Virtual Laboratory as Custom E-learning Implementation and Design Solution

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Abstract
Carrying out high-quality training in the conditions of quarantine restrictions puts forward new actual tasks for carrying out practical laboratory works and activities. Model of Implementation Online-Education Systems for Educational Process Supporting at the high education institutions and schools has been discussed. The problem of the development software of virtual laboratory work is relevant, because preparing high-quality virtual laboratory work is a time-consuming task for the natural sciences. E-learning laboratory work are mainly remote and should be integrated with Learning Management System for more effective learning process. A set of three hierarchical models with learning objectives, level of complexity and specificity have been taking into account in the implemented Learning Management System. Learning objectives in the cognitive, affective and sensory domains are related with Blooms taxonomy.

Keywords
Online Education Systems, E-learning, Supporting Technology, Learning Management System, Virtual Learning Environment, Virtual Classes, Virtual Laboratory.

1. Introduction

The proliferation of new technologies and internet tools is fundamentally changing the way we live and work. The lifelong learning sector is no exception with technology having a major impact on teaching and learning. This in turn is affecting the skills needs of the learning delivery workforce. From Moodle to Edmodo to Inquisiqr3, there's a lot of tools we can use to manage, track, and deliver educational courses and training programs in our universities.

The classification of Supporting Technology (fig.1) that could be used to deliver educational courses and programs.

All supporting Technologies could be classified into several groups by their role in the educational process (table 1).

Among some terms for online education we can mention Internet and web based education, education by the means of computer-mediated communication virtual and virtual learning. The definition of online education that is connected with definition of distance eLearning has been discussed in the Web-Edu project [1,2].

- Unlike face-to-face learning, students and teachers are mainly spatially separated
- Students may benefit from communication with teachers, staff and each other by the means of bilateral communication in a computer network .
- Private education and independent study are influenced by the educational organization
- The presentation and distribution of educational content takes place via a computer network
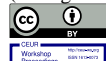
In e-learning, important attention is paid to interactivity, which provides feedback to the student's learning in automatic mode [3]. However, in most cases, the emphasis is on learning materials available on the Internet, rather than on communication between teachers and students.
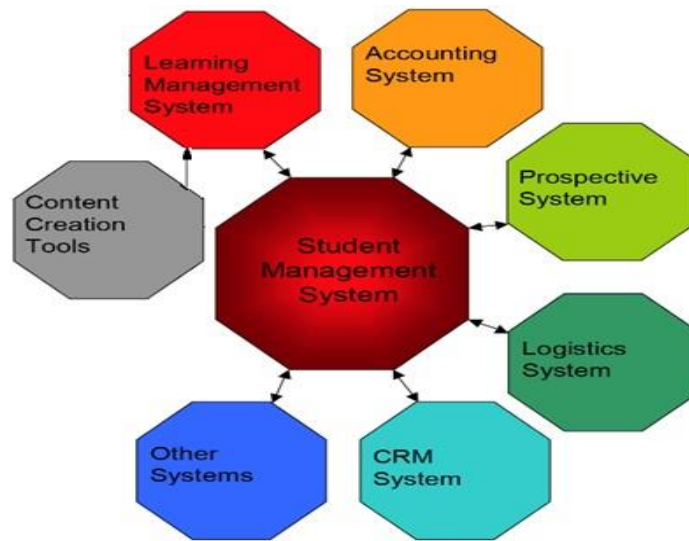

Figure 1: Online Educational Systems Support

Table 1
Classification of Supporting Technology

Learning Management System (LMS)	Content Creation Tools (CCT)	Management System (MS)	Online Education Systems
1. LMS	1. Content Creation Tools	1. Student Management System	1.Online Education
2. Learning Service Provider (LSP)	2. Learning Objects	2. Knowledge Management System	2. Integrated Online Education Systems
3. Learning Platform	3. Assessment Tools	3. Competency Management System	3.Online Education Systems
4. Virtual Learning Environment (VLE)	4. Authoring Tools	4. Human Resource Information System	4.E-learning
	5. Learning Content Management Systems (LCMS)	5. Enterprise Resource Planning System	5. Standards Specifications

The term e-learning is very frequently using as a equivalent for online education. E-learning contains a number of processes and applications, as instance Virtual laboratories and classrooms, Web-based and computer-based learning, digital collaboration. Learning content or information is mostly delivered over the Internet. Therefore, e-learning covers all systems where it is possible to support it.

For instance one of the models for online education is Jigsaw [4] and the other is many so different Hub Models.

The various online education systems must be able to share data and be integrated according to these models. This is relevant for large-scale education systems. Besides content, an integrated learning system - ILS includes tools for making tests, notes, reports, and student files that help to identify and evaluate a monitoring progress of learning via students competences and needs.

For example, a number of standard specifications have been developed within the "IMS project" to facilitate the growing requirements for data exchange and integration. To specify and describe the metadata of IMS training resources, the uniform method was developed [5].

Teachers and developers use the CCT tool to create content for online training courses. This tool is used to develop learning materials such as drawings, simulations, animations, text, slides, graphics, audio, video and assessments. Copyright development tools can also be classified as a subset of CCT. Software applications that use a metaphor (algorithm or book) to create online courses by non-programmers are described in [6].

Workflow management procedures for collaboration within a common environment are provided in the LCMS. This computer program is used to service from a central interface to create tutorials and publications, modify and edit content, organize, and delete. It is used for blended learning and the online learning process, creating learning materials and content. As a modular building material for e-learning content, the Learning Object is used. It is a media-independent, reusable, piece of information. To increase efficiency, learning objects are stored in a data warehouse such as LCMS and organized by a metadata classification system. In general, more attention is paid to the creation, development, and management of content for online courses, but less attention is paid to the control of students' experience in content management systems.

2. LMS and Management System

A course management system (CMS), a virtual learning environment (VLE), a virtual learning system (VLS), a learning platform, or an e-learning portal are commonly referred to as LMS. The determining factor is the software that supports the administration of courses in the learning environment, the development and administration of courses, assessment of the level of knowledge in full-time, online learning, or blended learning. In an educational institution, it can be integrated with other software systems and tools. Institutions use LMS software to plan the learning process, implement and evaluate, and support the organization of learning. Important elements are supporting the access of teachers and students, monitoring student learning and assessing the learning process.

Besides this, the software provides educational content and resources according to the standards or templates during course preparation. Conducting and monitoring student activities during training, such as teamwork, discussion, tasks, assessments is centralized. All these activities will control by the virtual environment of LMS that provides user data protection.

To identify patterns that may suggest ways to make the learning process more effective for students, all typical information about the learning process in the learning system can be analyzed. LMS Administrator and teachers have access to information about student activities and it helps to improve their educational schedules and more effectively develop delivery guidelines and courses, to make communication and collaboration, and improve the clear and understanding system for student assessment.

The most popular LMS software is Moodle, Desire2Learn, Blackboard by Angel and WebCT, Instructure Canvas, Sakai and Pearson LearningStudio.

Each LMS is different and it gives to users different possibilities for implementation such as content-oriented, activity-oriented, network-oriented, linear, and branching. Some systems realize asynchronous instruction, while others provide only synchronous directions.

Some LMS deliver content to students by the means of the mobile technologies, others are using only web-application. That is why organizations need to identify the approaches used and choose the most effective to promote learning at their institutions. Then, they should explore the LMS tools and features and how they will be used. So, selecting a convenient LMS depends on different components.

Between two systems LMS and LCMS a few key exceptions, LMS is a system for managing somebody and LCMS is a system for handling content creation, but both of them create a learning environment.

Software for the learning environment is developed as a comprehensive solution. For an educational institution, this can make it easier to study online. However, in some cases, the ability to track online courses that have not been created in this particular learning environment may be lacking. The learning management system interface allows students to register and attend courses while staying in that environment during the study. The program part contains sections for both self-study and the academic model of a multi-week course. In this case, the group can perform the tasks weekly

with the help of the seminar teacher. The possibility of creating additional courses for the teacher is provided in most learning environments.

Software for commercial services, rent-based training programs and placement of educational institutions. learning process management is provided by the LSP organization. An effective student management system (SMS) is crucial for all educational institutions. Banner and PeopleSoft are examples of such commercial SMS systems. These are the major systems of the educational institution. It is used to manage critical information about organizations such as courses, faculty, students and applications, admission, exams, testing, and payment. The national systems LADOK (Sweden), STADS (Denmark), FS and MSTAS (Norway) are widespread in Scandinavian universities.

Human Resource Information Systems (HRIS) and Enterprise Resource Planning (ERP) systems are either used by corporations and companies. These systems do not contain data on students but employees. They contain important information about their employees and have the same functions as SMS. There are many different types of LMS, or LCMS, to manage the learning process and course content delivery. That way one is the important question is how to choose effective LMS or LCMS according to the organization's needs. The main rule is to know how LMS will be deliver training materials to students, and then compare your organization's needs with LMS opportunities by the LMS functionality.

For choosing LMS it is necessary to take into account some points.

It is LMS free or commercial. Each of these has minuses and pluses [6].

Ability of LMS to scale up or down quickly and easily. It means that LMS is hosted on an organization's servers, or as a Software-as-a-Service (SaaS) offering, which is hosted on the vendor's servers and is accessible from anywhere (the data is stored in "the cloud"). It depends on which type of LMS will be used - commercial or non-commercial. A locally installed LMS offers users the ability to individualize and customize their LMS. Therefore, if an organization already has an IT staff in place that can administer the system, handle support and customization and scalability concerns, a locally hosted LMS can be powerful. If not, a SaaS hosted platform may make more sense.

Ability to create learning content in LMS without using LCMS is very important. Because, some LMS is a tool for sharing and distribute program content, which should be created in the LCMS or another additional application.

Ability to integrate LMS with other applications your organization already uses, depending on your organization's needs.

According to this information, you can use the matrix for LMS choosing (table2).

First, you need to know the way your organization plans to organize online training and e-learning - and also concentrate on how much flexibility you'll need in the future. The other one is personal teachers/staff knowledge and skills for using and support LMS or LCMS. Let discuss conditions for teachers/staff learning and development for using all LMS or LCMS functionalities in the further.

Explore the ratings, experience, skill sets, qualifications, customer support and background of the LMS/LCMS providers during the selection process. Another important thing from LCMS/LMS providers is customer support services 24/7. If you will have access to help, you need to get the maximum advantage of your LCMS / LMS.

There are many aspects to the adaptability and support of LMS / LCMS. The price first depends on the technical specification requirements for implementing the LCMS / LMS strategy in the long run, how often and / or regularly you need to update the LCMS / LMS or possibly adapt to the future needs of your organization and how much it will cost.

For understanding these all moments, the good way will be to use a trial version of the software. How well the features and features fit into your learning and development, whether they need scalability and usability, is easy to determine with a demo version.

An LMS and/or LCMS system may be required to effectively organize the learning process and the LMS / LCMS tracking function. It includes an analysis of student data, with the ability of the effectiveness estimation of learning and determine changes or corrections in the course.

- The process of choosing the best LMS / LCMS for your company's training needs can take a lot of time and money. Therefore, you need to know the answer to the questions in Table 2.

- Good service providers who have worked in your area are important because they know the ways and topics of effective content delivery for a specific audience.

- Modern development of educational technologies testifies to the high popularity of online teaching and learning. Many companies provide full-featured e-Learning and design web portal services given the significant growth of educational technologies.
- The e-Learning contains:
- Virtual laboratory as Custom eLearning implementation and design solution for virtual class.
- Game-based learning - involving learners in interactive e-learning lessons, creating course-based game content.
- Streaming video - Video simplifies the study of difficult-to-understand topics.
- Virtual Classes - Virtual classes make it easy to learn at a convenient time for geographically separated students.
- Online assessment - online assessment encourages students to test their level of knowledge in the comfort of their apartment.

Table 2

Matrix for LMS/LCMS choosing

Criteria	LMS	LCMS
1. The development, creation and managing content for online courses.	–	+
2. Instructions for the students on how to make their education better	+	1
3. Getting feedback from the students about the educational process and course content.	+	+
4. Getting feedback from the professional staff about how the new learning system will be combined with your current software and technologies.	+	+
5. Evaluation of learner achievement.	+	
6. Knowledge achievement by the students during estimation.	+	
7. Receiving feedback from the staff/teachers about what characteristics would they like to observe in the new LCMS/LMS.	+	+
8. Receiving feedback from the technical staff about any technological limitations or considerations (whether LCMS/LMS supports mobile platforms, the way how the students will acquire access to the information? Which set of assignments required for different users? Will you need to include social learning features, content reusability and gamification?)	+	+
9. Need to know education progress and student's skills.	+	–
10. Good course contents.	–	+
11. The main Learning and development purposes and plans.	+	+
12. Software for controlling staff and students during the instructional process.	+	–

3. Virtual laboratory as a design solution for virtual class

In STEM (Science, Technology, Engineering and Mathematics) education, work with simulators and virtual laboratory work (VLW) occupies a leading place. Gaining experience with original equipment is essential for students [7]. In fact, conducting an experiment and obtaining the result without the aid of hardware laboratory equipment and devices allow essentially specialized computer applications VLW.

A VLW may have the characteristics of a virtual simulator in case the interactive model of such a laboratory installation includes virtual instruments and controls, as well as appropriate mathematical modeling tools that reproduce a practical experiment with a given accuracy. Appropriate computer support of laboratory activity in the educational process is provided for conducting modern classes in classrooms and laboratories, as well as for improving students' independent learning activities [8,9,10,11,12].

There are several projects for the development of remote laboratory work in the field of natural sciences[13, 14, 15, 16]. A remote laboratory is a distributed computing environment that allows students to conduct experiments, interacting with real devices, tools and mechanisms using a special

telecommunications platform [17, 18]. Laboratory activities are an integral part of the educational process in higher education institutions in the study of natural sciences. Conducting laboratory work, the student not only acquires fundamental knowledge but also acquires the necessary skills, which is a requirement for its formation as a competent specialist [19, 20].

Electronic laboratory work is used in different parts of the world. In particular, the use of electronic laboratory work in medicine is considered in [21]. The research describes the practice with medical devices using data exchange in cloud environments, the use of servers and real-time data visualization. The main purpose of the examination is to consider ways to help students gain access to virtual tools in the classroom. This goal includes the development, testing, implementation and dissemination of training modules, teaching methods, didactical approaches based on the use of virtual devices in natural sciences, such as chemistry, electronics, biology and physics. Students mastering learning skills in a virtual laboratory (a striking example is the TEALSIM environment), which uses not only virtual tools but also dynamic models of physical laws [22,23].

Elements of gamification with modeling of dynamics of physical processes are realized in laboratory work on materials science. The main objectives of the study are to ensure the highest standards of e-learning. VLW is implemented at IT education classes for students of technical disciplines. To achieve the main objectives of the study a special virtual simulator was implemented;

The main steps of the work include the following actions:
• choose an adequate measurement algorithm in the virtual simulator;
• create a software system of mathematical calculations and modeling for VLW.

These steps have been successfully implemented and presented in developed VLW. Examples of created VLW, simulations of virtual physical measurements were presented in [24]. As a result of our study, some VLWs with adaptive algorithms were created. As an example, we will discuss VLW's state-of-the-art electronic chip design technology. It provides the bulk lifetime measurement of charge carriers in Silicon by the method of conductivity modulation.
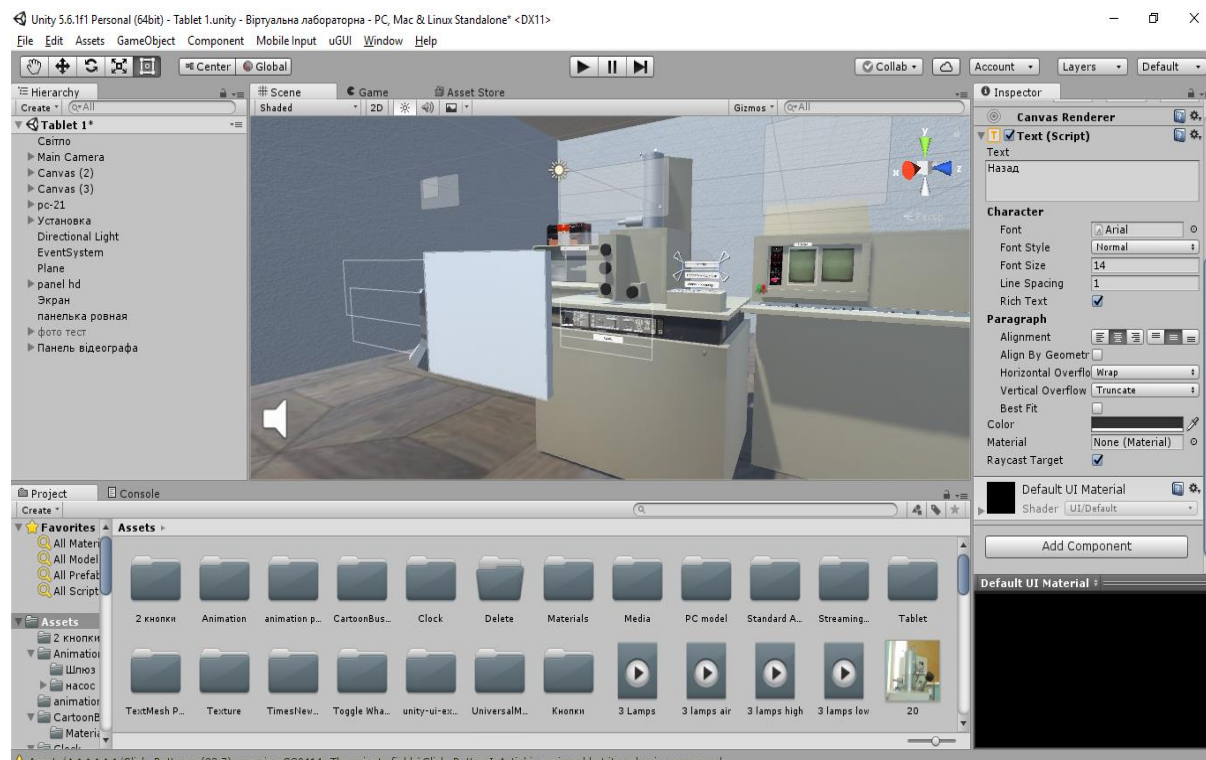

Figure 2: Developer Interface of Unity

With this software, the operator can easily modify and update not only the product but also existing elements specifically designed for this work and create new laboratory activities. Despite the fundamental differences in these operating systems, the project functions on each of them. Unity user interface is presented in fig. 2.

This virtual laboratory practice has been developed in the development environment "Unity".

In most cases, the amount of investigation efforts that can be determined by the tracking system depends on ratings, feedback and gradual progression, current status, visibility, tables of leaders of collective responsibility groups. This VLW combined with Moodle as one of the popular university education systems. In fig. 3. a screenshot of measurements from electron microscopy is presented. During the research in the virtual laboratory, there is the possibility of interactive interaction with devices. The panels and buttons of the device, and other available elements, when activated, cause interactive software scripts. To develop a virtual laboratory, a popular software tool for developing three-dimensional 3D-animated images Unity was chosen [25].

Figure 3: Screenshot of laboratory activity

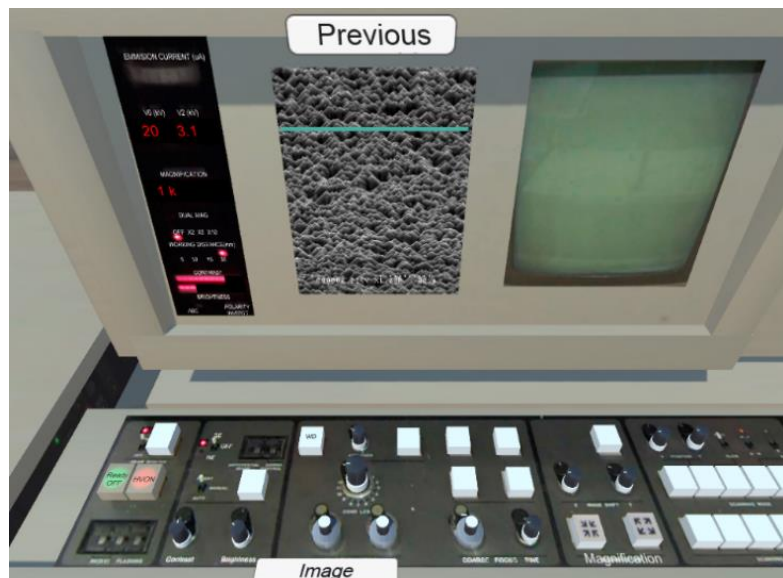The control panel of the videographer is shown in fig. 4.

Figure 4: Controls of the setup

The screen displays a photo of the silicon surface obtained using an electron microscope. The virtual lab allows the student to work with this image as if the operator were working with the image on a real installation. The contrast of the image can be changed by the student. The student has also the opportunity to increase the selected area of the sample within certain limits. In the virtual

laboratory practice, many images of real sample surfaces were introduced. During the laboratory work, the student must measure the dimensions of the pyramid on the surface of the sample of the solar battery. This action is shown in fig. 4.

A graphic scale can be overlayed on the photo of the sample. Having this scale, a photo and knowing the angle of inclination of the specimen, it is possible to investigate the surface irregularities with satisfactory accuracy. This operation is used in industry to control the quality of electronic products, which determines the importance.

An electron microscope is a complex setup that includes a fairly large number of multiple types of equipment. And complex equipment always requires strict compliance with directions for operating. Failure to follow the directions in most cases will cause the destruction of the equipment in physical world. Therefore, the user of the software must strictly follow the instructions that will ensure uninterrupted operation of the equipment and avoid damages when working with complex and high-voltage devices. Safety precautions warn of dangerous factors for human life and health. Therefore, the emphasis in the algorithm is made on anticipating the wrong steps of the student, warning about the danger of performing or not performing certain actions with the equipment.

4. The Algorithm of the development and verification of the Finite-State Machine in Laboratory Works
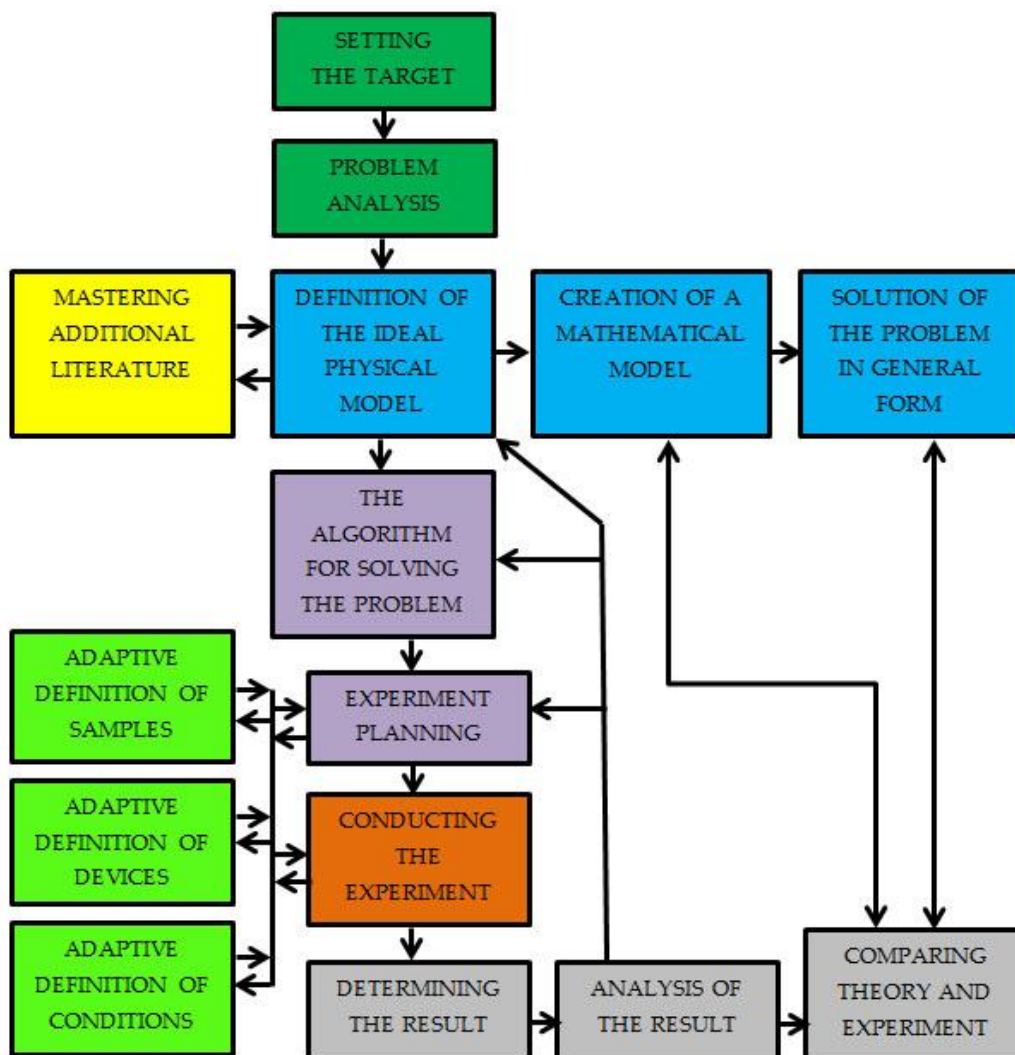

Figure 5: Block diagram describing the algorithm of the student's performance of electronic laboratory work

The use of interactive algorithms with interdisciplinary teaching significantly improves the quality of virtual works in natural sciences. This must first be taken into account when designing them to expand the ways of virtual laboratory work at every step. The next important component is the methods of evaluating the results, as well as the presence of self-control. During laboratory work relating to the means of the experimental process, students must perform conscious choice assignments. It is especially important to plan the interactive conditions of the experiment and the list of virtual devices with the with the possibility of update software library. The model of the virtual electronic laboratory using adaptive scenarios is presented in fig.5.
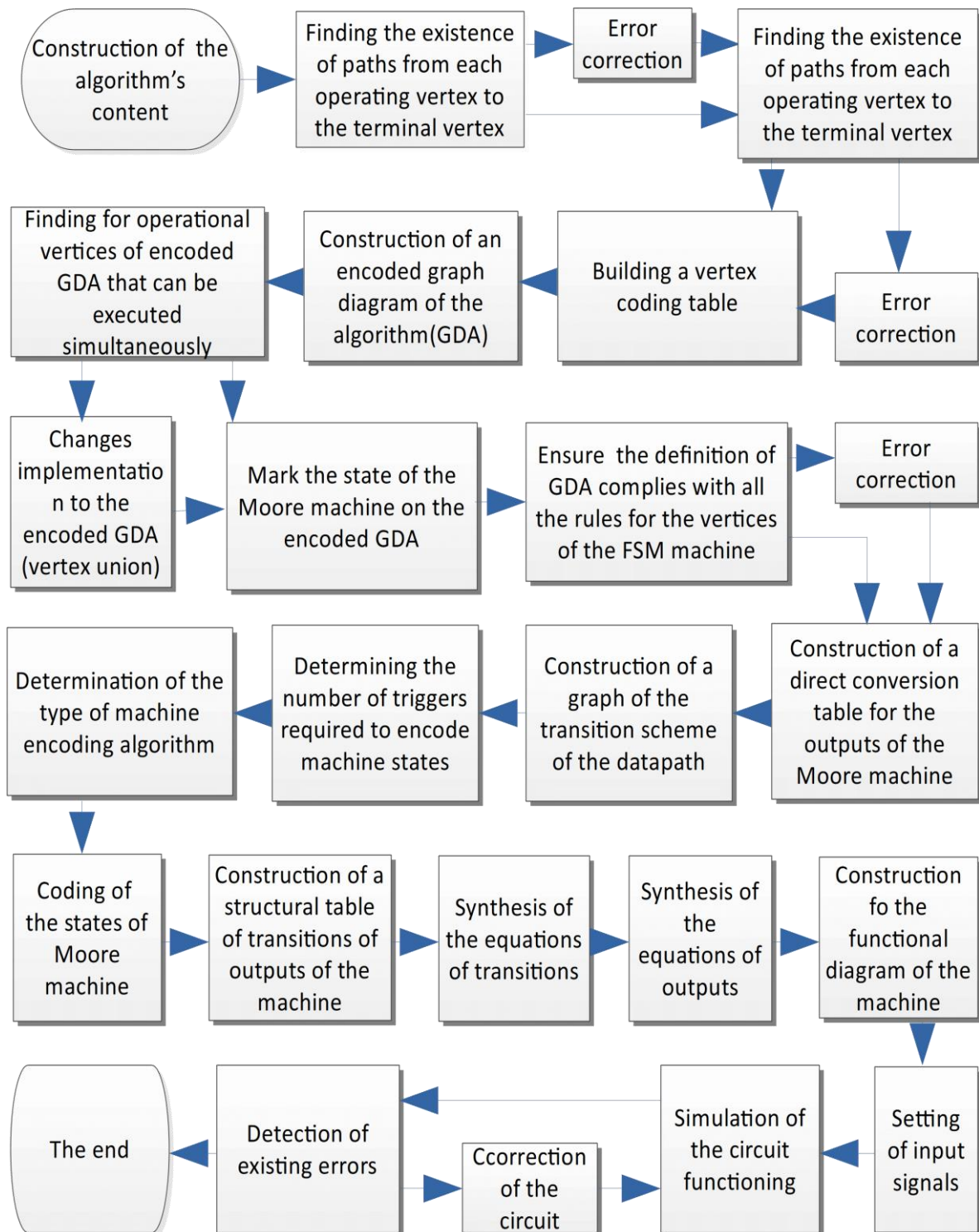
Figure 6: The algorithm for developing and checking the operability of the control automaton

Methods of visual intercommunication, methods of modeling and data acquisition have been also realized for virtual laboratory development. Tasks are performed in real-time, with the illustration of complex processes and interactive analysis of additional data.

At any step of the process, the student can investigate the measurements from the current dataset.

Each element of the virtual device can interchange data with other elements of the VLW and external programs by the means of network technologies.

To study the technical features of original laboratory devices with limited physical access, VLW can also be a fine training tool.

In the usual case, finite-state machines are processors that are represented in the form of mathematical models of actually existing or possible discrete devices. The gathering of such mathematical models and computational tasks that can be resolved using these models is the case of a study of discrete mathematics, the theory of automatons. The implementation of the logic of converting information by digital machines can be hardware, for example, by the means of integrated circuits, as well as software, using programming languages or specific software, including CAD software - Computer-Aided Design.

In the course "Applied Theory of Finite-State Machines", students are asked to construct a control machine system based on the digital Moore finite-state machine that will complete some task of hardware control. The algorithm for developing and checking the operability of the control automaton is presented in fig.6.

5. Conclusion

VLW as a custom eLearning implementation and design solution for the virtual class are based on real experimental setups. The developed software algorithm provides effective use of adaptive scenarios in online courses of IT and natural sciences laboratories. Virtualization-based experiments conducted in the virtual laboratory with a combination of STEM technology and computer graphics improve the transparency and systematicity of complex processes and phenomena and the involve of the author's computer models in the learning process.

The integration process of Moodle with VLW and a variety of other programs with functional together as a system is further very useful to meet various needs of a website for eLearning, including developing courses using authoring tools and make it available through Moodle with the internal course booking system.

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