Student model implementation in the digital educational environment for IT specialists training

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Abstract. The article presents the key aspects of implementation of the IT student model in the digital educational environment. The student model is the basis of the intelligent component of the digital environment to support the process of personalized e-learning, taking into account the needs and abilities of each student. The article provides justification, systematization and formal description of the main structural elements of the IT student model. The importance of the student model for monitoring the development of professionally significant personal qualities of students in IT areas is proven, and set of parameters of the student's personal model is determined. The results of the experiments performed by the authors, are analyzed, which confirm the adequacy of the developed model and allow us to establish relationships between its components. The software for the implementation of intelligent features for managing adaptive learning based on the developed student model is presented briefly.

1. Introduction

In the modern digital world, improving the quality of training of specialists in the field of information technology is one of the priority tasks of higher education. In the course of solving this problem, a promising direction is the development of intellectual capabilities of the digital educational environment for training bachelors and masters in the field of IT [1]. One of the most important intelligent features of the digital environment is an individual approach to each student in the learning process. Flexible adaptation of the educational environment to the needs and abilities of students can be implemented using the student model.

In a broad sense, the student model is understood as the knowledge of the e-learning system about the student used to organize the learning process [2]. This interpretation of the term "student model" is used in the works of P. L. Brusilovsky, G. A. Atanov, R. Mizoguchi, B. Woolf, and B. du Boulay. These authors position the student model as the basis of an intelligent e-learning system, and offer various ways to build and use this model. There is a noticeable increase of interest in implementing the student model due to the increasing popularity of Massive Open Online Courses (MOOCs). The authors of the investigations claim that the application of the student model in MOOCs will increase the effectiveness of training and reduce the still very high dropout rate of students [3].

The problem of intellectualization of the educational environment of the University based on the student model does not lose its relevance. However, there are still many debatable questions about the
implementation of the student model – set of model parameters, ways to obtain them, and algorithms for using them.

This article presents the authors' experience in implementing, supporting and using the student model in a digital environment for training IT specialists at Vologda State University.

2. The role of the IT student model in the digital educational environment

The educational environment for training IT specialists has come a long way of formation and development, starting from a scattered set of training resources. At present, it is an integrated information system with a number of intelligent features (figure 1).

![Figure 1. Architecture of the digital environment for IT specialists training.](image)

During their studies at the university, students are trained in several dozen different disciplines in accordance with the curriculum. For most disciplines, training courses are implemented in the MOODLE distance learning system. For the comprehensive development of professional skills, there is a distance trainer for the IT subjects (programming and algorithmization, databases, operating systems, etc.). The built-in system of automatic testing of students' solutions provides not only educational, but also diagnostic functions. To collect additional information about the psychological and cognitive characteristics of students, separate software tools are used [4], since the capabilities of MOODLE do not allow us to comfortably organize non-standard types of testing and questionnaires.

Databases of all components of the educational environment are integrated. During the learning process, they accumulate a large amount of detailed information about the progress in learning and development of each student. However, a significant part of this data is stored in a form that is not convenient for intellectual analysis, forecast of learning outcomes and flexible management of the personalized learning process. The implementation of the student model allows us to systematize the available information arrays and provide convenient access to data about students from the software for the implementation of intellectual features.

3. The main structural elements of the student model: justification and formal description

To develop a formal description of a student's model, it is required to select set of model parameters and describe the properties of each parameter. Each of the following components of the student model can be positioned as an independent model. Nevertheless, their joint use as part of a student's model makes it possible to take into account all the available individual characteristics of students in the learning management process.
3.1. Student initial model

This model serves to systematize the data that are entered by the student during his registration in the digital educational environment and the input questionnaire. The formal description of the input information can be represented by three sets:

\[
\{\text{Contact details}\} = \{\text{Name, Group, E-mail, Phone, Login, Password}\}
\]

\[
\{\text{Needs}\} = \{\{\text{Goals}\}, \{\text{Interests}\}\}
\]

\[
\{\text{Abilities}\} = \{\{\text{Previous\_education}\}, \text{Language}, \{\text{Health}\}\}
\]

The set \{Previous\_education\} includes the name and type of the previous educational institution graduated by the student and the assessment in profile subjects. The Language parameter allows us to identify students for whom the language of instruction is not native.

It should be noted that the entrance survey is carried out on a voluntary basis, but experience shows that the vast majority of students willingly take part in it. This allows us to collect some information about the needs and abilities of the student even before he started learning. The input data can be considered as static elements, although rare single updates are acceptable (for example, the phone has changed). They can be used as input information in all training courses, while for each specific course the set \{Needs\} can be specified separately in accordance with the specifics of the discipline.

3.2. Student learning progress models

Education at the university is carried out in strict accordance with the curriculum of the direction of training and the work programs of the disciplines. The learning outcome depends significantly on the needs and abilities of the student, but in any case, it must meet the regulatory requirements set forth in the educational standard. The strict regulation of the educational process slightly limits the possibilities of individualization of training. But from the point of view of implementing models of student progress, it is convenient, since it allows us to assess progress in the study of each academic course using a unified model for assessing progress. On this basis, it is possible to derive an overall assessment of the formation of competencies, using information on interdisciplinary relationships.

The work program of each discipline contains requirements for the input and output competencies, usually with an accuracy of didactic units (topics, sections). The formalization of the requirements will be called the normative model of the requirements for the learning outcomes. It is a sequence of units indicating the knowledge and skills that must be obtained in the study of each of them.

\[
\{\text{Requirements}\}_n = \{\text{Unit\_name, Finish\_date, \{Knowledge\}, \{Skills\}}\}_n, n=(1, 2, \ldots N),
\]

where \(n\) is the number of the didactic unit, \(N\) is the quantity of didactic units.

Knowledge and skills are separated only for the convenience of organizing diagnostic procedures. The didactic units are lined up in a sequence in the order they appear in the work program of the discipline. In this case, the output requirements of the previous unit are input for the next one. IT learning content has to be updated frequently, so defining and continually updating more complex relationships between didactic units is unnecessarily time-consuming.

The normative model of output knowledge and skills, in fact, is a norm with which the current level of knowledge and skills of a student can be compared when he is passing a certain course. For IT students, knowledge is usually assessed using various types of tests in the MOODLE system, skills — based on the results of laboratory works, course projects, and independent work with a distance trainer. The use of tools for automatic diagnostics of knowledge and skills makes it possible to fill a model of real current learning outcomes for each student with objective data.

\[
\{\text{Results}\}_n = \{\text{Unit\_name, Real\_finish\_date, Real\_Knowledge}, \{\text{Real\_Skills}\}\}_n, n=(1, \ldots N).
\]

The imposition of the model of current learning outcomes on the normative model of requirements for learning outcomes allows us to obtain an overlay model of student learning progress for each discipline. To analyze the progress in teaching IT students, a dynamic vector overlay model was
implemented using numerical assessments of each unit (it is convenient to use a 100-point assessment system). In the normative model, in this case, threshold values of points are set at which a didactic unit is counted as mastered. Points are recalculated after each significant event (the test is passed; the problem is solved) with the mandatory saving of the history of all training details.

After completing a discipline, student scores can be used as input values for subsequent disciplines that contribute to the development of the same competencies.

The implemented overlay model for assessing progress in learning has a significant drawback for the training of IT specialists — it does not allow evaluating additional knowledge and skills of a student that are not included in the normative model. At this stage, it is positioned only as a tool for a teacher who makes the final decisions on the organization of training and the assessment of its results.

3.3. Psychological and cognitive model of the student

In most works on intelligent systems and adaptive learning, the student's personal characteristics are analyzed only from the point of view of their consideration in the e-learning process. The authors of the article understand this problem more broadly. We believe that the development of professionally significant personal qualities of a student is one of the most important tasks in the training of an IT specialist. This opinion is confirmed by employers and graduates. Based on the importance of the problem, a separate component was identified in the student model that is responsible for the development of the student's psychological and cognitive sphere in the learning process.

We emphasize that the student's psychological and cognitive model is an interdisciplinary one. It is recommended for use by teachers of all disciplines. First, it allows us to fully implement the principles of a person-centered approach in teaching various disciplines. Secondly, the development of professionally significant personal qualities of a student in the process of studying at the University is possible only through the joint efforts of teachers of all disciplines.

A broad interpretation of the student's personality model affected the definition of its structural elements. In the course of the research, the task of identifying a set of professionally significant personal qualities of an IT specialist was solved. Analysis of scientific works, for example, [5], and Internet resources devoted to this problem, allowed us to determine three sets of parameters:

\[
\{\text{Cognitive\_ability}\} = \{\text{Intelligence, Memory, Attention, Logical\_thinking, Creativity}\}
\]

\[
\{\text{Regulation\_of\_activities}\} = \{\text{Responsibility, Working\_capacity, Independence, Initiative}\}
\]

\[
\{\text{Volitional\_qualities}\} = \{\text{Motivation, Goal\_setting, Problem\_solving\_skills}\}
\]

This list was discussed with members of the Club of IT directors of the Vologda region, who identified the most significant, from their point of view, qualities of an IT specialist. The majority of respondents among the cognitive qualities put attention in the first place, many also noted logical thinking. Of the other components, the leaders were responsibility, working capacity and ability to solve problems. According to the interviewed university professors, the quality of a training essentially depends on motivation and goal setting; this opinion is supported by many students.

It is important that all the selected qualities are quantifiable using tests and expert assessments [5]. Quantitative indicators change slowly, therefore, it is recommended to carry out measuring procedures in order to track the dynamics of change no more than once a year.

4. Results of experiments

In this section, we present the results of recent experiments, the material for which was collected in the process of distance learning during the period of restrictive measures due to a difficult epidemic situation. The unexpected transition to distance learning proved to be a serious test of the digital educational environment, and this test was successful. As a result of intensive e-learning, a lot of information has been collected in databases that is useful for analysis.

One of the directions of experimental research was the assessment of the impact on the progress in learning of the psychological and cognitive characteristics of the student and the previously acquired
knowledge and skills. The experiment was carried out in order to confirm the adequacy of the developed student model and to determine the relationships between its components. Correlation analysis was used to process the experimental data.

We will present the results of the analysis for two disciplines — "Databases" (core subject of IT directions, 3rd year, 26 students) and "Foreign language" (subject develops universal communicative skills, 1st year, 25 students). The values of the parameters of the student's psychological and cognitive model were obtained even before the introduction of quarantine measures by testing and questioning on a voluntary basis. Thus, all the data required to perform the correlation analysis were available.

During the analysis, the influence of various parameters of the student's model on knowledge and skills was assessed based on the results of their automatic diagnostics in a digital environment. For each of the parameters, a check was made for the correspondence of its values to the normal distribution law, and scatter diagrams were constructed to represent the nature of the dependence of the learning outcomes on the parameter [4]. The scatter diagrams showed a good approximation to the linear dependence for all parameters, but the distribution laws of the parameter values did not always correspond to the normal one. In this regard, for a quantitative assessment of the dependencies, the Spearman's rank correlation coefficient was calculated (table 1 and table 2).

Table 1. Correlation between learning outcomes and student model parameters for the discipline "Databases".

| Student model parameter                      | Parameter measurement method         | Correlation coefficient |
|----------------------------------------------|--------------------------------------|-------------------------|
|                                              |                                       | Knowledge  | Skills     |
| Input knowledge                              | Computer Science Tests                | 0.71        | 0.56       |
| Input skills                                 | Solving programming problems          | 0.67        | 0.92       |
| Attention                                    | Bourdon proof test                    | 0.63        | 0.68       |
| Responsibility                               | Assessment by group mates and teachers| 0.82        | 0.57       |
| Logical thinking                             | Voinarovsky test                      | 0.75        | 0.78       |
| Intelligence (IQ)                            | Eysenck test                          | 0.55        | 0.68       |
| Creativity                                   | Tunik Questionnaire                    | 0.15        | 0.31       |
| Memorizing logically related material        | The method of Loeser                  | 0.61        | 0.47       |
| Memorizing unrelated material                |                                       | 0.41        | 0.22       |

Table 2. Correlation between learning outcomes and student model parameters for the discipline "Foreign language".

| Student model parameter       | Correlation coefficient |
|------------------------------|-------------------------|
|                              | Vocabulary   | Speech skills |
| Input vocabulary             | 0.85         | 0.87          |
| Input Speech skills          | 0.73         | 0.86          |
| Motivation                   | 0.82         | 0.65          |
| Intelligence (IQ)            | 0.73         | 0.71          |
| Memory                       | 0.82         | 0.69          |

In fact, the results of the processing of experimental data confirm the opinion of employers that the most important qualities of an IT specialist are attention, logical ability and responsibility. Not is it surprising that there is the highest correlation between database skills and programming success (prior discipline). A weaker, but still significant correlation with Eysenck's IQ test results is noted for many core disciplines of the IT direction.

The results of the correlation analysis for the discipline "Foreign language" are different. The data in table 2 are also in good agreement with the real state of affairs — interest in mastering the English language, IQ and memory within the normal range will ensure the successful development of the student's English-speaking skills.
5. Development of intelligent software based on the student model

The student model presented in the article is implemented in a digital educational environment for training IT specialists at Vologda State University in the form of a consolidated data warehouse and software for data collection and data access. Implementation of the student model is available for teachers online for flexible management of the learning process and assessment of learning outcomes. It also serves as an information basis for the developed smart adaptive e-learning software using artificial intelligence methods.

When developing the intellectual component of the digital educational environment, the authors used an agent-based approach, which made it possible to make the software implementation process more manageable and increase its efficiency. The architecture of an intelligent agent-based system using the student model and some details of its development are presented in [6]. Currently, a number of useful smart features have been implemented, such as selecting of personal educational material, evaluating of the difficulty of training tasks, predicting learning outcomes, building and adjusting individual learning paths to meet the needs and abilities of IT students. Some of them are presented in [7] and [8].

Intelligent software tools are implemented now in the form of electronic assistants for the student and the teacher, which perform recommendatory functions. The final decisions on the organization of the learning process are made by the teacher, taking into account the opinions of students.

6. Conclusion

The process of developing a digital educational environment for training IT specialists at Vologda State University is still far from complete. IT students take an active part in the development and testing of educational software. Thanks to the joint efforts of all participants in the educational process, the opportunities for digital education of students are gradually improving and expanding, which makes it possible to improve the quality of training for IT specialists.

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