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**Electronic Knowledge Assessment Systems**

**Anotácia:** Autori štúdie poskytujú informácie o elektronických systémoch na overovanie znalostí. Opisujú možnosti implementácie, ako aj výhody a nevýhody vybraných systémov. Na základe kritérií odvodených zo skúseností s elektronickým overovaním znalostí porovnávajú vybrané aplikácie a na základe výsledkov porovnania realizujú overovanie získaných znalostí pomocou softvéru TCExam. Táto realizácia je potom opísaná v závere štúdie.

**Kľúčové slová:** vzdelávanie, overovanie vedomostí, MS-Teams, TCExam, MS-Forms, TaoTesting

Introduction

The application of an automated knowledge assessment system is not a new idea, and the first mentions of standardized tests date back to the Han Dynasty (260BC - AD220) in China, where they were used to assess the knowledge of candidates for official positions in the empire[[1]](#footnote-1). This idea was further developed and typically included a textual form with standard answers that could be efficiently and impartially evaluated. Assessment of the knowledge acquired must be based on the content that was presented to students during the teaching process in lectures, seminars, and exercises. Computing technology not only makes the entire knowledge assessment system process more efficient but also introduces new possibilities through statistical evaluation methods. By applying these methods, we can determine:

* the level of knowledge acquired by an individual or a selected group,
* the level of understanding of the questions posed,
* differences in results over specified time periods among individuals or selected groups.

The electronic knowledge assessment system offers a different perspective on the system of testing and examining students. It is not intended to replace standard oral exams or written tests but to serve as a possible alternative when other forms of knowledge assessment are less suitable.

A typical example could be the situation influenced by the Covid-19 pandemic, where the online form of the electronic knowledge assessment system was practically the only option to assess the level of knowledge acquired by students.

**Methods**

The research set was selected by the method of selection of software suitable for use in testing the level of students’ knowledge.

The following research methods and techniques were used in the research:

Exploratory and observational methods were used in the selection of the researched software, forming the research database. These empirical methods were used in synergy with the logical method of qualitative and quantitative analysis, while the supporting criterion for the selection was the analysis of tools, techniques, stimuli and automated documents to fulfil the main objective of the research, which was to find the most effective software for electronic testing of students' knowledge.

The method of deduction used in the selection of the objects of the research set was used to determine the level of software outputs offered and their potential to be implemented in the practice of university examination programs.

The research was carried out on the database of selected software based on the criteria established by the authors of this article, and the method of induction of the shortcomings found in each of the investigated software was used to determine the recommended software in the end by deduction.

**Definition of the problem**

During the Covid-19 pandemic, we faced the issue of how to conduct semester progression exams more than ever before. Outside of the pandemic period, the Informatics Group at the Department of Informatics and Management focuses on progression exams via a system of practical assignments and tests in the department's computer labs. With the shift to distance learning, we had to adapt to the situation and create an environment for verifying acquired knowledge that would sufficiently meet our required criteria. The criteria we defined reflect the current needs for knowledge assessment in the fields of technology, security, and efficiency.

We divided these criteria into two separate parts. The first part concerns communication software, and the second part is dedicated to testing software. The choice of communication software is crucial, especially for the period of lectures and exercises, where it must meet the criteria necessary for quality and efficient provision of the educational process in a distance learning format. The criteria we defined are based on practical experience of distance teaching and examination during the previous pandemic wave.

The requirements for selecting communication software primarily include:

* Availability for both students and teachers,
* Ability to present and display the desktop or application of the presenter,
* Ability to verify the identity of the student,
* Multiplatform compatibility of the software,
* Integration with existing information systems at APZ in Bratislava,
* Support for the educational process through additional tools and features.

Currently, the most widely used software at the Police Academy in Bratislava is MS Teams, as the sporadically used Zoom is not recommended by the Ministry of Interior due to high security risks. Other options, such as Google Meet or Skype, would require user registration into another system, which would be counterproductive, especially since MS Teams meets most of the criteria we defined and is part of MS Office 365, to which all students and teachers have free access through their academic accounts (name.surname@akademiapz.sk).

In the case of progression exams, MS Teams is primarily used as a communication channel between the student(s) and the examiner. Communication is conducted as a video conference (meeting), which is pre-scheduled by the teacher in the calendar for specific dates with specific students invited according to their exam registration.

Teachers have several options for conducting the exam. Some prefer oral examinations or the use of tests through MS Forms or Google Forms, or assigning graded tasks directly in the MS Teams system. Google Forms and MS Forms are very sophisticated, but they are based on the concept and environment of surveys and quizzes, which are tailor-made for each group of students. This system is time-consuming mainly due to the preparation of individual test sets. To be thorough, a teacher must prepare at least one test set for each exam date and, if the system allows, utilize the shuffling of questions and answers for each test launched. The evaluation is straightforward, as both systems provide a clear table with a summary of points earned for correct answers. These tables can then be exported to spreadsheet format, making them ready for further statistical processing.

The system of graded tasks in MS Teams is also an option for assessing acquired knowledge. The teacher defines a task for an individual student, selected students, or an entire group (team). Tasks can be divided into several subtasks, which can be scored. After the student submits the completed task, the teacher must check the task and assign points for the individual subtasks, which can be very time-consuming with a larger number of students.

Another option is to use knowledge assessment software that includes a database of questions from which tests for individual students are randomly generated at each exam session.

Since there are multiple possible systems for knowledge assessment, we have defined criteria - requirements such a system should meet:

* One of the main requirements for the software was to be network-based, specifically of the client-server type, as this solution allows for easy manipulation of prepared questions, tests, and test results from a single computer on the network.
* Another requirement was universality, specifically the ability to create question databases for different subjects and the ability to categorize questions within individual subjects. Such a question database greatly facilitates the creation or generation of individual tests.
* Another requirement was the ability to create various types of questions, for example:
  + Choosing one correct answer from multiple answers,
  + Choosing multiple correct answers from multiple options,
  + Determining the correct order.

These types of questions are sufficient for creating tests. Naturally, the ability to use graphic objects in questions is a given.

* Another requirement was the creation of unique tests. Unique tests are very important in assessing acquired knowledge, as they eliminate opportunities for cheating or other forms of dishonesty.
* Not less important is the creation of clear test results. Such result tables should contain all necessary information to determine the achieved level of assessment. This is associated with the statistical evaluation of the results.

From the aforementioned requirements, we created a table, with some of the requirements expanded into multiple questions. We applied the evaluation of these criteria to the software we selected. The evaluation was conducted using a system of "yes" or "no" responses, where some questions are interpreted more broadly, as a comment on our decision. As for software, we selected the already mentioned popular and readily available systems MS Forms and Google Forms, in contrast with the relatively unknown systems TC Exam and TAO Testing. We did not include the task assignment system in MS Teams in our decision-making due to the lack of automated evaluation of assigned tasks. Nevertheless, we consider this system practical and useful for tasks that assess students' practical skills, as evidenced by its use during selected practical control assignments in exercises from the subject Informatics I.

The graphic representation of the decision-making process is shown in chart no. 1. and the source data are in table no. 1.

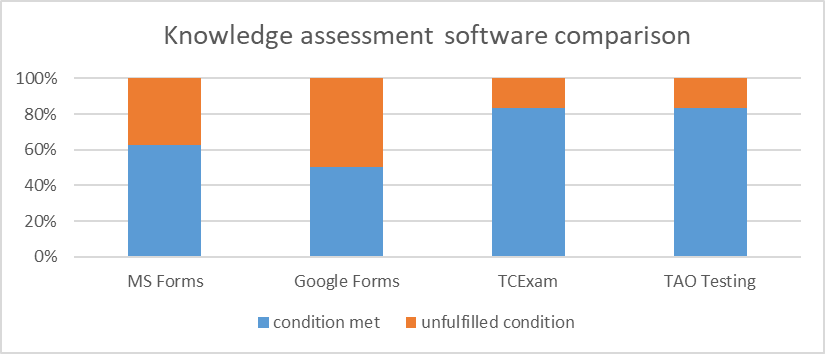


Chart : Comparison of knowledge assessment software Source: own processing

Source: own processing

*Table 1: Comparison of knowledge verification software Source: own processing*

*Source: own processing*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Criterion** | **MS Forms** | **Google Forms** | **TCExam** | **TAO Testing** |
| **Free software** | No - it is part of the paid MS Office package | Yes for non-commercial purposes | Yes for non-commercial purposes | Yes for non-commercial purposes |
| **Network version** | Yes, server at the provider | Yes, server at the provider | Yes, own server | Yes, own server |
| **Web interface** | Yes | Yes | Yes | Yes |
| **Creation of a hierarchical database of questions** | Not | Not | Yes | Yes |
| **One-to-many questions** | Yes | Yes | Yes | Yes |
| **More-than-many questions** | Yes | Yes | Yes | Yes |
| **Questions of determining the correct order** | Yes | Yes | Yes | Yes |
| **Scoring questions** | Yes | Not | Yes | Yes |
| **Generating tests from a database of questions** | Not | Not | Yes | Yes |
| **Random order of questions** | Yes | Not | Yes | Yes |
| **Random order of answers** | Not | Not | Yes | Yes |
| **Graphic objects** | Yes | Yes | Yes | Yes |
| **Statistics of student results** | Yes | Not | Yes | Yes |
| **Question results statistics** | Not | Not | Yes | Yes |
| **Advanced statistics** | Not | Not | Yes | Yes |
| **Continuous monitoring of the test** | Not | Not | Yes | Yes |
| **Data backup** | Yes by generating a scoreboard | Yes by generating a scoreboard | Yes in the database | Yes in the database |
| **Data printing** | No - just printing the results and the form | No - just printing the results and the form | Creating print reports from the database | Creating print reports from the database |
| **Creating a printed version of the test** | Not | Not | Yes | not |
| **Sending the result by email** | Yes | Not | Yes | Yes |
| **Online support** | Yes | Yes | no - support in the form of email communication with the authors | no - for the freely available version through the technical forum |
| **Slovak language mutation** | Yes | Yes | not | no - only partially |
| **Friendly user environment** | Yes | Yes | rather not | Yes |
| **Easy to install and run** | yes - managed by a third party | yes - managed by a third party | Rather not - installation requires knowledge of creating and managing a Web server | no - the installation requires knowledge of creating and managing a Web server, and at the same time the installation of the freely distributable Linux version for Ubuntu / Debian fully works only on the 18.04 system with php version 7.2 |
| **Result Yes / No** | 15 vs 9 | 12 vs 12 | 20 vs 4 | 20 vs 4 |

From our decision-making process, we drew the following conclusions:

* Google Forms meets only half of the specified criteria and is more suited for creating surveys or quizzes. An advantage of this system is the easily accessible system support and a modern, commercially managed environment with frequent updates.
* MS Forms offers more features than Google Forms, such as random ordering of questions, scoring of questions, and displaying results after a student completes a test, as well as sending results via email. MS Forms allows for generating a results table, similar to Google Forms, enabling partial result analysis through spreadsheet software.
* TCExam, although relatively unknown for knowledge assessment, caught our interest mainly with its data analysis capabilities and question database creation system, which we considered a significant part of this system. However, no system is perfect in every aspect. A disadvantage of TCExam is the insufficient author support, which can only be addressed through email communication. Most problems that may arise are described in the program's documentation or can be found on internet forums. However, there's a risk of encountering a unique problem whose resolution could be complicated or nonexistent. Other limitations include the absence of a Slovak language version and a rather Spartan user interface.
* TAO Testing is an interactive software for test creation. It features an intuitive user interface and extensive options for setting up tests. Like TCExam, it offers some form of result analysis and a question database creation system. However, it shares the support issue with TCExam, where the support for freely distributed version is provided via a forum. Common issues include software malfunction after a PHP update or installation problems on a Linux version different from the one recommended in the documentation. These issues are discussed in TAO Testing's forums and were a main reason for discontinuing its use.

Based on the above, we decided to opt for using the TCExam system due to its relatively simple installation, operation, and user-friendliness.

TCExam – description of the program and selected features

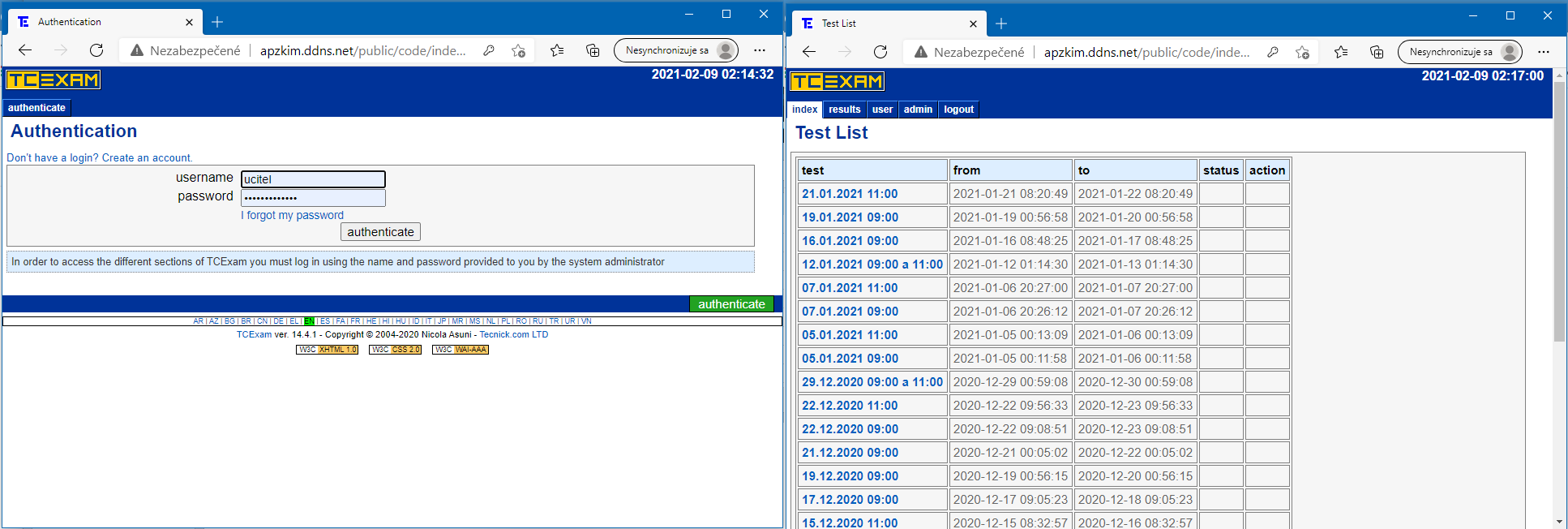
TCExam is an open-source system for electronic knowledge assessment, also known as Computer-Based Assessment (CBA), Computer-Based Testing (CBT), or E-Exam. It allows educators to create, schedule, and deliver test results, exams, or quizzes. The program is web-oriented, platform-independent, and developed in accordance with the World Wide Web Consortium (W3C) guidelines. It operates exclusively as a client/server network version, requiring only a web browser that supports XHTML 1.0 on the client side, which today is practically any browser on any hardware or software platform[[2]](#footnote-2). TCExam includes features for creating an extensive database of questions according to a user-defined structure. It facilitates the automation of test creation, execution, and analysis, with the option to deliver results to students. The system does not require expensive hardware and users can connect via standard web browsers.

TCExam stores detailed statistics on student responses, including the time students take to answer each question. The installation of TCExam is relatively straightforward and can be done on virtually any platform that can run a web server with Apache, MySQL, and PHP. It allows for data backup, creation of print reports, and the generation of printed tests with subsequent checking through an Optical Mark Recognition (OMR) system[[3]](#footnote-3).

**TCExam environment**

TCExam is designed as a web application, meaning all information is recorded in a database on the server and provided based on user requests. While the user interface is somewhat austere, it offers adequate tools for system management.

After logging in, a user can see all the tests that have been generated for their account. If the user has higher permissions, they have access to an admin item that switches them to the administrative menu. In this menu, it is possible to perform all the settings necessary for the system's operation, such as creating users, groups, defining questions and their categories, creating tests, and backing up data.



Picture : TCExam environment

Source: own processing

**Users and groups**

The TCExam system allows for the creation of its own user database. In the freely distributable version, there are two predefined user levels:

* Level 1 - permission to take a test,
* Level 10 – administrative permissions allowing full control over the system.

Users can be organized into groups, with each user being able to belong to multiple groups. In our case, we generated four user groups: OOMin, OOMex, BVSin, and BVSex. These groups were basic, and we further filtered users into groups created for specific exam dates. This means that each user was at least in two groups: one basic group based on their field of study and one exam group based on their registration for the date. Naturally, students who took resit exams appeared in multiple groups.

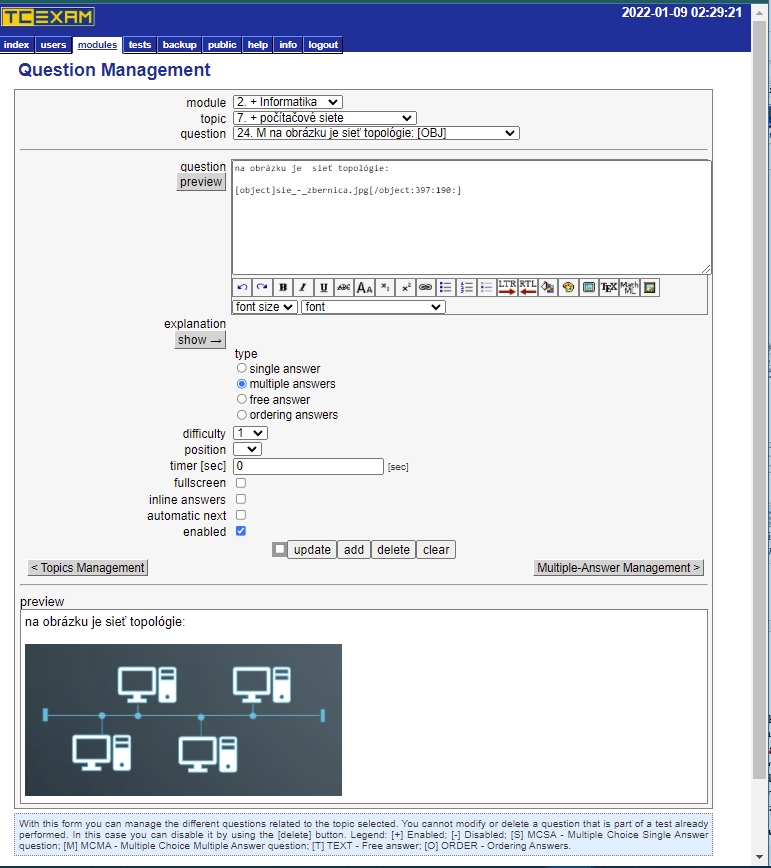
**Creating a database of questions**

The question database in TCExam is structured as follows:

* Modules (modules),
* Topics (topics),
* Questions (questions),
* Answers to questions (answers).

The term "modules" can be construed as individual subjects, for example, Informatics I, Security Management, etc. "Topics" refer to the subdivision of a selected subject according to thematic focus. For instance, for the subject Informatics I, possible topics could be hardware, software, computer networks, etc. This is particularly advantageous if the TCExam system is also used for continuous assessment. In this way, an educator can prepare tests based on individual topics and select a combination of multiple topics for semester exams. The main advantage is ensuring an even representation of each topic when generating tests.

When defining a question, it is necessary to first select a module and topic. Then, within the selected topic, questions are defined, and for each question, answers are provided. Each question has its serial number and an indication of the type of question it is. Four types of questions can be used: choosing a single correct answer, selecting multiple correct answers, free text, or ordering. Questions can be formatted in a simple graphical HTML editor, with the appearance of the defined question displayed at the bottom of the window. If the questions include graphic elements, these are uploaded separately to a chosen folder and then selected in the menu as an image insertion.



Picture : TCExam - question setting

Source: own processing

Additional optional settings include specifying the difficulty level of the question, the position of the correct answer, a display timer, full-screen mode, arranging answers side by side, and automatic advancement to the next question. The last option is to enable or disable a question. This feature is crucial since questions that have been used in a test cannot be deleted or edited to maintain the integrity of the entire system and the traceability of results. However, it is possible to disable a question, meaning it remains in the system but will not be included in subsequent test generations. This is also a common feature of the used database. An element, whether a user, group, or question, cannot be deleted if it has already been part of a test.

After creating a question, the process continues with defining the answers, which are created similarly in a simple HTML editor. Multiple correct and incorrect answers can be defined. If creating answers for a multiple-response question, the test may include a combination of correct and incorrect answers. For a single-answer question, only one correct answer is selected for the test.

**Creating tests**

The configuration of the test itself consists of multiple items and is created in two steps: first, setting the test parameters, and then selecting the pool of questions and their parameters.

Initially, the test's name, description, active time window, and test duration are set. The setting of an allowed IP address is optional. This is followed by selecting the group for which the test is intended and choosing an SSL certificate if used.

Next there is the setting of the scoring system: a number of points awarded for a correct answer, points (expressed as a negative number) deducted for an incorrect answer or for not answering a question, and a number of points required to pass the test.

Additional optional items include:

* Random selection and ordering of questions and answers,
* Checkbox fields for questions with multiple answers,
* Enabling a "no answer" button,
* Displaying answers in a dropdown menu,
* Comments on the test,
* Displaying results to users,
* Sending test results to the user's email,
* The option to retake the test,
* Automatic logout from the test upon time expiration,
* Setting a password for the test.

After defining the test parameters, the next step is to select the pool of questions, their number in the test, type, difficulty if defined, and the number of answers per question.

After adding the questions, the newly created test automatically becomes available to the selected user group. If users are within the set time window, an "execute" button will appear in their table of available tests, which they can use to start the test. During the test, every user selection is recorded, with users having the freedom to navigate through the test, answer questions in their chosen order, or change their answers until the pre-set test time expires. The progress of the test can be monitored, as well as how each user responded to specific questions.

**Test analysis**

The "results" item in the "tests" tab allows for the previously mentioned monitoring of test progress and viewing of test results. Users can customize which data they want to display. Results can be viewed according to various sorting criteria:

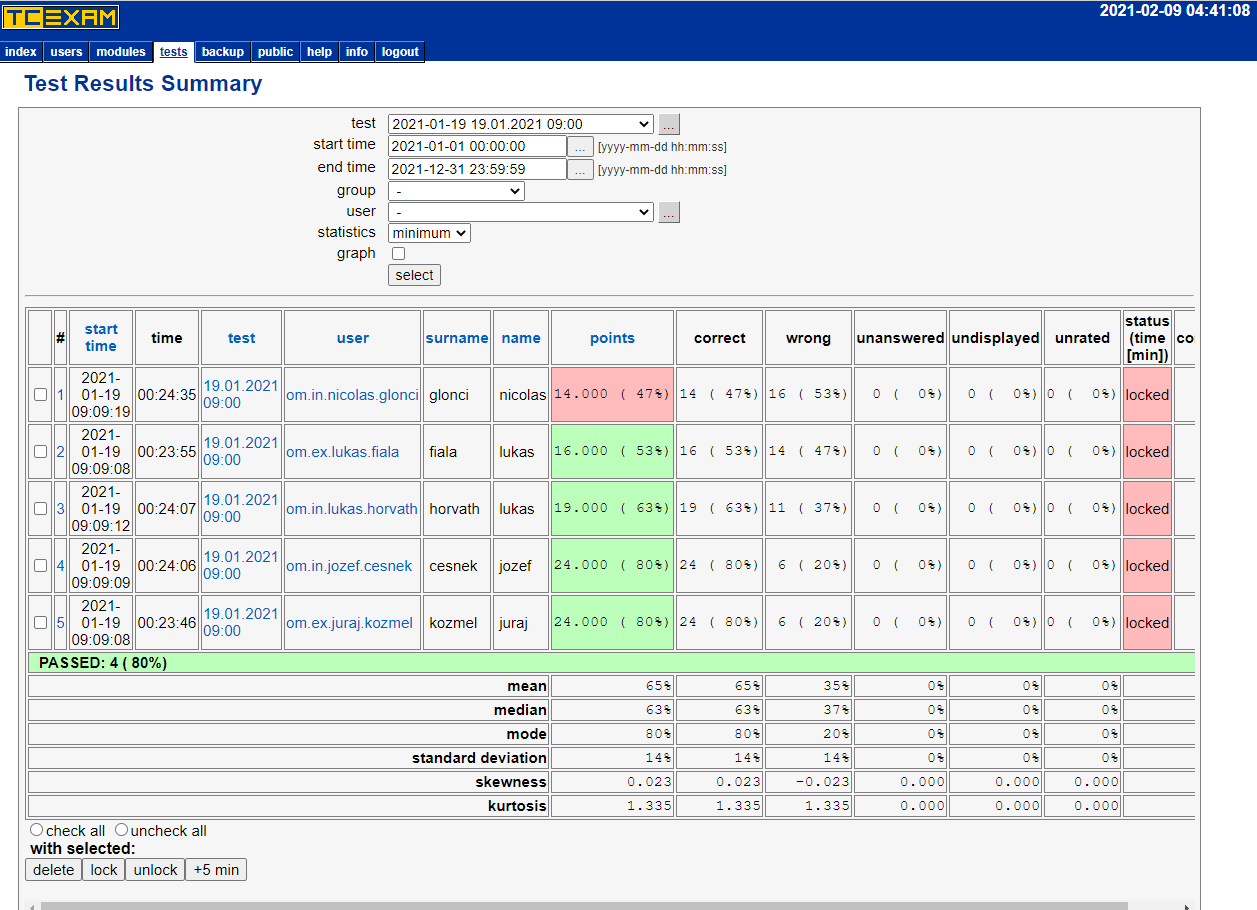
* specific test,
* time range,
* specific group,
* specific user.

Furthermore, the sorted results can be displayed without statistics, with minimal statistics, or with detailed statistics for the module, topic, question, or answers. There's also an option to enable graph visualization.

Users who passed the test are highlighted in green, while red indicates those who did not achieve the required number of points, with the success rate displayed in points and percentages. The table also shows the number of correct, incorrect, unanswered, and unviewed answers.

When viewing more detailed statistics, data about the frequency of a question's use in tests, the success rate of correct answers, the response time for each question, and how many times each answer was selected are displayed. This level of detail provides a comprehensive insight into the effectiveness of both the questions and the test-takers' performance.

**Practical implementation of the system for the assessment of knowledge in a distance form**



Obrázok : TCExam – test results summary

Source: own processing

During the pandemic, in the winter semester of 2020/2021, within the context of remote teaching, we successfully tested the operation of the TCExam testing system. The goal was to create a testing environment in the simplest way possible that would offer a secure and reliable operation of TCExam. Since the test was conducted under home conditions, we opted for an alternative computer system, which, despite its small size, provided sufficient system performance for running TCExam.

The system was set up as follows:

* The server was an OrangePi PC single-board microcomputer.
* The operating system was Armbian 20.08.16 Focal, based on the Ubuntu Focal distribution.
* The database used was MariaDB, compatible with MySQL.
* The web server was Apache2.
* The Hypertext Preprocessor was PHP.
* TCExam.

Currently, the system is built around a traditional HP server with Ubuntu Server. The rest of the configuration remains identical. Exams are conducted within the local network of the Police Academy, allowing for the exclusion of communication software. This transition to a more traditional server setup likely provides enhanced stability, scalability, and ease of maintenance for the TCExam system within the academy's local network environment.

**Conclusion**

Information technologies are an integral part of our lives. We encounter various opinions regarding the symbiosis of humans and information technologies. In this context, we can observe a rapid increase in the use of information technologies in the educational process, resulting in computer literacy being considered an essential part of every student's fundamental knowledge. Associated with this is the integration of information technologies into the educational process, including the assessment of students' acquired knowledge.

An electronic knowledge assessment system offers a different perspective on the system of examining and testing students. It is not meant to replace standard oral exams or written tests but to serve as a possible alternative when other forms of knowledge assessment are less suitable.

The main assumption is that any knowledge assessment system provides educators with information about the level and quantity of knowledge acquired, which can be used to express the degree of success in completing a subject in terms of grades, credits, points, verbal assessments, etc.

Therefore, obtaining a final evaluation on a certain grading scale is the primary function of a knowledge assessment system. At the same time, it is essential for educators to receive feedback on why a student achieves a certain level of knowledge, thus understanding what influences them in the learning process.

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<https://www.google.com/forms/about/> [online, cit. 01.02.2025]

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[online, cit. 01.02.2025]

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**Keywords:** education, knowledge assessment, MS-Teams, TCExam, MS-Forms, TaoTesting

**Summary**

The need to use an electronic knowledge assessment system is much more pronounced today than ever before. The restrictions imposed during the individual waves of the Covid-19 pandemic are unprecedented in protecting citizens' lives, but they also have negatives, such as a disrupted educational process at all levels of education.

The educational process also includes a knowledge assessment system, which had to be applied in a distance form. Current information technologies can perform knowledge assessment via the Internet in various ways, for example in traditional ways such as verbal response, real-time processing of a given task on a virtual whiteboard, independent processing of a given task or in a test form. It is necessary to use a webcam as a control element to prevent fraud on the part of students. Unfortunately, this control element is the most vulnerable part of the knowledge assessment system. Its credibility depends on the parameters of the camera, the speed and type of Internet connection, as well as the location of the camera.

The authors compare selected software solutions for the implementation of knowledge assessment through tests. The system of using tests is very effective in the distance form of knowledge assessment, especially if it is possible to automate it as much as possible. For this purpose, the authors select the TCExam solution from the compared software solutions. This software allows you to generate a unique test for each student from the question database. The test result is known immediately after the end of the test time.

The authors then describe the environment of the TCExam system and its use in the real educational process. The advantage of this software is also the possibility of subsequent analysis of processed tests, such as the speed of answers to individual questions, the success in solving individual questions and the frequency of integration of individual questions into tests.

Finally, the authors want to underline that they already have practical experience of using the TCExam software to test students' knowledge.

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Mgr. Martin Krajčík, PhD.

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2. Part of the students use Apple computers with the Safari browser, or others, during their studies, and in three cases the test was carried out on an Android device (mobile phone, tablet). [↑](#footnote-ref-2)
3. OMR requires a plug-in application - this option has not been tested [↑](#footnote-ref-3)