Online training of students of applied physics in the field of circuitry

D Luchaninov, R Bazhenov, V Sabirova, M Mamyrova and A Zholdosheva

1 Sholom-Aleichem Priamursky State University, 70a Shirokaya str., Birobidzhan, 679015, Russia
2 Osh State University, 331 Lenin str., Osh, 723500, Kyrgyz Republic

E-mail: r-i-bazhenov@yandex.ru

Abstract. The aim of the study is to test the effectiveness of online teaching of students of applied physics (directions "Electric power and electrical engineering", "Physics") to the basics of circuitry and robotics. For the practical development of the principles of circuitry, the TinkerCAD Circuits modeling system is used, lectures and consulting events are implemented using Skype online communication and YouTube broadcasts. The training is based on the principles of gradual complication of tasks and training in invention. The study was conducted at Sholom-Aleichem Priamursky State University and Osh State University in the 2020-2021 academic year. Two groups were selected for the study, the control group (60 students) studied the basics of circuitry using the prepared tasks, the experimental group (72 students) used the TinkerCAD modeling system for training. The results of the study showed the effectiveness of the methodology used for the assimilation of knowledge and skills: an increase in the control group was 13 percent, while in the experimental group an increase of 42 percent was noted. During the research, an increase in the interest of students in the performance of work, attempts to self-improve working devices was noted. Further improvement of the methodology may be associated with the technical design of remote laboratories for circuitry and robotics.

1. Introduction
The current situation in education, which is quite seriously dependent on the epidemiological situation, makes teachers look for new ways and specific platforms as means of implementing their educational programs. Within the framework of higher education in the areas of training "Electricity and Electrical Engineering" this leads to the use of systems for the implementation of schemes and modeling their work. At the moment, there is not a very wide variety of such platforms on the market, one of them is the TinkerCAD Circuits system from Autodesk (TinkerCAD) [1], recognized by many developers in the field of robotics as a tool for preliminary modeling [2].

For teaching circuitry and robotics, various systems are often used, which, being combined according to a modular principle, are able to ensure the effectiveness of the educational process [3]. At the same time, instrumental systems, such as TinkerCAD, are used for many implementations, both by education levels [4] and by areas of use [5]. As one of the modules, TinkerCAD integrates well into the educational process according to the principle of all-pervasive learning [6].

The aim of this work is to study the effectiveness of teaching applied physics students in the field of circuitry and the basics of robotics using TinkerCAD Circuits as an online modeling tool.
2. Methods

Given the current epidemiological situation, universities were forced to switch to distance learning, which entailed a number of difficulties. The difficulties concerned both the problems of finding the best means for organizing online classes in disciplines, and the processing of material and tasks for organizing this form of education. The impossibility of organizing lectures and consultations in full-time format posed a difficult task for teachers to convey information to students. In these conditions, it was decided to collect a set of tools that would allow to organize communication with student groups in a short time, implement practical tasks and test students' knowledge.

As a result of the analysis, it was revealed that for any training there is an invariant set of educational tools [7-10]. Their use has a fairly long history, so there is already a stable set of course components. It should be noted that in this case we are talking about digital means and instruments, however, analog means are quite amenable to digitization. In general terms, this list includes:

- Lectures: text with possible hypertext, time-stamped video, audio recording.
- Practical tasks in a wide variety depending on the subject taught and approach.
- A set of test items: training tests, checkpoint tests, control tests.

When describing the current experiment, we will focus on the principle of organizing practical tasks in the TinkerCAD system, the rest of the elements have a broad description in the sources presented.

When implementing the system, a concept appears - an approach to learning. In this sense, over three types of approaches are of interest:

- Cognitive, in which learning takes place from the "what if?"
- Inductive, in which learning uses a process "from the particular to the general."
- Integrated, in which cognition is combined with induction.

In the learning process, in order to achieve educational results, it is necessary to combine the application of the student's general experience to a particular situation, combined with curiosity and experimentation. In accordance with this approach, the very form and content of tasks is built, which has the following features:

1. The task is based on the existing knowledge base, at least partially (in case of lack of knowledge, the closest analogue is selected, for example, a light-emitting diode - a light bulb).
2. The goal of the preparatory steps for the task is created according to the principle of gradual complication of the material (for example, when using LEDs, a gradual increase in their number and joint work, the transition to devices that control them, etc.).
3. There is a gradual relief of the "hand on the shoulder", the number of clear and unambiguous instructions decreases, the student's freedom of action is added as the material becomes more complex.

Thus, when studying circuitry, on the one hand, getting used to the elements and devices with which the student works, gaining confidence in his actions, on the other hand, the range of possibilities expands, which consists in the application of software and technical approaches to instrument making. Due to the emergence of freer instructions and the step-by-step execution of tasks, the assembled devices eventually acquire the individuality of the person who creates them. The same can be said about the implementation of the program code. Thus, we can talk about an individualized learning path.

In the case of distance learning, mainly an independent part is used, which is quite difficult to control and "target" a student. For face-to-face training in circuitry and robotics, specific Arduino kits are usually used; in a distance format, it is better to use simulation systems such as TinkerCAD. In the TinkerCAD system there is a large set of tools both for implementing the process of modeling schemes and projects, and for organizing the work of students and their control.

The simplest control method in Arduino is to create a class (figure 1).
In the window that appears, click on the "Create a new class" button and fill in the fields in the menu that appears, for example, as done on Figure 2.

![New class](image)

**Figure 1.** Classes item in TinkerCAD system.

Then it becomes possible to add students to the class (figure 3).

![Add students](image)

**Figure 2.** Creation of a new class in the TinkerCAD system.

Then it becomes possible to add students to the class (figure 3).

There are two ways to add students. If they already have accounts and a list of users exists, you can manually enroll them in a class by searching by name. Alternatively, you can copy the class code and send it out to the students so they can join without using manual addition.

The main benefit of using a classroom is to be able to track the status of students' work. To do this, in the class menu, you can select the Designs item and switch to the Arduino Circuits models (figure 4).
The list contains works with signatures of students' names and in what state they are now. After that, you can go to the work of any student, for example, to add, add signatures or explain his mistakes, and click the "Change" button that pops up on the image of his work. In addition, having a list of already added group students, you can go to their profile and view (and also edit) their projects. The entire access system is similar to a workbook, which can be accessed even while a student is working, although more or less online tracking requires either the use of systems such as Zoom and Skype, or sometimes refresh the page.

The problem is that the use of training tools in the system is quite cumbersome, and the system itself takes a long time to load, so to organize an information hub it is better to use another platform, for example, a social network.

The usual structure of the lesson creates the following learning pace: maximum 15-20 minutes for theory, then practice. If possible, remotely, it is necessary to use live communication (using Zoom and Skype) to explain the theoretical points, and then proceed to control and individual consultation using TinkerCAD and the specified means.

Thus, if we talk about remote learning tools for circuitry and robotics, they are as follows:

- To create organizational moments such as schedules, grades, group lists, study materials, etc. more suitable either a community on a social network, or learning environments in the MOOK format (massive open online courses such as courses in Stepik, Coursera, Udemy, etc.)
- To create live communication, Internet communication tools such as Zoom and Skype.
- To create the workspace, the TinkerCAD Circuits modeling system.
- To create test materials, any testing and assessment tools, for example, Google forms, MOOK system tools.

It is necessary to add to the previous point that knowledge testing is needed not so much to quantify the student's work as to understand what he did not learn in the learning process, respectively, with these results, you can either correct further training, or conduct individual work.
3. Results and discussion
An experiment on using the TinkerCAD Circuits modeling system for teaching students was carried out during the fall semester of the 2020-2021 academic year at Sholom-Aleichem Primursky State University and Osh State University for students in applied physics (directions "Electrical power and electrical engineering", "Physics"). Two groups were selected for the study, a control group of 60 people studied the basics of circuitry using prepared tasks, an experimental group of 72 people used the TinkerCAD simulation system for training. When assessing knowledge and skills, a 100-point scale was used. Students' achievements were assessed at the beginning and at the end of the studied course. According to the test results, all students were divided into three groups depending on their level of qualifications: low (less than 33 points), medium (34-66 points) and high (more than 67 points). The research results are shown in figure 5.

The results of the study showed the effectiveness of the technique used: the increase in the control group was only 13 percent, while in the experimental group there was an increase of 42 percent. During the research, an increase in the interest of students when performing work, attempts to self-improve working devices were noted.

4. Conclusion
The use of the TinkerCAD system as a modeling tool for teaching students of the "Electric Power and Electrical Engineering" field of study has shown its effectiveness. The main feature is that no additional software or technical training is required to use it, that is, the modeling system can be easily integrated into the concept of all-pervasive learning. Further improvement can be associated with the technical design of remote laboratories for circuitry and robotics, as well as with the deepening of the theory of invention in conjunction with the use of project and team activities.

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