Virtual Lab Model for Making Online Courses More Inclusive for Students with Special Educational Needs

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Abstract—This study is devoted to the peculiarities of online education, namely, the use of virtual laboratories. The emphasis is being placed on the development of a laboratory model that can take advantage of the available online courses and adapt them for students with special educational needs. The research describes the learning process in a virtual laboratory, options for integrating online courses, and the ways of presenting them to students with certain educational needs. As a result, a virtual laboratory model was developed; it has been primarily designed for people with hearing and vision impairment, and musculoskeletal disorders. Thus, each user category was submitted several options for the educational process implementation within the virtual laboratory. The theoretical model allows creating a virtual laboratory to teach students with special educational needs. Based on the student experience of using the laboratory, research aimed at searching for new ways of presenting information and improving existing ones could be conducted.

Keywords—Distance education; inclusive education; massive open online courses; open educational resources; virtual laboratory

1 Introduction

It is notorious that education has a huge impact on personality development. This applies to both knowledge acquisition and social development of a human. Modern approaches and teaching methods consider a number of aspects that make the learning process the most comfortable and convenient for students. This refers to traditional classes and e-learning. E-learning techniques are being constantly updated and improved due to the mass adoption of modern technologies. Modern technologies include the development of computer technologies, mobile platforms, communication means, and naturally the development of various Internet technologies [1]. It is the Internet and the opportunities that it provides that make it possible to implement all sorts of ideas.
Thus, the Internet offers a number of resources and platforms for acquiring knowledge in various disciplines and the teaching methods can be adjusted to suit the needs of students.

Clearly, massive open online courses (MOOCs) and open educational resources (OER) are the most popular distance education resources [2]. The development of open education initiatives began in the early 21st century with the launch of the OOP OpenCourseWare at the Massachusetts Institute of Technology. This was an online platform with educational materials of the university: various literature (books, textbooks, course notes), videos of classes, tests. This way of sharing knowledge and popularizing education immediately became very popular among other leading higher educational institutions, and soon similar resources were introduced all over the world (CollegeOpenTextbooks, CommonwealthofLearning, OpenLearn - TheOpenUniversity [3-4]). The next phase in the distance education development was the introduction of MOOCs. The purpose of such resources is to provide academic courses from the world's leading higher educational institutions to the general public from around the world via the Internet. This was a step towards the transformation of the traditional educational process into the virtual one. The difference between massive open online courses and open educational resources was the involvement of a teacher. Teacher responsibilities may also include consulting students, answering their questions, monitoring current student progress, etc. The features of the teacher's participation in the educational process may vary and can be defined by the focus of the course, the specifics of providing information, the number of students [5].

It is obvious that the development of any course requires consideration of every aspect. It is important that the student is able to apply the knowledge received properly. Due to the specifics of e-learning, it is difficult to imagine how a student can acquire important practical skills while taking an online course. Practical assignments help students to realize the value of the acquired information and understand the nature of a particular process. It is virtual laboratories that open up new opportunities for optimizing the educational process [6].

Virtual laboratories are also implemented in traditional classroom learning. A number of educational institutions around the world are experiencing difficulties in equipping their laboratories with modern installations, instruments and various materials for conducting practical classes. The problem can be solved through the technology of virtual laboratories. This is facilitated by the development and use of various programming languages, available scientific descriptions of various principles that determine the processes occurring in devices, materials, and other objects being explored. Virtual laboratories are most commonly implemented in physics [7], robotics, engineering [8], chemistry [9], biology [10] and programming [11].

In general terms, a virtual laboratory is a computer-based activity realized by programs or web-sites, where students interact with an experimental apparatus or programmed soft via a computer interface. Today, "virtual laboratory" can be defined differently due to the variety of ways to implement the educational process. By the method of implementation, virtual laboratories are divided into the following categories:
1. Classical simulations that involve certain elements of laboratory experiments. The research can be conducted locally; it does not require local networks or the Internet access
2. Classical simulations that include certain elements of laboratory experiments, but are available online via the Internet
3. Simulation of laboratory experiments based on programming to make them as close to reality as possible
4. Simulation of laboratory experiments based on programming, virtual and augmented reality technologies
5. Real experiments that are carried out in the laboratory and controlled via a local network or the Internet. [12]

When creating a virtual laboratory, various factors that make it user-friendly should be taken into account. Thus, visualization tools must be portable to different hardware platforms and operating systems, the control of the experiment must be understandable to any user, the laboratory must fully display real processes in order to help the student gain practical experience, user data must be protected, the performance of the system should not depend on the number of its users. Compliance with these rules guarantees the convenience and comfort of the use of virtual laboratory [13-14].

Despite the general trend towards popularization and dissemination of accessible education, there are still many people that cannot fully or partially use modern technologies to obtain education. There are a number of reasons for this, including the lack of access to the Internet, the language barrier when using educational platforms, uncertainty about the effectiveness of training, etc. However, there is one drawback in the distance education system, which can and should be solved by the creators of any educational content. This refers to students with special educational needs as there are educational resources that do not provide them with specific features. Therefore, it is important to switch to the inclusive education system as soon as possible. This is an education system that accommodates students regardless of their physical, intellectual, social, emotional, linguistic and other characteristics. Inclusive education includes both pedagogical and technological variables. Thus, the adaptation of students to the educational process occurs in accordance with their characteristics (personal, physical, cognitive, social), needs and interests.

The introduction of inclusive education is a complex and multifaceted process that is defined by different types of education. To solve these problems, there is continuous research in distance education aimed at determining difficulties associated with e-learning that students may experience [15]. New teaching and learning methods are used in the educational process based on various technologies, such as 3D computer games, augmented reality, virtual reality, in order to find a solution to the problems faced by people with special educational needs. These technologies simplify the learning process for students with disabilities. They eliminate difficulties of perceiving information by students through presenting it in a simplified and playful way [16]. E-learning and social learning platforms are being created for people with special educational needs to help them interact and develop. The virtual space ensures a learning environment that
supports different types of learning, special tools that contribute to the creative dialogue, as well as dynamic individual and collective development [17].

Nationally, the dissemination of inclusive education in Russia began in 2012 after the ratification of the UN Convention on the Rights of Persons with Disabilities. Since then, inclusive education has acquired the major components, namely, certain funding mechanisms, the principles of adapting the educational environment for students, the establishment of the appropriate conditions. The top-priority goal involved the development of normative legal acts intended to promote inclusive education; the development of solutions for the implementation of effective inclusion; providing students with special equipment to facilitate the learning process; training of personnel to teach students with special educational needs. However, this cannot be implemented in a relatively short period of time. Therefore, the issues related to the material security of educational institutions and students, the readiness of teachers and the learning environment for inclusive education have not been completely solved [18].

The purpose of the study is to create a virtual laboratory model based on online courses and ensuring user-friendly learning environment that is adapted for users with special educational needs. The following issues have been studied in order to create a virtual laboratory for people with special educational needs:

- The development of a study plan to be implemented in the virtual laboratory environment. The creation of a sequence of actions aimed at optimizing the learning process and at the best digestion of the information.
- The consideration of the categories of people with special educational needs to find the best ways to provide information to them. The study of the difficulties that students may have when using different models of information retrieval.
- The analysis of online courses that can be used to create a virtual laboratory.

## Methods

The research objectives require the development of a clear laboratory class plan. Students must have theoretical knowledge, which should be the basis for further research, to perform any practical task. Theoretical knowledge should reveal the nature of the studied processes, explain them and provide information on their possible practical application. Practical tasks should immerse the student in the process of performing the work so that there is a sense of being fully involved in real professional activities in the workplace. At the same time, modern methods and technologies make virtual laboratory classes simple and convenient.

It is also important to identify what special educational needs users may have and, based on this information, consider options for the best virtual laboratory implementation. This will define the way of presenting educational materials. The information on the problems to be addressed when creating a virtual laboratory helps to determine the most convenient type of information presentation and the way it should be placed in the structure of the virtual laboratory.

The virtual laboratory model is a physics laboratory model. This was due to the fact that physics studies a number of processes and phenomena that can be practically...
implemented through laboratory classes. For example, this allows the use of laboratory equipment (laboratory works with ammeters, oscillographs, optical instruments), describes and visualizes physical processes (coulomb interaction, nuclear physics, light interference).

The virtual laboratory will be aimed at teaching students with hearing and vision impairment, and musculoskeletal disorders. The research focuses on this category of people as they do not need a special psychological approach, which is difficult to be implemented within the framework of this study. People with cognitive impairment, mental retardation, and disorders of the emotional and volitional sphere need an almost individual approach. The research relies on available online education courses, namely, various text and video-based content, which will be submitted in a form that will allow people with special educational needs to fully perceive the subject being studied. A communication mechanism should be established in order to ensure user feedback. This will provide deep insight into the difficulties that students experience during the course and help to introduce adjustments in order to make the laboratory generally accessible. This refers to both the assessment of user experience and the ability to provide extensive feedback that could be used to improve the lab. Naturally, this should be implemented taking into account the needs of users.

Therefore, a model of a virtual physics and chemistry laboratory will be developed; it will facilitate the learning process of people with hearing and vision impairment, and musculoskeletal disorders. The disadvantage of the study is the lack of integration of online courses for people with cognitive impairment, mental retardation, and disorders of the emotional and volitional sphere as they mostly need an individual approach. Due to the fact that this is a laboratory model, it is impossible to get feedback from potential users, analyze their user experience, and identify issues that have not been addressed.

3 Results

Modern technologies allow creating different types of virtual laboratories, which have their own advantages and disadvantages. Simulation-based virtual laboratories are the best option for people with special educational needs. To access such a laboratory, a student needs a device that can connect to the Internet and, accordingly, access to the Internet. Schematically, this laboratory is described as follows (Fig. 1).
Virtual observation and research objects are created based on computer modeling of the processes being studied (programming in various languages; for example, LabView, Python).

In fact, it is not necessary to use real equipment to conduct experiments and research on various processes. Everything is done by simulating the operation of devices. In highly interactive laboratories, it is necessary to thoroughly test the capabilities of the virtual simulator in various use cases, so that the simulated process does not conflict with the real one. The scheme also allows implementing practical activities through the use of laboratory equipment and various interactive learning methods. These methods include games aimed at learning, visualization of the studied processes. Primarily, this should be aimed at younger users, as working with lab devices may be too difficult for them, and instead of focusing on learning and gaining experience, they will think about the difficulties in using this equipment. Therefore, if we compare the available virtual
lab implementation models (classical online or offline simulations, simulation of laboratory experiments based only on programming or on programming, virtual and augmented technologies), option based on the use of software will be the most acceptable will be the most acceptable (see Table 1). In the table, "+" gives a positive assessment of the use of a certain type of laboratory, "-" is a negative assessment, and "0" is a neutral one.

**Table 1. Comparison of different types of virtual laboratories**

| Assessment criteria                  | Virtual lab based on the use of real equipment | Virtual lab based on the use of software | Virtual lab based on software and virtual reality |
|--------------------------------------|-----------------------------------------------|----------------------------------------|--------------------------------------------------|
| Highly realistic                     | +                                             | 0                                      | +                                                |
| User-friendly                        | -                                             | +                                      | +                                                |
| Low cost                             | -                                             | +                                      | +                                                |
| Maintenance-friendly                 | -                                             | +                                      | 0                                                |
| Available to various users           | -                                             | +                                      | +                                                |

Any educational process, especially in laboratory works, provides for the availability of both theoretical and practical activities. Obviously, the theoretical part should be discussed first. It should clearly formulate the purpose of the work, and the tasks to be performed. After the student has got an insight into the work to be completed, the related theoretical framework should be presented. This part is crucial for further work. It should contain the information about the studied processes; formulas and physical quantities used in the work; a description of the devices involved. At this stage, online courses can be integrated into the laboratory class. Text information, various videos or presentations can be inserted. Educational resources are characterized by a huge amount of educational information; thus, it could be structured by its complexity so that people with different levels of attainment can perform certain laboratory tests. This will allow reaching a wider audience and making the virtual laboratory more accessible.

The introductory section should be followed by practical activities. If the activity involves the use of equipment, it is necessary to create a device model so that the user has an idea of its structure and operation principles. This will allow students to immerse themselves in the experiment and gain experience that is close to real conditions. To study the processes at the micro level, or to teach younger users, practical activities should be based on game mechanics or simple visualizations with student participation in the process. Information from online courses can also be used at this stage. It should be presented as small inserts with educational materials that would not distract the user but give short theoretical information about the actions taken. They can be implemented in the text or video format.

Obviously, practical exercises should be followed by conclusions that summarize the work completed and highlight the most important points to be noted. Educational materials from online resources can also be integrated at this stage. The best summary example is the use of the information, which will assess the importance of the work done, the possibility of using the acquired skills and knowledge for further study of the discipline. The final part of the laboratory research should be a test that will allow the
user to assess their success in digesting the information obtained. The test should consist of both theoretical and practical questions; it should be based on the key points of the laboratory research and not miss anything important. The concept of the virtual laboratory being considered is described in the diagram (Fig. 2).

The proposed physics laboratory model includes four key laboratory research stages described in Table 2. The example shows that in order to study the physical process video materials from Coursera.org with theoretical data revealing its physical fundamentals and describing the basic formulas for the topic under study were used. The practical part of the laboratory research can be implemented by simulating the experiment with programming tools. In this part, the whole experiment is based on tabular values of physical constants, which makes the observed process closer to the real one. The user is expected to observe the physical process visualization and record the results in the table in order to calculate the desired parameters, namely dynamic viscosity and kinematic viscosity. Obviously, calculations may require values that cannot be measured. Thus, the user should be provided with those indicators before the beginning of the laboratory research. In the conclusion section, it is necessary to summarize the work done; indicate that the user has learned to carry out calculations of the two types of viscosity, and describe the physical laws used to conduct the study. To reflect the relevance of the laboratory research, it is necessary to note that the material studied is used in theoretical physics, namely in the continuum mechanics course, as well as in practice - the considered physical processes are used to design fluid mechanics systems. The final stage is testing that will allow the user to check their understanding of the processes that occur in the laboratory experiment and the relationship between the physical properties.

Fig. 2. The educational process based on the use of a virtual laboratory
Due to the fact that the virtual laboratory is designed for students with special educational needs, the ways of adapting the educational materials for users with special educational needs should be considered. The laboratory model has been designed for people with hearing and vision impairment, and musculoskeletal disorders; thus, the focus should be placed on the options to provide these groups of people with educational opportunities.

Users with hearing impairment rely on visual perception. Therefore, the information should be presented to them through visual instruments. That is, in the laboratory research, videos should include subtitles or audio translations into the sign language. For deaf people, this is an important feature; it is their way of self-identification in society. Therefore, it is important to consider this when creating educational content for people with hearing impairments. This can be implemented through videos translated into the sign language. Today technologies for real-time translation into the sign language are being developed. The technology will make the virtual laboratory modifications flexible; it will reduce the time spent on the development of educational materials and greatly distinguish the virtual laboratory against the background of other similar platforms. It should also be noted that the practical part of the virtual laboratory research should focus on visual design in order to convey as much information as possible to the student. A good solution would be to convey sound effects through text, visual effects, or the sign language. This will also allow the student to better perceive the learning process.

Accordingly, people with vision impairment rely on hearing and tactile sensation. Due to the fact that this is a virtual laboratory, and modern technologies do not yet allow transferring the shape of objects with the help of assistive devices, it is necessary to focus on auditory perception. It should be noted that complete blindness does not allow the implementation of a virtual laboratory; therefore, a case with partial loss of vision

| Laboratory research on dynamic and kinematic viscosity of liquids based on the Stokes method |
|-----------------------------------------------|
| 1. Theoretical part Introduction of basic formulas and theoretical information using the materials from online educational courses. |
| 2. Practical part Performing the experiment and entering all important data in the table. |
| 3. Conclusions Summarizing the work done. Analysis of the results obtained. Consideration of the knowledge gained and examples of its further application. |
| 4. Final test Assessment of the knowledge gained to conclude on the digestion of the information studied. |

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and impaired eye function will be considered. For example, people with different types of color blindness lose the ability to distinguish colors; therefore, it is necessary to create a color design of the laboratory in compliance with these conditions (Fig. 3). Bright contrasting colors should be used to present the educational material to people with partial loss of vision. There should be the "Read text" function, which will allow students not to strain their eyes and speed up the process of studying the material. Also, when performing practical activities, the audio component should convey the nature of the process under study; thus, it is necessary to use 3D audio effects to ensure complete immersion in the experiment.

![Fig. 3. Peculiarities of different types of color blindness: a) - normal vision, b) - deuteranopia, c) - protanopia, d) - tritanopia [19]](http://www.i-jet.org)

The biggest challenge for users with musculoskeletal disorders when using a virtual lab can be data entry and management of the virtual lab environment. Therefore, simplified management and a decrease in the number of manipulations to perform a certain action should be implemented. Thus, for example, the data required for the practical part can be arranged beforehand; it could be entered in the proper order by pressing one button. The voice input function, which replaces keyboard input or automatically selects the desired answer in the final test, can also be used. It is possible to implement the data entry system through simple mouse movements over the highlighted field in the virtual laboratory window.

Let us consider the features of the virtual laboratory use by people with vision impairment through the example of the physics laboratory research discussed earlier. In the context of this work, all the considered ways of presenting information to people with visual impairment can be used. Thus, at all stages, a special color filter or contrasting bright presentation of the material can be applied, which will be determined by the type of the user vision problem. As has been mentioned, the user can have different types of color blindness; therefore, a certain color scheme will be applied so that they can fully distinguish colors. The parts of the experiment dominated by text information
should be converted into audio files with the help of a speech synthesizer; this is mostly related to the section with theoretical information and conclusions. The text and answer options in the final test section should also be voiced. These measures will speed up the process of work and make it comfortable for the user.

It should be noted that any learning process should be open to participants; they should communicate with each other. Therefore, it would be feasible to create an environment for communication between users in the virtual laboratory. It will allow them to share their experience, ask and answer questions, and simply communicate with like-minded people. In addition, there should be an option to evaluate the laboratory research performed. That is, the user should have a chance to assess the research, for example, on a ten-point scale, which would reflect their general impression of the work. It is also important to introduce the function to add a comment in which the user could more fully describe their point of view regarding the assessment given: positive and negative aspects; points to be changed, or completely removed; points to be added to improve the resource. This would provide better insights into user preferences and their attitude to the virtual laboratory. A more convenient interaction in the environment can be ensured through the implementation of different methods for posting reviews. That is, the function to add feedback in audio format should be introduced; this will be convenient for people with vision impairment and musculoskeletal problems. It is also necessary to create a function to attach files to a review; this will be especially relevant when investigating aspects that should be changed in the virtual laboratory.

Regardless of the prevailing information perception type, the user has all perception patterns known in general psychology: selectivity, meaningfulness, generalization, and constancy. The manifestation and development of these properties depend on the type of perception, as well as on the level of mental development of a person. Accordingly, some properties of perception will be reduced in accordance with the way the person perceives the world. This affects the individual in general, as well as the way they perceive information. The person, being in the environment saturated with information, misses a significant amount of it; this decreases the emotional level of perception, and as a result, depletes sensory experience. Therefore, it is important to develop accessible ways of perception and use them for the development of each person.

The creation of such an environment will also help the developers of the virtual laboratory to identify project problems and user preferences for its further modernization. Communication is a powerful tool in any structure, and in the virtual laboratory designed for students with special educational needs, it is a must. It is expected that there will be a single study; however, the laboratory research will be adapted to each group of users (this may refer to choosing the desired way of presenting information when selecting certain laboratory research, or choosing a method when entering the website). Obviously, the proposed methods can be implemented in any laboratory research; therefore, it is also possible to create the type of laboratory research to be implemented by a certain category of people with special educational needs.
4 Discussion

The modern world is defined by technology. Its application in various spheres of human activity helps to give an adequate response to the events affecting people. Education is not an exception in this case. Distance learning allows us to break down geographic, linguistic, social and physical barriers to knowledge [20]. It is the focus on various problems of distance education users that should develop this sphere and introduce new methods and techniques of teaching. Student is often referred to as an integral figure that is characterized only by age. It is necessary to abandon this concept and expand the view in order to model a holistic picture of the audience of distance education [21]. Therefore, the development of inclusive education is a step towards the future where everyone will have equal opportunities for self-realization [22].

Today, the introduction of inclusive education in the education system is a priority task in many countries. This refers both to developed economies and developing countries that have a lot of unresolved problems. Kosovo is a vivid example here. The small Balkan state demonstrates good integration of inclusive education into its education system compared to more developed member states of the European Union. When comparing Kosovo and the Walloon region of Belgium (they have similar population size and the ratio of students with special educational needs to the total number of students), the proportion of children who study in inclusive schools and classes will be the same [23]. However, on the other hand, not all developing countries can provide students with special educational needs with decent educational opportunities. This refers the Republic of South Africa, which in 1994, having embarked on the path of democracy, showed the desire and political will to change the educational system by adjusting the legislation. The country proves that there is a clear and significant gap between the idealistic concept of inclusive education described in government documents and its implementation in practice. Due to the wrong decision on the development priority of the education system, a number of children and adolescents in the country did not receive quality education, and there is a huge gap between them and students without special educational needs [24]. Despite the fact that the development of inclusive education is a process that should affect every person with special educational needs, some countries focus on certain groups of people. According to the Organization for Economic Cooperation and Development, there are three categories of students in the system of inclusive education. The first category includes students with physical disabilities, the second - students who have mental development problems, and the third - those who are experiencing difficulties due to physical disadvantages. Thus, the policy of inclusive education in Turkey is aimed at the first and second groups, but in Argentina - at the third category [25].

There is constant research to study new teaching methods and predict the dynamics of inclusive education. The issue is addressed both from a social point of view and from a technical and economic perspective [26-27]. At the same time, resources to share experience and knowledge to facilitate the development of inclusive education are being developed [28].

As for the virtual laboratory, its advantages and disadvantages compared to the physical one should be noted. The virtual laboratory allows customizing student tasks; there
is anytime access to the laboratory; the time spent on setting up the experiment is reduced, which allows students to spend more time studying the material; the user is always safe as there is no direct work with devices or hazardous materials. However, on the other hand, no matter how the virtual laboratory brings the process of performing work closer to the real-life experience, there is still no direct interaction with the equipment or the materials under study; there is no direct connection with the teacher who could help with the experiment [13,29].

Our virtual laboratory model and the ideas that have been chosen for its implementation harmonize with global research and best practices in the development of various materials for people with special educational needs. Thus, the available solutions for people with hearing impairment have already been introduced in the study of foreign languages [30,31]; variable color contrast for people with vision impairment is used in a number of programs and services [32]; the model of learning through games has been implemented as a virtual laboratory for studying the structure of atoms [33].

5 Conclusion

To conduct the study, the types of available online courses, the options for implementing virtual laboratories and the features of presenting information on the Internet to people with special educational needs have been analyzed. As a result, a virtual laboratory model that relies on online courses which could be used by people with special educational needs has been developed. According to the model, a virtual laboratory must be implemented in compliance with a number of conditions. First, the laboratory should have a clear structure, namely, it should consist of an introductory theoretical part, a practical part, conclusions on the work done and the theory studied, and a final test. Secondly, materials from open educational resources and massive open online courses should be integrated into all parts, except for the final test. This can be done in the text and video format. Thirdly, tools that would allow teaching students with different types of special educational needs should be used in the virtual laboratory environment. The virtual laboratory model developed in the study focuses on people with hearing and vision impairment, and musculoskeletal disorders. According to the types of the special needs discussed, a number of solutions for this laboratory have been considered. The virtual laboratory should provide people with hearing impairment with the tools that allow translating audio information into the text format (and vice versa) or into the sign language. There should be color consistency in the lab design and tools to adjust contrast and brightness to help students with visual impairment. Users with musculoskeletal disorders should have tools that can simplify operation and minimize the number of actions performed.

Today, there are not many virtual labs that are adapted for people with special educational needs; thus, our model is a good option for implementation. First of all, it should be focused on teaching people, and can also be used to study the features of the learning process in order to modernize the methods used. Further research should be aimed at studying the ways of adapting the virtual laboratory model for people with other types of special educational needs.
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