевченка. – 2020. – № 170 (1). – С. 83-89.

5. Данилюк О. Особистісно орієнтований підхід у системі вищої освіти на основі технологій штучного інтелекту / О. Данилюк // Освіта та розвиток обдарованої особистості. – 2019. – № 12 (31). – С. 31-36.

6. Гуцол С. Використання технологій штучного інтелекту в освіті. / С. Гуцол, В. Хорошкевич // Східноєвропейський журнал передових технологій. – 2020. – № 4 (10). – С. 20-25.

7. Okhten O. Intelligent tutoring system based on the scenarized approach to knowledge representation / O. Okhten, A. Gromovoy // Proceedings of the 2017 IEEE First International Conference on Data Stream Mining & Processing (DSMP). – 2017. – S. 120-124.

8. Varchenko-Trotsenko L. Scenarization of the educational process: A new vector of development of modern pedagogy / L. Varchenko-Trotsenko, N. Derkach // Proceedings of the 2019 IEEE First International Conference on Advanced Information and Communication Technologies (AICT). – 2017. – S. 254-259.

9. Voronenko Y. Scenario-based learning environment for the basics of computer programming / Y. Voronenko, I. Kovtun // Proceedings of the 2017 IEEE First International Conference on Data Stream Mining & Processing (DSMP). – 2017. – S. 111-115.

10. Fari A. Intelligent tutoring systems: A comprehensive survey / A. Faria, P. Martins, D. Carneiro// Artificial Intelligence Review. – 2017. – № 47 (2). – S. 147-165.

11. Woolf B.P. Building intelligent interactive tutors: student-centered strategies for revolutionizing e-learning / B.P. Woolf . – Morgan Kaufmann, 2017. – 120 s.

12. Randler C. Didactic units on genetics: Their effects on students' interest and conceptual understanding / C. Randler, C. Vollmer // Journal of Biological Education. – 2017. – № 53 (4). – S. 376-388.