Development and analysis of the training course "Organization of databases" with AI

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Abstract

This article explores approaches to teaching database organization and management, emphasizing the importance of effective learning methods. It analyzes various teaching strategies, including project-based learning and optimized pedagogical approaches, to enhance students' skills in database design, implementation, and maintenance. The study highlights the significance of addressing knowledge gaps, implementing innovative teaching methods, and evaluating learning effectiveness.

The research also examines different resources for learning database organization, from online courses to certifications. A key focus is on the development of a web application for assessing the quality of educational tests using the Rasch model. This application allows for the construction and analysis of test information curves, item characteristic curves, and test score distributions.

The article describes the technical implementation of the application, including its architecture, development tools, and functionalities. It provides a detailed overview of how the application processes test data and generates visual representations to aid in test quality assessment, ultimately contributing to the improvement of database education methods.

Keywords

Information technology, intelligent communication technologies, educational environment, online education, course quality, technology in education, database learning. 1

1. Introduction

Effective training of the organization and management of databases is of great importance to ensure optimal use of data resources and maintain system performance. In this work, several approaches to learning in this field, aimed at improving students' skills in designing, implementing and maintaining databases, were considered and analyzed. These approaches include various methods and tools for providing comprehensive training [1]. By reviewing existing approaches to database organization and management education, we can gain valuable information about the most effective strategies for teaching students the necessary skills and knowledge for proficient database management:

1. Project-based learning: one approach to organizational learning and database management involves the implementation of the project-based learning method. This approach focuses on organizing learning through a course management system that allows participants to participate in hands-on projects that simulate real-world database scenarios. Project-based learning can be an effective way to gain hands-on experience and allow students to apply their knowledge in real-world contexts, which is critical to developing database management competence
2. Optimization of the approach to learning: approach to learning plays an important role in the learning process. It is at this stage that you can prove AI, for example, to create test tasks or automate their filling, AI copes well to create a knowledge bank in a training course. It is also possible to use interactive methods to involve students and integrate theoretical concepts

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with practical applications. Thus, mentors of the curriculum may guarantee that participants will receive a deep understanding of the course materials

3. Bridging Knowledge Gaps: One of the challenges of taking a course is bridging knowledge gaps. To address this issue, a determined effort must be made to identify and fill any existing gaps in participants' understanding of database concepts and technologies. Training programs should include targeted activities aimed at explaining unclear parts of the material, thus providing participants with a comprehensive understanding of the principles that are taught in the training course
4. Approaches to training: effective approaches to training are essential to ensure high quality training. Educators and mentors should use innovative and interactive learning methods to engage participants and promote their productive outcomes. By using a variety of instructional approaches, such as case studies, group discussions, and simulations, instructors can facilitate the creation of diverse curriculum styles and enhance student learning of course materials
5. Assessing the effectiveness of training: Training is of utmost importance to ensure that participants acquire the necessary skills and knowledge. By implementing systematic assessment methods, mentors can measure students' performance, skills, and overall success
6. Best Practices: Applying best practices to training is essential to ensure participants are able to learn the latest industry standards and methodologies. Collecting and organizing data, as well as following established procedures, are integral components of any training. Training participants in such practices will contribute to the effective assimilation of educational materials.

When it comes to learning about database organization, there are a number of resources to consider, from online courses to certifications [2] and training programs. These resources are designed to provide individuals with the knowledge and skills needed to effectively manage and organize databases, both professionally and for personal development.

Online platforms such as Coursera [3], Udemy [4], and LinkedIn Learning [5] offer a wide variety of database management courses. These courses cover fundamental topics such as database structure and administration, SQL queries and data security, etc. In addition, they often offer practical exercises and projects to consolidate the studied materials.

Another valuable resource is the availability of certificates from organizations such as Oracle [6], Microsoft [7], and MongoDB [8]. These certifications not only validate individuals' expertise in database management, but also provide structured learning resources for exam preparation. They cover a variety of areas such as relational database management systems, NoSQL databases and cloud database solutions.

In addition, institutions such as edX [9] and Khan Academy [10] also offer free courses in database management, making learning accessible to a wider audience. These courses are developed by industry experts and cover various aspects of database management, including database modeling, indexing, and performance optimization. They often use interactive tools and simulations to enhance the learning experience.

In addition to online courses and certifications, professional associations and industry organizations often offer training and workshops related to database training. These may include live webinars, seminars and conferences where participants can learn from leading experts in the field and stay abreast of the latest database management trends and practices.

In addition, given the constant development of technology, blogs, forums and communities dedicated both to the specific topic of databases and to many other topics in general will help to stay abreast of new information. Platforms such as Stack Overflow [11], Database Journal [12], and Oracle Community [6] provide a space for professionals and enthusiasts to share knowledge, advice, and stay abreast of best practices and new trends in the industry.

Finally, gaining hands-on experience through internships, studentships, or personal projects can go a long way toward improving database organization and management skills. By working on real-world database implementations and troubleshooting scenarios, individuals can gain practical insight into the complexity of database management and improve their problem-solving skills.

In summary, the resources and approaches available for teaching organization and database management are varied and designed for students of varying skill levels and preferences. Through structured online courses, industry-recognized certifications, professional seminars, or hands-on experience, individuals have ample opportunities to acquire and improve their skills in this important field of information technology. By integrating the existing learning approaches described above into their programs, organizations can ensure that students develop the necessary skills and knowledge to skillfully manage and optimize databases to improve business performance and decision-making systems.

2. Description of the educational course on the organization of databases

DFD, IDEF0 and IDEF3 context diagrams of various approximations were created to describe the course model. The BPWin software environment was used to create diagrams. These models visually represent system functions and data flows, providing important information for possible further improvement of the system and optimization of its performance:

The diagram of the Figure 1, demonstrates how various input materials and resources are transformed into course outcomes under the guidance of certain rules and with the participation of students and teachers. This is a high-level representation of the entire learning process within this course. A student and a teacher interact with each other in the system.

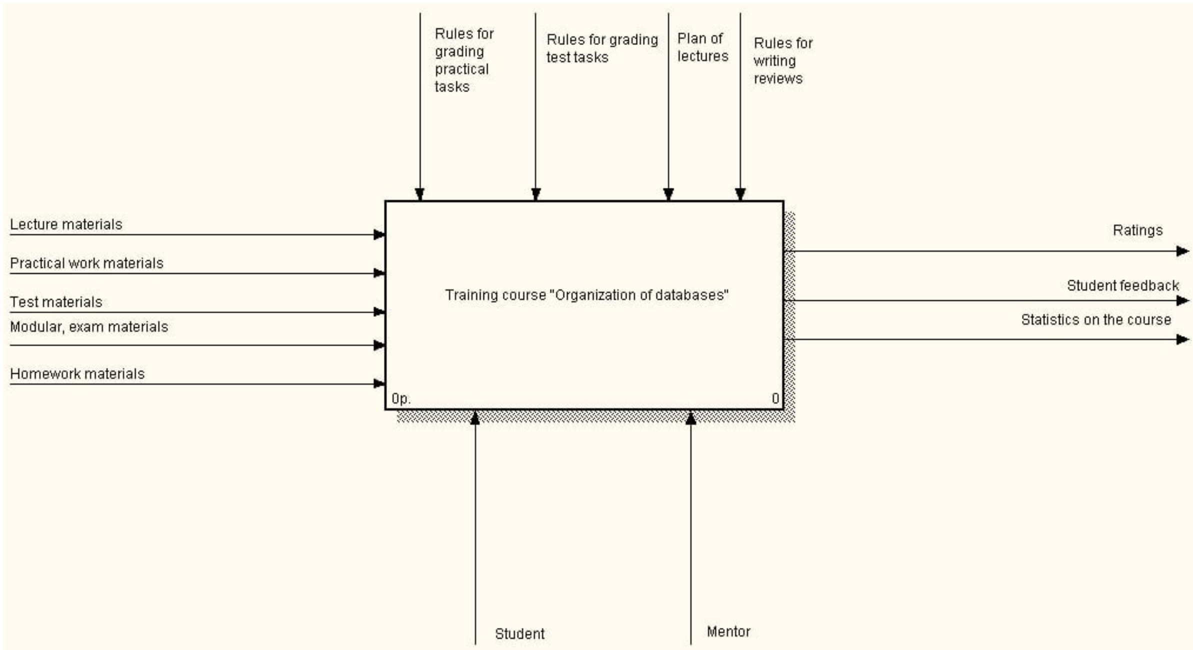

Figure 1: General view "Organization of Databases"

This is an IDEF0 context diagram showing an overview of the "Organization of Databases" training course.

The diagram in Figure 2 shows an IDEF0 flow chart for a course titled “Database Organization”. The diagram illustrates the process flow of the various course components and activities. It begins with “Lecture Materials” and “Test Materials” on the left-hand side, moving on to activities such as “Studying or Participating in Lecture” and “Taking Tests.” The diagram progresses through practical work, homework, and module exams, with arrows indicating the flow and relationships between the various stages. The diagram culminates with “Feedback Writing” on the right-hand side. Throughout the diagram, there are notations of rules, knowledge transfer, and student-teacher interactions, represented by arrows of different colors. The overall layout provides a visual representation of the course structure and the flow of learning.

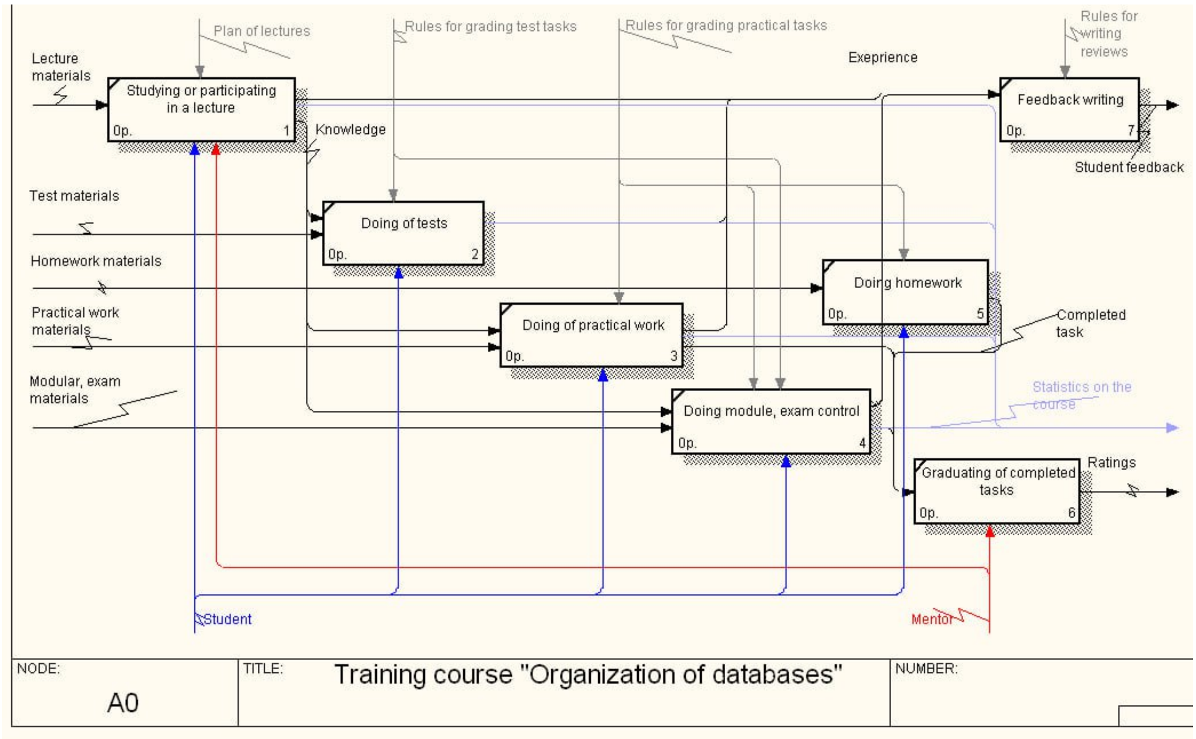

Figure 2: Comprehensive structure of a organization of databases training course

The diagram in Figure 3 shows a process flow chart consisting of several interrelated stages. The diagram illustrates a complex process using IDEF3 notation to model the sequence of operations and decision-making logic. The diagram effectively displays both sequential and parallel actions, as well as decision points in the process. For example, at the initial stage, participation in a lecture or its elaboration is required (element 1), then two parallel units of behavior (UOB): "Completing a test task" (element 2), "Completing a practice" (element 3). After completing several units, in accordance with the curriculum, a module control must be passed (element 4). At the end of the course, an exam is provided (element 6). Also, during the study, it is necessary to complete homework (element 5).

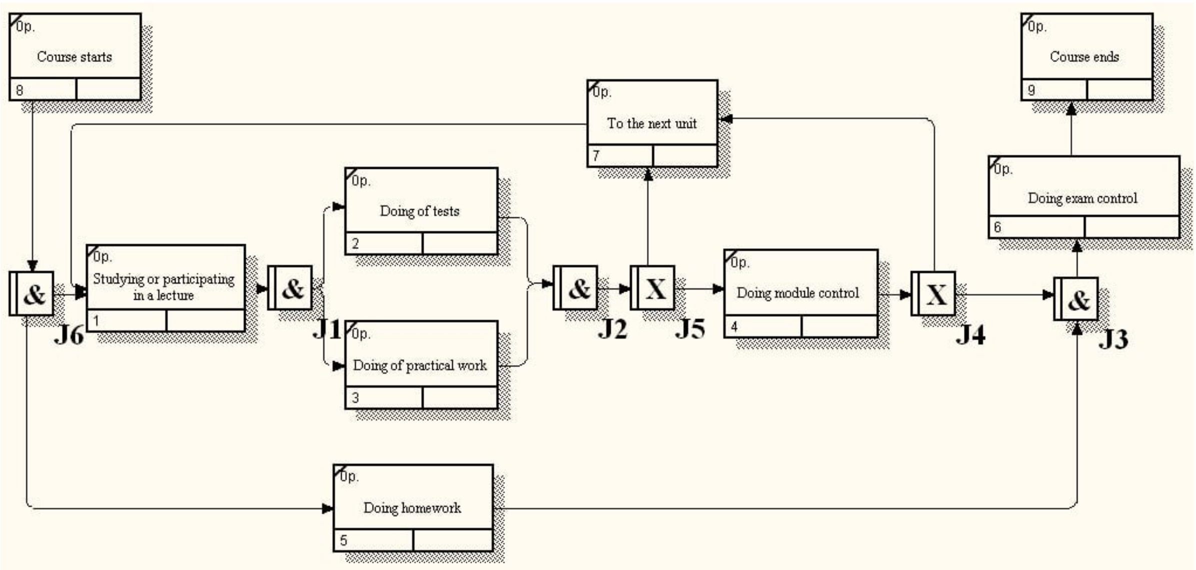

Figure 3: Sequence diagram of the learning process

The data flow diagram (DFD) depicts the interaction process between a student, a mentor, a course, and a database within the Database Organization course. The diagram shows the main components of the system: a student, a course, a mentor, and the STM database. A student accesses the course learning materials and completes assignments. After completing the assignments, the student provides feedback and grades for the course. Completed assignments, feedback, and grades are transferred to the course. The course, in turn, sends this data to the STM database for storage and analysis. The mentor also accesses the student learning materials and completed assignments. The mentor can view the student feedback and grades to assess their progress and provide recommendations. The course sends statistics and information about the student's progress to the STM database. The STM database stores all learning materials, completed assignments, grades, and feedback. This data is used to analyze the effectiveness of the course and improve the quality of training. Students and mentors can access data from the database to monitor progress and adjust the learning process. Course materials may include lectures, practical assignments, tests and other resources. Assessments and feedback from students help the course adapt to the needs of learners. The interaction between the student, mentor and course occurs through data exchange, which ensures transparency and efficiency of learning. Each component of the system plays its role in ensuring the quality of the educational process. Course materials are updated and stored in the database, ensuring the relevance of information. The mentor plays an important role in supporting students and providing them with feedback. The STM database is the central repository of all course information. It allows collecting and analyzing data to improve the learning process. This diagram helps to understand how information flows between participants in the process and how each component interacts with each other.

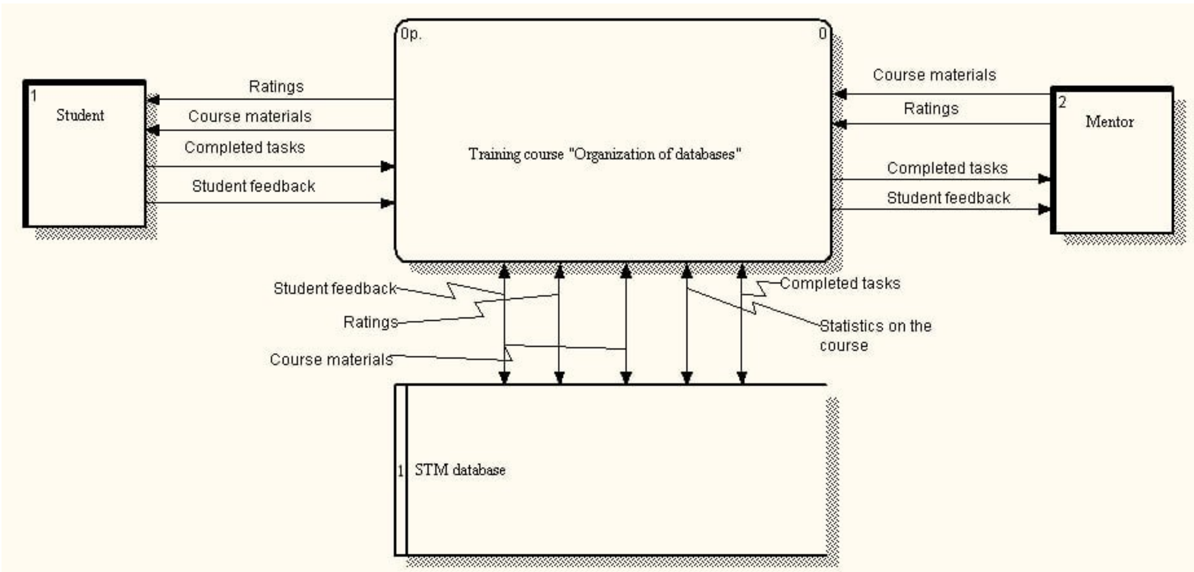

Figure 4: Data flow diagram for the database organization course

The data flow diagram (DFD) depicts the interaction process between the components of the Database Management course system, from uploading course materials to receiving feedback from students. The diagram shows the main processes: uploading course materials, grading completed assignments, uploading completed assignments, and writing feedback. The process begins with uploading course materials, which are provided to students for study. These materials include lectures, practical assignments, and other learning resources. Students upload these materials and begin completing assignments. After completing the assignments, students upload them for grading. The assignments are sent for grading, where a mentor evaluates their quality and correctness. Evaluation includes checking answers, their compliance with criteria, and assigning grades. Students provide feedback on the course and graded assignments. Feedback can include comments, reviews, and suggestions for improving the course. This process collects information about how students perceive the course. Each process interacts with the data flow, ensuring the transfer of information between participants. Course materials, grades, completed assignments, and feedback move between students and the course system. This interaction enables effective learning and assessment. Uploading completed assignments and feedback allows the course system to store all information in a centralized database. This makes it easier to access the data for analysis and reporting. Thus, this data flow diagram illustrates all the stages of interaction between students and the course system. It helps to understand how information is transferred and used to improve learning.

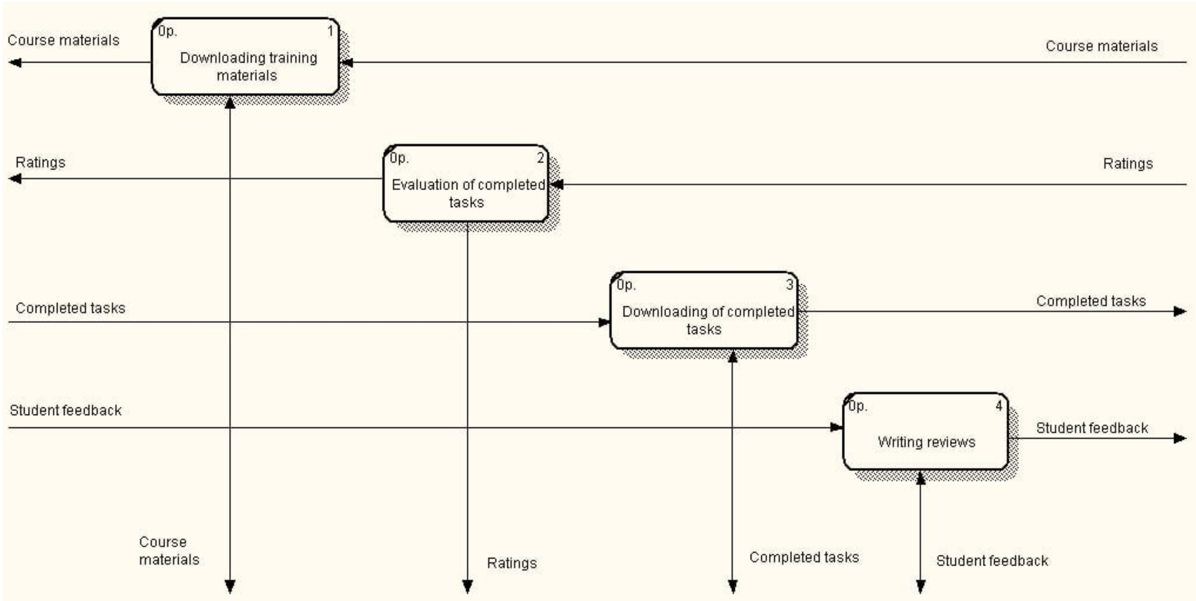

Figure 5: Data flow diagram of interaction of elements in the learning process

Figure 6 and Figure 7 present the structure and overall view of the training course on the STM platform, respectively. As we can see from the graphic materials, the training course consists of 16 units (the leaves in the figure represent individual units), namely:

1. Main sections – 10 units;
2. Modular controls – 2 units;
3. Homework – 1 unit;
4. Exam – 1 unit;
5. Auxiliary section – 1 unit;
6. Additional tasks – 1 unit.

The diagram illustrates the structure of the "Database Organization" course, divided into main, secondary and control sections. Core sections include topics such as ADO.NET, Entity Framework, and LINQ, which cover basic concepts of working with data. Secondary sections and homework complement the main materials and help deepen knowledge. Control sections contain modules for checking knowledge and exams. This structure helps students study the material consistently and assess their knowledge as they progress through the course.

The main part of the course [13], with which the most interaction takes place during training, is 10 unit parts. Figure 7 shows the view of one of the units. Each such unit of this course contains the following elements:

1. Theoretical material for independent study;
2. Practice work;
3. The form for downloading the Practice report;
4. Useful resources and instructions for laboratory work;
5. Test task;

6. Questions for self-control;
7. Link to the general forum of the course.

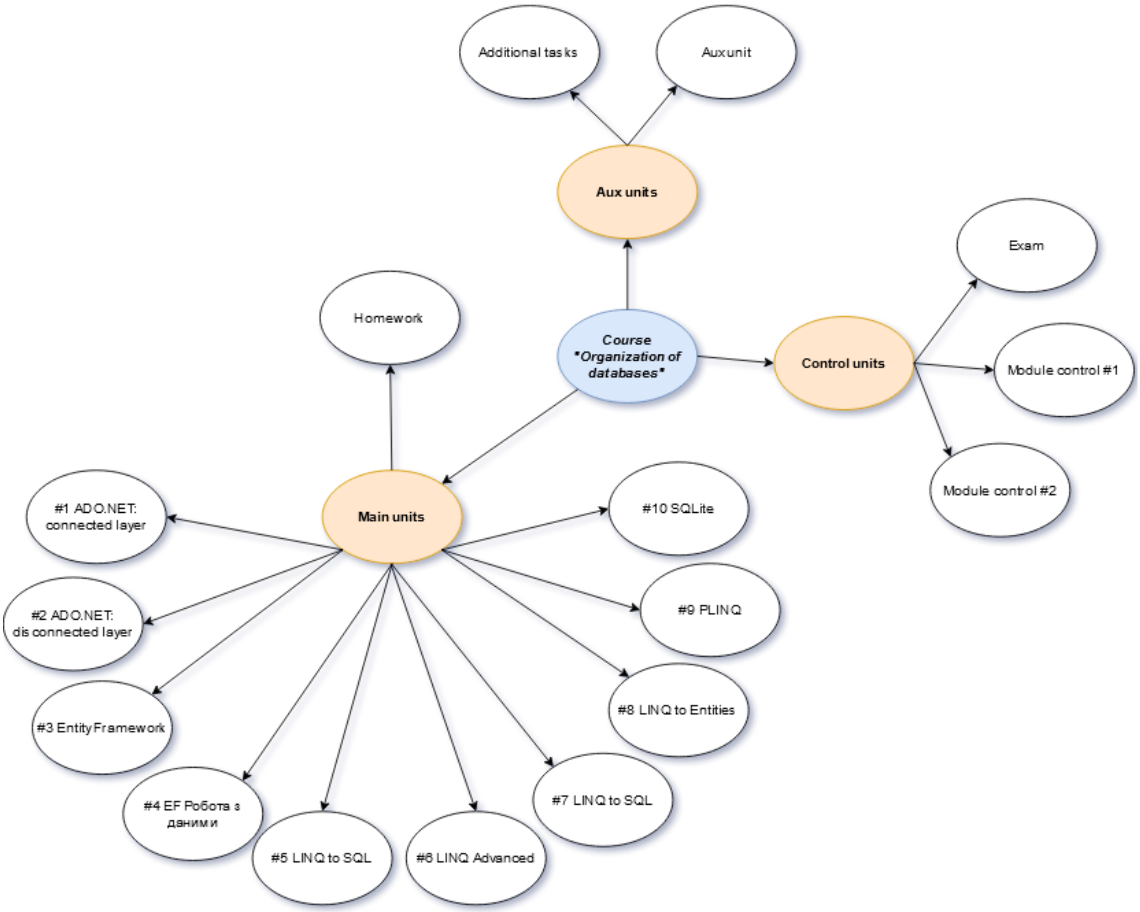

Figure 6: Structure of the course "Organization of databases"

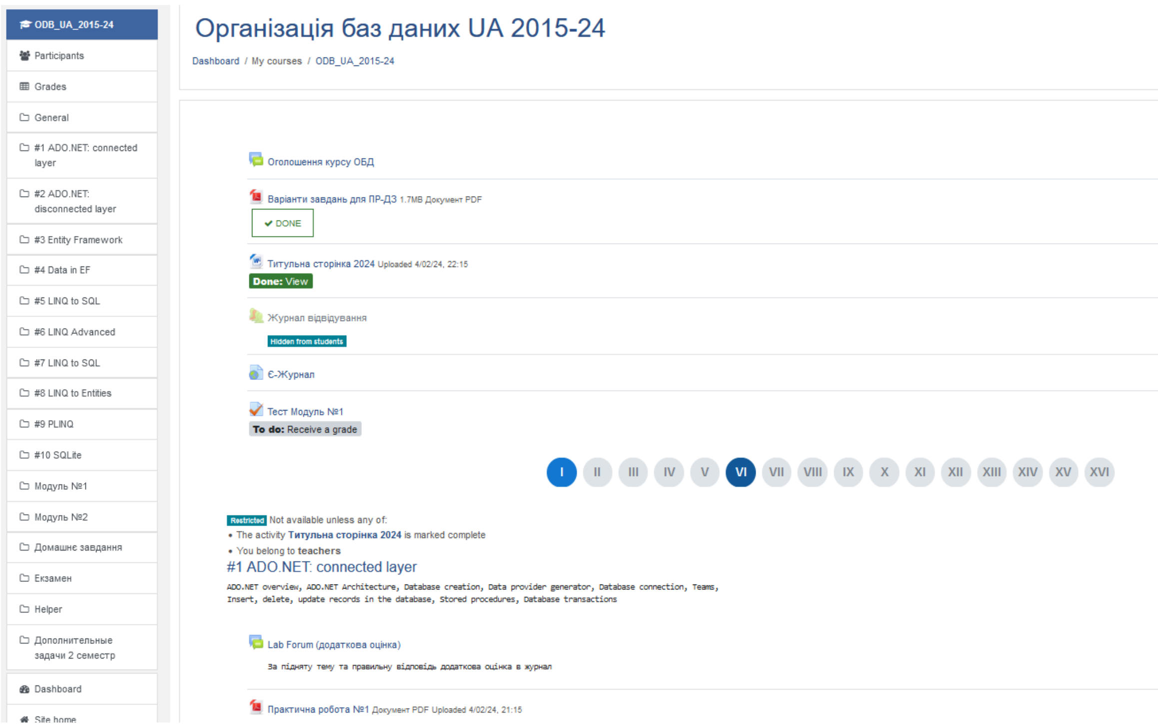

Figure 7: General view of the course on the STM platform

3. Means of evaluating the effectiveness of the course

With a systematic approach to assessment, instructors can tailor their online courses to effectively meet the needs of students. Below are some methods that are often used to evaluate the effectiveness of a course:

1. Exams – one of the methods of evaluating the effectiveness of the course is the analysis of exam scores to measure success after completing the main topics of the online course;
2. Pre- and post-tests – in some cases, the use of pre- and post-tests can be an effective way to assess the effectiveness of the training program by comparing knowledge or skills before and after the course;
3. Feedback and surveys - collecting feedback from students using surveys is the main and widely used technique for obtaining valuable information about the effectiveness of the course;
4. Analysis of student data – by analyzing data related to students, the level of progress and interaction with the course materials, it is also possible to evaluate its effectiveness.

Enabling a learning management system (LMS) – such as Moodle, Canvas or Blackboard – to deliver a course usually includes access to analytics and reporting features. With LMS analytics, you can gain insight into student engagement, covering aspects such as course availability, activity duration, completion rate, and academic performance.

An important criterion for the effectiveness of the course is the assessment of the difficulty of the test tasks. One of the options for assessing complexity is the use of psychometric paradigms. Psychometric paradigms refer to the approaches and methodologies used to evaluate the quality and effectiveness of tests, particularly in the fields of psychology and educational assessment. There are specific methods used to evaluate various aspects of tests that examine key criteria such as reliability, validity, standardized administration, and cognitive models. Psychometric paradigms include two main ones - classical test theory (CTT) and task response theory (IRT). These paradigms serve as a foundation for test development, quality assurance, data interpretation, and analysis, playing a key role in ensuring the accuracy and completeness of psychometric assessments:

1. Reliability and validity – Psychometric paradigms include methods for assessing the reliability and validity of tests, ensuring that the test qualitatively measures what it is intended to measure (reliability) and that it actually measures the construct it is intended to measure. These aspects provide a reliable framework for understanding the accuracy of assessment instruments, which is critical for obtaining valid estimates of test scores.
2. Item Response Theory – Item Response Theory (IRT) is one of the major psychometric paradigms that focuses on describing the relationship between latent traits, such as abilities, and the probability of different responses to test items. IRT increases the accuracy and efficiency of test scoring and analysis by providing insight into the characteristics of test items and the abilities of test takers.
3. Classical Test Theory – Unlike IRT, Classical Test Theory (CTT) is another fundamental psychometric paradigm that examines the relationship between observed test scores and true scores and how measurement error affects the accuracy of test scores.

By applying these psychometric paradigms, psychologists, educators, and researchers can design, refine, and evaluate tests to ensure their accuracy, validity, and overall effectiveness in measuring cognitive abilities, skills, and other relevant constructs. Below is a more detailed description of test scoring methods and test items.

The Rasch model "1 Parametric Logistic Latent Trait Model", also known as the one-parametric logistic model (1PL), is a psychometric model for analyzing categorical data, such as answers to questions in tests. It was developed by the Danish mathematician Georg Rasch and published in 1960.

The model is used to measure latent traits, such as attitudes or abilities, and it shows the probability that a person will get the correct answer to a test item:

$$P_i(\theta) = \frac{e^{(\theta - b_i)}}{1+e^{(\theta - b_i)}},$$

where θ and b_i are parameters of respondents' ability and task complexity, respectively.

The interaction of two sets θ_j i b_i forms data that demonstrate a property known as conjoint additivity. Skillful application of the Rasch model ensures complete independence of respondents' parameters from the tasks they solve, and vice versa. This quality, called specific objectivity, emphasizes the precision of measurement achieved by the Rasch model.

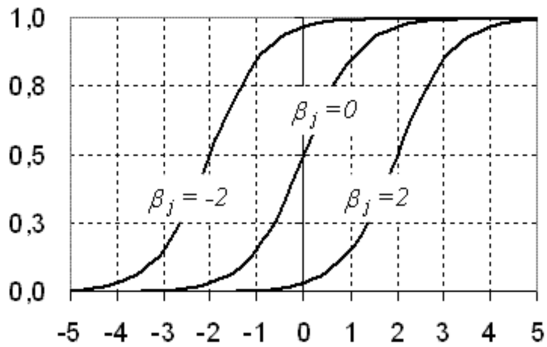

Figure 8: Task characteristic curves (ICC) in the model (1PL)

Figure 8 shows the item characteristic curves (ICC) in the 1PL model. The difficulties of tasks are described at different levels of -2, 0 and +2 logits, where the first is the easiest, the second is medium, and the third is the most difficult. The figure highlights that the subject's probability of success in the task increases with his readiness level θ. Tasks can vary in probability of getting the correct answer, with probabilities approaching one, 0.5, and near zero for the easiest, medium, and hardest tasks, respectively.

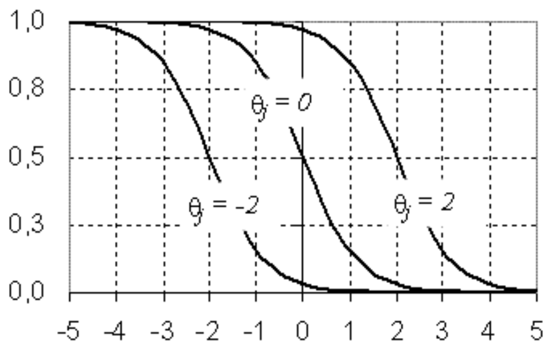

Figure 9: Subject characteristic curves (ICC) in the 1PL model

Figure 9 presents the within-subjects characteristic curves (ICCs) in the 1PL model, which represent the curves for subjects with readiness levels ranging from -2 logits (weakest) to +2 logits (strongest). The illustrations emphasize that a higher level of task difficulty gives a lower probability of providing the correct answer to the task. For example, a task with a difficulty parameter of 0 represents a serious problem for a subject with a readiness level of -2 logits, while a subject with 0 logits has a probability of completing the task of 0.5, and subjects with +2 logits have almost sure success.

Birnbaum's two-parameter model:

$$P_i(\theta) = \frac{e^{a_i(\theta - b_i)}}{1+e^{a_i(\theta - b_i)}},$$

where a_i - discriminability parameter;

If the test consists of tasks with different levels of differential ability (a_i), then the one-parameter 1PL model is inadequate for such data characterization. To eliminate this limitation, A. Birnbaum introduced an additional parameter - a_i, identified as the element discrimination parameter or the discriminability parameter.

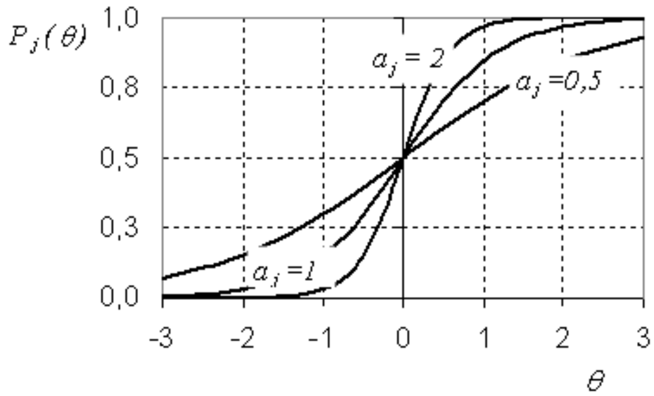

Figure 10: ICC in the two-parameter 2PL model

The parameter ai determines the steepness of the characteristic curve for the i-th point. Figure 10 provides examples of characteristic curves that demonstrate that a higher value of ai results in a steeper curve, indicating a greater differentiating capability of the element.

In Birnbaum's two-parameter model, instead of the differential ability parameter a_i for the element, the parameter a_j can be introduced, which means the measure of respondents' knowledge structuring. This parameter a_j determines the steepness of the characteristic curve for the j respondent, while b is the respondent parameter. The model calculates the probability of a correct answer based on these parameters using the formula:

$$P_j(\theta) = \frac{e^{a_j(\theta_j - b)}}{1+e^{a_j(\theta_j - b)}},$$

where a_i - measure of respondents' knowledge structuring.

It is proposed to integrate both versions of Birnbaum's two-parameter model regarding tasks and respondents, with the aim of unifying the consideration of the differential ability and structuring of respondents' knowledge. This unified model calculates the probability of a correct answer using the formula:

$$P_{ij}(\theta_j, b_i) = \frac{e^{\frac{a_j a_i}{\sqrt{a_j^2 + a_i^2}}(\theta_j - b_i)}}{1+e^{\frac{a_j a_i}{\sqrt{a_j^2 + a_i^2}}(\theta_j - b_i)}},$$

In the simplified interpretation of Birnbaum's two-parameter model, the differentiated ability of the element or the structuring index of the respondent is replaced by the characteristic $\frac{a_j a_i}{\sqrt{a_j^2 + a_i^2}}$,, which is constantly lower than individual values a_j and a_i.

This model is most suitable for scenarios involving a large number of tasks and respondents. With the collective estimation of task and respondent parameters and potential multimodality in the likelihood function, the risk of erroneous decisions increases due to the multiple parameters that require estimation.

Classical testing theory postulates the existence of a true score, "T," which represents the score that would be achieved without any measurement error. This true score, T, is essentially the expected score in an infinite number of error-free tests. However, in practice, people never see this true estimate; instead, they get only the observed score X, which is assumed to be the true score modified by some error rate E:

$$X = T + E$$

In classical test theory, the interaction between the observed X score, the true T score, and the error score is a central theme that focuses on these relationships in the population to assess the quality of the test score. Central to this assessment is the concept of reliability, which is defined as the ratio of the variance of true scores, T, to the variance of observed scores, X. The reliability of the observed test results, denoted as ρ^2_{XT}, quantifies the proportion of the variance of the true score σ^2_T to the variance of the observed score σ^2_X:

$$\rho^2_{XT} = \frac{\sigma^2_T}{\sigma^2_X},$$

Based on the relation that the variance of the observed estimates is equal to the sum of the variance of the true estimate and the variance of the error estimate, this translates into a reliability equation that establishes the effect of the signal-to-noise ratio:

$$\rho^2_{XT} = \frac{\sigma^2_T}{\sigma^2_X} = \frac{\sigma^2_T}{\sigma^2_T + \sigma^2_E},$$

This equation intuitively emphasizes that higher reliability of test results corresponds to smaller percentages of error variance in test results, and vice versa. Furthermore, reliability actually represents the proportion of variance in test scores that would be accounted for if true scores were known. In addition, the square root of reliability represents the absolute value of the correlation between true and observed scores.

Question response theory (IRT) is a well-known statistical technique used to measure individual differences in fields such as education and psychology. This approach is widely used in the development, analysis, and evaluation of tests, questionnaires, and similar instruments for measuring latent traits. Here is a comprehensive look at the main aspects of IRT:

1. Integrated application – in an educational context, IRT plays a key role in assessing test task parameters, such as discrimination and task difficulty, through comprehensive task analysis;

2. Models – IRT typically uses univariate models to measure a single latent trait to ensure accurate test scoring and design test items to measure a variety of abilities;

3. Scoring - An essential aspect of IRT is its ability to produce scores that account for differences in task difficulty across test forms.

Cognitive models and situational learning are concepts that have received considerable attention in educational psychology. Situational learning, also known as situational cognition, was first introduced as a learning model through the research of Paul Duguid. The theory suggests that people learn best when they can place information in a context that emphasizes the social nature of learning. The concept of situated learning essentially revolves around making meaning out of real everyday activities where learning takes place in relation to a specific context or situation.

In risk perception research, the standardized administration of a psychometric paradigm plays a fundamental role in the empirical investigation of potential terrorism and other hazards. Applying consistent testing processes to different situations allows researchers to draw reliable conclusions based on the data collected, allowing qualitative comparisons and analysis of risk perception.

Reliability and validity are fundamental aspects of the psychometric paradigm that play a critical role in ensuring the accuracy and consistency of assessment instruments. Reliability refers to the consistency and stability of measurement instruments to produce comparable results over time and under different conditions. This embodies the ability to provide reliable, reproducible results, allowing researchers to have confidence in the accuracy of the method's measurements.

Essentially, reliability focuses on the consistency and repeatability of measurements, while validity focuses on the accuracy and appropriateness of conclusions drawn from those measurements. Both reliability and validity are integral components of psychometric assessment that work together to ensure that assessment instruments are reliable, accurate, and produce quality results.

4. Training course support

The system supports the following main mode of operation, in which application subsystems perform all their main functions.

In the main mode of operation, parts of the system provide:

- work in user mode - 24 hours a day, 7 days a week;
- performance of its functions - collection, processing and uploading of data, designed for the user interface.

The product is a web application for evaluating the quality of educational tests. Includes the following features:

- construction and review of the informativeness curve of the test;
- construction and revision of informativeness curves of test tasks;
- construction and revision of characteristic curves of test tasks;
- construction and revision of characteristic curves of test subjects;
- construction and revision of test score distribution;
- construction and review of the table of informativeness of the test.

As can be seen in Figure 11, the user goes to the appropriate page, selects a file and sends it to the server, which, in turn, processes it and sends a response in the form of test evaluation data.

The client, having received this data, saves it and based on it calculates data for graphs and tables. This diagram illustrates the process of analyzing test results. The algorithm includes the following key stages:

1. Initiation of the process by the user and loading of the data file.
2. Formation of a set of analytical materials.
3. Conducting a test assessment based on the obtained data and visualizations.
4. Providing the user with the analysis results, including assessment results and data for graphs.
5. The user has the opportunity to review the results and, if necessary, start a new analysis cycle.

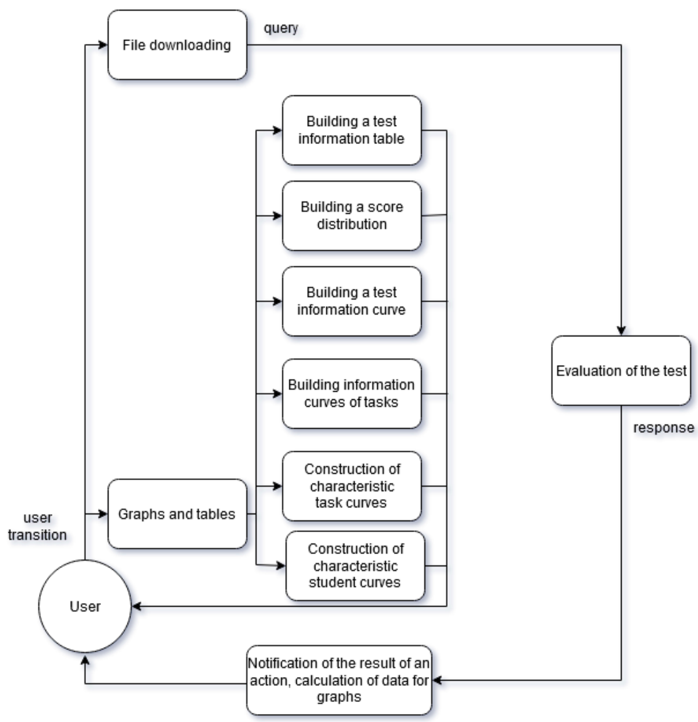

Figure 11: User diagram

This algorithm provides a comprehensive analysis of test results, providing a variety of tools for assessing the quality of the test and the level of student preparation.

5. Analysis of course support results

After entering the web application page, we immediately find ourselves on the file download page. Click the "Choose File" button and select a JSON file with test result data previously exported from the STM platform. Press the "Get Score" button and wait for a message about the result of the operation.

The graph shows a curve of test information, where the X-axis shows the test values and the Y-axis shows the informativeness (k). This graph is used to analyze the results of course support by assessing how informative the test is at different points on the scale.

Top of the curve: The greatest information content of the test is achieved in the range from -1 to 1. This indicates that the test is most effective for students with this level of knowledge.

Symmetry of the curve: The curve is symmetrical around the central point, which indicates a uniform assessment of the knowledge of students with both low and high levels of knowledge.

After downloading the file and receiving a message about the successful execution of the operation, we go to the page called "Test Information Curve", the view of which is presented in Figure 12. Here we can see the constructed curve of the informativeness of the test and more detailed information when drawing on the graph in the place we need.

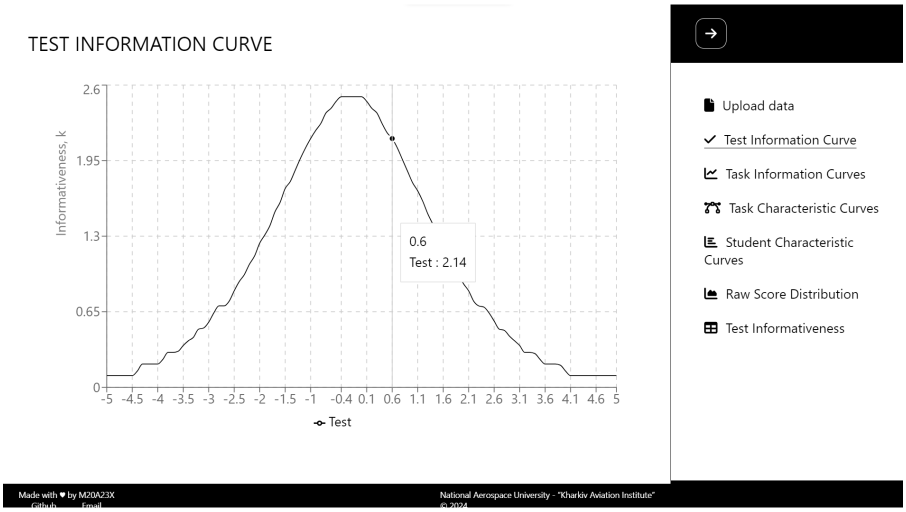

Figure 12: Test informativeness curve page

Similar to the previous step, we go to the page called "Tasks Information Curves", the view of which is presented in Figure 13. Here we can see the constructed informativeness curves of individual tests. It is worth noting that the curves often overlap each other.

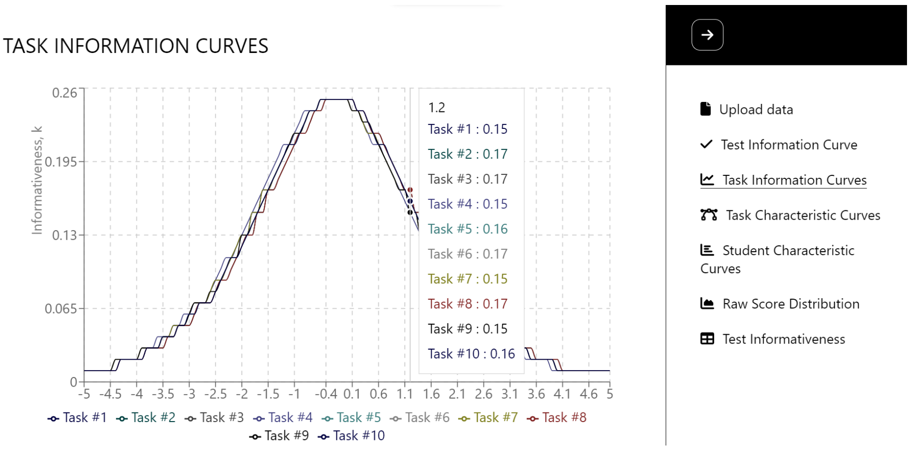

Figure 13: The page of informativeness curves of tasks

Similar to the previous step, we go to the page called "Tasks Characteristic Curves", the view of which is presented in Figure 14. Here we can see the constructed characteristic curves of individual test tasks and more detailed information when drawing on the graph in the place we need.

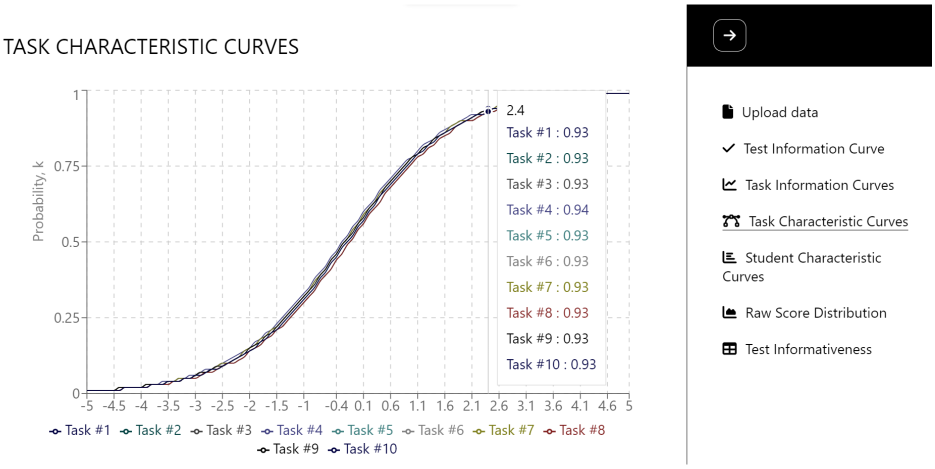

Figure 14: Characteristic curve tasks page

We can also view it by going to the page called "Student Characteristic Curves", the view of which is presented in Figure 15. Here we can see the constructed characteristic curves of individual subjects.

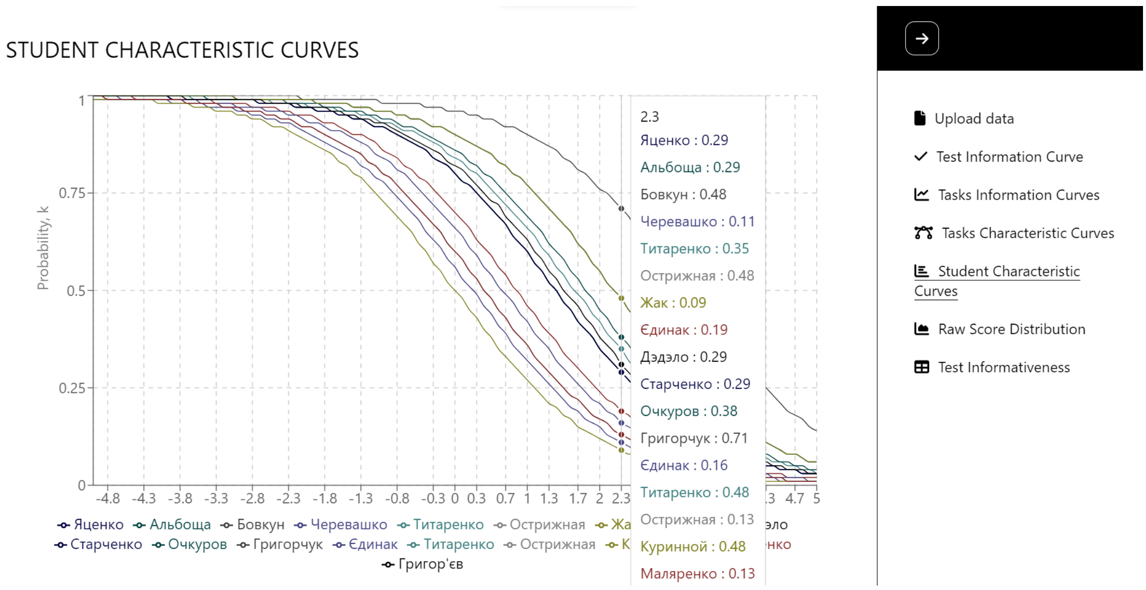

Figure 15: Subject characteristic curve page

And on the last page called "Test Informativeness", we can see a table of the main points of severity of the indicator of the difficulty of the test task and, based on these points, the probability of getting the correct answer and informativeness for a separate test task. This table is built on the basis of data for graphs of characteristic curves and informativeness curves of test tasks.

This paper describes the breakdown of client software for the evaluation and analysis of tests performed during the assessment of their effectiveness and adjustment of their complexity, as well as their further development and implementation into operation.

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