Review and analysis of existing solutions in terms of remote technologies for the implementation of the discipline “Databases”

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Abstract. This paper provides a detailed overview of existing solutions in the sphere of remote technologies that allow one to train a domain IT-expert in working with databases. As the main tool of the electronic educational course on this topic, the authors justify the development of an electronic module integrated into the LMS Moodle, which would simulate an interface similar to a console MySQL client with a connection to a real MySQL server. Such an electronic element will allow students to improve the skills of forming SQL queries directly from the electronic course, and the teacher to control the learning process automatically and with minimal labor costs.

1. Introduction
The development of distance learning is a topical issue all over the world. In the modern world, covered by information technologies, it is already difficult to imagine our life without e-learning and distance learning. The problem becomes especially urgent in various types of emergency situations, when students are not recommended to attend face-to-face classes, or are forbidden to attend them at all.

Distance learning is the acquisition of knowledge or skills in a particular field using the Internet or other information technologies. In the process of distance learning, learning management systems (LMS) can be used to help organize mass continuous self-learning and mass information exchange.

Another important area in modern education is practice-oriented learning. Such learning is necessary, because it is not always possible to become a specialist in any industry, especially in the IT sphere, after studying the theory only.

A database (DB) – is an organized structure designed to store, modify, and process interconnected information, mostly of large volumes. Currently, databases are actively used in the development of many software applications, so their study is one of the most important areas of IT education.

Today the most popular data model for database design is the relational model. In such a database, data is stored in tables with predefined relationships between them. Data extraction and processing in them is most often performed using SQL-queries. SQL is a declarative language used in relational database management systems (DBMS) for creating database structures, adding, modifying, and manipulating data.

Therefore, learning the SQL language in practice is considered to be the most important element in the training of an IT specialist. And the development of applied electronic training courses for the study
of databases, which allow combining the theoretical basis and practical component, is an urgent and important problem of modern education.

2. Problem statement
In the process of working in a remote way, a teacher who implements the discipline “Databases” faces problems related to the lack or insufficiency of funds for monitoring the learning process, and thus the inability to assess the real practical skills of the student.

An e-learning course for learning databases developed in LMS should contain tools that allow the teacher to develop tasks for generating SQL queries, and the student to implement them directly in the e-course. This aspect is extremely significant due to the fact that each job must be assessed, and the statement is stored in the log evaluation of the course. The labor costs of a teacher or tutor are also important. To check such practical work is especially critical for mass learning during such a course.

Thus, for a distance learning course, one needs to have tools that allow them to integrate external applications, such as MySQL, into the e-learning course and automatically generate grades in the LMS assessment log.

The main purpose of this tool is to develop the skills and consolidate the skills of writing SQL queries for students in the framework of studying the discipline “Databases”. It must contain at least the following elements:

- creating and editing tasks;
- task description;
- interface that simulates a console MySQL client with a connection to a real MySQL server and the ability to send queries and receive a response from the server;
- a system for automatically checking the correctness of the task and forming an assessment in LMS;
- view tasks completed by students with tracking of completion stages.

In this case, it is necessary to review existing solutions in the field of e-learning and distance learning technologies used for the development of e-learning courses for training IT specialists.

3. Analytical review of distance learning platforms
The review includes Russian-language services with a user-friendly interface and easy configuration. For the most part, these are universal platforms for various specializations with advanced features: integration, access rights differentiation, gamification, webinars, tests, and certificate issuance. To analyze the state of the issue in the field of distance learning, electronic courses on the study of databases on the most popular distance education platforms were considered. On some of the resources reviewed, courses on the necessary topics were not available at all, such as, for example, the Lectorium platform.

3.1. Open education platform [2]
The distance course “Databases” was considered. Performing practical tasks in the course involves installing the MySQL database on the user's computer and using it. Verification of such works is not automated and is carried out exclusively by the teacher. The course also includes test tasks based on the simplest type of questions with the ability to choose the correct answer.

3.2. “INTUIT” platform [4]
This resource contains a large number of training courses for studying relational databases. For example, “SQL and procedure-oriented languages”, “SQL Basics”, “Introduction to relational databases”, “Introduction to the SQL data model”, “Basics of working with databases”. All these courses contain detailed theoretical content on a given topic, and testing is used as practical tasks.
3.3. “Stepik” platform

This platform is also replete with electronic database courses. The most popular ones are: “Introduction to databases” [11], “Databases”, “Free immersion in DBMS”. These e-courses, like all previously reviewed ones, also contain only lectures and tests. However, there are also more interesting courses on this platform from an applied point of view: “Interactive SQL simulator”, “SQL basics”. They contain online simulators where one can directly generate SQL queries. Queries are automatically executed on the MySQL server in an isolated database. Their results are automatically checked and the result is recorded. However, a more detailed study revealed some shortcomings in such workshops.

For example, if in the course “Interactive SQL simulator” when creating a table, specify its name in single quotes (`), as is customary in SQL queries, so the system returns an error when checking the task (figure 1).

![Figure 1. SQL query error message for creating a table.](image1)

And if one specifies a similar query without quotation marks (which is incorrect from the point of view of syntax), the error is not fixed (figure 2) and the user receives a message about the positive result of the task. This approach for applied database learning can be a bit disorienting for the user and thus reduce their involvement in the learning process.

![Figure 2. Message about the “correct” execution of the SQL query to create a table.](image2)

Thus, we can conclude that among the variety of courses presented on Russian-language distance learning platforms, there are only a small number of electronic courses on the study of databases, which contain simulators for writing and testing SQL queries in practice. There are even fewer such courses if we consider only free resources.
4. LMS Moodle as a mechanism for creating an applied e-course
The Learning management system (LMS) is an information system designed for planning, conducting, and managing various training activities in an organization, including both face-to-face and distance learning.

Such systems enable the implementation of mass open distance courses. Thanks to them, one can increase the speed of information transfer to the student (including through asynchronous learning), deepen their knowledge and install additional skills at the same time. Learning technologies are also changing along with the improvement of technical means. Its new forms are spreading – problem-oriented or practice-oriented learning [16], business games are becoming more and more popular and education is being gamified, i.e. game techniques and elements are being introduced into the learning process. Now the demand for educational services dictates the need to learn from real examples, the ability to learn quickly, clearly and partially (or completely) remotely. Learning should include a multi-level system that will motivate students to acquire new and develop existing competencies.

One of the most popular open source systems is Moodle, a learning management system (LMS) that focuses primarily on creating interaction between teachers and students. Its main purpose is to organize distance learning. The Moodle system can be used to smooth out the effect of uneven activity of students during the semester. To do this, the academic discipline is divided into small stages that correspond to the score-rating system, and the student's work is evaluated at the end of each module. It is also necessary to note the importance of a differentiated system for evaluating students' knowledge, so that only in exceptional cases the student can not proceed to the next module. If this principle is not implemented, the teacher's workload will increase dramatically due to the fact that (s)he will be forced to train lagging students to the required level, giving them additional time [18].

Moodle (stands for the English acronym Module Object-Oriented Dynamic Learning Environment) is a free Learning Management System (or Virtual Learning Environment) distributed under the GNU General Public License [19].

The Moodle system was created by Martin Doujiamos at the University Of Technology in Perth (Australia). From the very beginning, Moodle was conceived as open source software that is accessible to everyone, free of charge, and easy to install for the maximum number of users. Anyone can help to develop and add their own add-ons (or plug-ins) to the Moodle environment and share information about using Moodle through forums and communities.

The Moodle system can provide:

- choosing a convenient time and place to study, both for the teacher and the student;
- substantial knowledge acquisition
- the interaction of the teacher and student as needed;
- individualization of learning;
- save money and time.

Users often like course modules (such as forums, databases, and wikis) because they can create a practical environment for sharing information about the topics they are studying, while others prefer to use Moodle to provide various information to students (such as the SCORM package standard) and evaluate learning outcomes using assignments or tests.

Let us consider the possible use of LMS Moodle for teaching students information technology disciplines on the example of one of them. When designing a Learning course on the discipline “Databases” in LMS Moodle, one can use the following set of elements: “Glossary”, “Task”, “Test”, “Forum”, “Resource”, “Group project”, as well as opportunities for integrating SCORM packages or exercises developed in the H5P environment. But none of these tools allow us to get practical skills in writing SQL queries. H5P tools are not enough to implement an application for working with the MySQL server, and SCORM packages have significant disadvantages.

In remote courses, one can use links to third-party web applications with any interactive exercises, but in this case, the user will need to register and log in to an external resource, and the teacher will need
to manually transfer grades from it to the Moodle LMS. To solve this problem, Moodle has an element of the course “External tool”, which allows one to use LTI-compatible applications in the educational process.

LTI (Learning Tools Interoperability) is a standard developed by the IMS global learning consortium that describes ways to interact between various learning applications and learning platforms, such as Moodle. It allows the user to open external applications without the need for registration or authorization, as well as save the assessment based on the results of the exercise to the distance learning system.

The standard divides applications into Providers (Tool Provider) and Consumers (Tool Consumer) Providers afford educational content for Consumers, such as lectures, lab work, and so on. Also, Providers can send an assessment for the learned material to Consumers.

The application being developed will be the Provider, and the Moodle distance learning system will be the Consumer.

In the LTI v1.3 version of the standard, interaction is performed using OAuth2 and JSON Web Token technologies.

Compared to SCORM packages, LTI applications have a number of advantages:

- Interaction with an external server without the need for explicit authentication. This means that the server has reliable information about the user who runs the application. When using SCORM packages, this information may be unreliable due to user intervention.
- Running the application on the server. The execution of SCORM packages is entirely on the user's side, which is why we can make changes to it and achieve any unplanned behavior. LTI applications involve a server and a client, which means that part of the application, is protected from modifications.
- The formation of assessments on the server. SCORM packets are executed on the user's device. Accordingly, ratings are also generated and sent on the user's device and can be easily faked. When using CTI applications, grades are generated on the server, signed using OAuth technology using a secret key, and sent to the distance learning system. Therefore, without knowledge of the secret key, the user will not be able to fake their rating.

Thus, we can conclude that it is best to implement the module for practicing the skills of writing SQL queries to the database using LTI technology.

5. Features of development of the external tool

In the LTI v1.3 version of the standard, interaction is performed using OAuth2 and JSON Web Token technologies.

At the beginning of the implementation of an LTI-compatible application, the developer has 2 ways:

- to find and use a ready-made library;
- to implement LTI on their own.

Each of these approaches has its own advantages and disadvantages. For example, to use an existing library, one needs to find it and make sure that it works correctly and meets the standards. In addition, the library may not be supported by the developer, i.e. it will not have updates to new versions of the standard and bug fixes. In the second case, the developer will need to spend time studying and implementing the LTI specifications.

A suitable library, ims-lti, was found and used to implement the application. Also, doing the search, 19 of the other public npm-packages were analyzed.

These libraries were found to have the following disadvantages:
• caccl, caccl-lti, caccl-grade-passback – designed for use together with the canvas LMS, some nuances of operation may differ;
• ltijs, lti-node-library, express ims-lti – can only be used with the framework Express.js;
• passport-lti, papers-lti – can only be used with the Passport framework;
• lti – Tool Provider not implemented, only Consumer;
• @crystaldelta/ims-lti, ims-lti-updated, @flat/ims-lti, @dinoboff/ims-lti, @smarterservices/ims-lti – forks of the ims-lti library with unknown or poorly documented changes;
• lti-hapijs, @node-lti/oauth, ltisaber, @firebase-lti/core – no description, project documentation.

The ims-lti library also has disadvantages. For example, it does not allow us to use multiple Providers “out of the box”. To implement this functionality, one will need to either implement it as part of the application, or add the library. However, this library contains all the necessary basic functionality and does not impose the use of any particular framework on the developer.

As an example, we implemented a JavaScript application on the NodeJS platform using ExpressJS and ims-lti, which, when opened in the Moodle environment, randomly generates a new score for the current user and saves it to the distance learning system. The JavaScript language was chosen because it is the most common for the Node JS platform and, if desired, JavaScript code can be easily rewritten into other languages, such as TypeScript, CoffeeScript, and others.

First, one needs to create an instance of the Provider class from the ims-lti library. Also, the library is based on callbacks, so all called library functions will be turned into functions that return promises thanks to the standard util.promise(). All code is written using an asynchronous approach using async/await constructs. This approach improves the readability of the source code.

```
// creating a Provider with the specified key and secret
const provider = new lti.Provider(process.env.CONSUMER_KEY, process.env.CONSUMER_SECRET);
// getting an asynchronous function to validate a launch request
const validateLaunch = promisify(provider.valid_request);
```

**Figure 3.** Initializing Provider.

To launch an external tool, use the Launch URL, which sends various information about the Consumer, the course, the current session, and users using the POST method. All information is signed with a secret key using the OAuth 2 standard.

```
// validation of query parameters and signatures
const isValid = await validateLaunch(req);
// error 403 for invalid query
if (!isValid) return res.sendStatus(403);
// error 400 if Tool Consumer does not support saving ratings
if (!provider.outcome_service) return res.sendStatus(400);
```

**Figure 4.** Processing an incoming query.

When we open the app, a new score is randomly generated in the range from 0 to 1 and sent to Moodle, replacing the previous one, if there was one. Moodle then saves this rating in the rating log.
Figure 5. Generating and sending a new rating.

After saving a new rating, the user is prompted to check the rating log with a message containing their name.

```javascript
// generating a new rating
const score = Math.random();
// getting an asynchronous function to send a rating to Tool Consumer
const sendReplaceResult = promisify(
  provider.outcome_service.send_replace_result.bind(provider.outcome_service)
);
// saving a new rating in Tool Consumer
const success = await sendReplaceResult(score);
// error 500 if saving the rating failed
if (!success) return res.sendStatus(500)
```

Figure 6. Sending a message to the user’s browser.

```
// getting the user name
const userName = req.body.lis_person_name_given || “Student”
// entering text to the user
res.send({$userName}, your new rating: $score. Check the rating book!);
```

The application under review does not have a session mechanism, which is necessary if the new score becomes known not immediately after opening the application, but only after performing some actions by the user, such as passing a test or performing laboratory work. However, this functionality is not included in the LTI standard and can be implemented in any appropriate way. Also, sending HTTP error codes to the application user without any description is bad practice for use in a real application.

After creating an LTI app, the teacher, course developer, or developer of the app can add it to one or more courses.

6. Conclusion

This paper provides a detailed review of existing solutions for the development of the applied part of distance courses for the study of the discipline “Databases”. In the course of research, it was found that the implementation of online simulators in electronic courses in order to practice the skills of writing SQL queries to the database is advisable to carry out in LMS Moodle, using LTI technology.

In this regard, it was decided to develop the following modules for integration into the Electronic training course “Databases” in LMS Moodle:

- a teacher’s office – an electronic element for creating and editing tasks for learning SQL;
- an interactive exercise – interface that simulates a console MySQL client with a connection to a real MySQL server and the ability to send queries and receive a response from the server;
- a system for automatically checking the correctness of the task and forming an assessment in LMS Moodle.

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