Using a mobile application to teach students to measure with a micrometer during remote laboratory work

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Abstract

In modern conditions, the transition to distance learning has set new tasks for teachers, in particular, related to laboratory work. In these works, students not only study the structure and features of special equipment, but also acquire practical skills in working with the tool. The purpose of the article is to present our own experience of developing and using in the educational process a mobile application for teaching micrometer measurements during the relevant remote laboratory work in the disciplines "Interchangeability, Standardization and Technical Measurements" and "Physics". The literature analysis showed that ICT is widely used in the educational process in higher education, but computer programs and mobile applications are usually developed for secondary school disciplines, so there was a need to develop an information program for teaching students in distance learning, in particular during laboratory work. In order to teach students to work with a micrometer during distance learning, we have developed a mobile application. The process of developing the application included modeling the micrometer in the CAD system, creating training scenes in the Unity game engine and writing scripts to fully immerse students in the learning process. The mobile application developed by us consists of three parts: theoretical, educational and practical. In the theoretical part, students learn the structure and principles of working with a micrometer. The training part is developed in the form of a video lesson of working with the equipment. The practical part contains an electronic model of the micrometer and allows you to make measurements. Thus, during distance learning using the developed application, the percentage of qualitative success of students in laboratory work on the topic "Measuring parts with a micrometer" increased by 7.3% compared to the same period of distance learning without the use of this application.

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1. Introduction

During the quarantine, distance learning has gained considerable popularity in all educational institutions [1, 2, 3]. Such training involves teachers conducting lectures as video conferences using Google Meet or Zoom platforms, and theoretical material and individual practical tasks are posted on the Moodle platform [4]. The experience of teachers in distance education in the study of mathematical disciplines in primary school showed the use of WebEx, e-class, e-Me, Word wall, Quiziiz, Learning apps, GCompris, Jigsaw planet, Wheel of Luck as tools for learning and practice [5].

Special attention is focused on laboratory classes, where students not only study the structure and features of special equipment, but also acquire practical skills in working with the tool. During distance learning, these works are also translated into the format of video demonstrations and have an exclusively review character. Passive observation by students negatively affects the assimilation of educational material and the acquisition of programmed learning outcomes in the specialty. At the end of distance learning, both teachers and students experienced a variety of positive and negative emotions, insufficient content of training, lack of technological equipment and knowledge [6, 7].

In this regard, there is a need to adapt the educational process to the new conditions of distance learning, which involves the assimilation of students not only theoretical material, but also the acquisition of appropriate skills during experiments in the laboratory. Especially urgent is the need to perform laboratory classes by students of engineering specialties, which is important for their future professional activities [8].

In order to solve this problem, we consider it necessary to organize the educational process using mobile applications when performing remote laboratory work. After all, the rapid development of educational computer technologies, including augmented (AR), virtual (VR) and mixed (MR) reality, has stimulated the creation of new approaches to the presentation of educational material and new teaching tools in all areas of education.

The purpose of the article is to present our own experience of developing and using in the educational process a mobile application for teaching micrometer measurements during the relevant distance laboratory work in the disciplines "Interchangeability, Standardization and Technical Measurements" and "Physics" by students majoring in 208 "Agroengineering" and 133 "Industrial Engineering". The article reveals all the stages of development and description of the application "Measuring parts with a micrometer", the experience of its use and the results of research on its practical implementation in the educational process during distance learning of students of technical specialties.

To achieve this goal it is necessary to perform the following tasks:

- to conduct a theoretical review of the literature on the issue of performing laboratory work remotely, including through educational information programs;
- to develop a micrometer model in CAD system;
- to develop a mobile application in the Unity game engine;
- to describe the basics of the information and educational program "Measuring parts with a micrometer";
- to analyze the results of students' success after studying this topic using a mobile application.

The object of research is the educational information program "Measuring parts with a micrometer" for conducting relevant laboratory work in the disciplines "Interchangeability, standardization and technical measurements" and "Physics" during distance learning of students of technical specialties. The subject of research is the process of development and implementation of this educational program in the educational process of higher educational institutions.

2. Literature review

The introduction of information and communication technologies in education has been a subject of debate and controversy among researchers for a long period of time. At the Department of Early Childhood Education of the University of Crete, Papadakis et al. [9] conducted a study to find out whether there are compelling benefits of using tablet devices in early childhood education to implement proposals for educational reform to introduce realistic mathematics education in kindergartens. According to the results of the study, scientists propose the integration of mobile devices with developmentally appropriate applications in kindergarten classes. Researchers note [10] that due to the flexibility and creativity of tablet-type devices, they can act as an active source of data receivers from a set of quite different experimental situations during STEM learning in preschool and early school education.

According to Dotsenko [11], a special mobile application can be considered as an educational game simulator. The main purpose of such a simulator is aimed at the formation of professional competencies in the information and educational environment. The work on the simulator develops professional engineering competencies, includes familiarization with parts and devices, principles of learning to operate complex equipment, installation skills, assembly and repair systems.

Voloshynov et al. [12] showed an educational information system of blended learning. It includes the alternation of traditional and online learning, virtual learning using VR technology and training on simulators. The authors described the results of an experiment on the introduction of VR technologies for the formation of professional competence "operation of rescue equipment". They noted the better dynamics of acquiring practical skills in using the simulator compared to online learning.

The technology of using 3D models in electrical engineering in laboratory work was presented by Batsurovska et al. [13] and Modlo et al. [14]. In the process of research, the Batsurovska et al. [13] developed 3D models and guidelines for the use and development of computer 3D modeling during laboratory work in the field of electrical engineering.

Kiv et al. [15, 16] note that the use of AR technology allows conducting physical experiments in laboratory work in the absence of the necessary equipment. AR provides the ability to move, rotate, scale 3D models, view them from any angle, combine and separate virtual objects, model processes and phenomena, etc. At the same time, the authors emphasize that most of the available mobile applications and computer programs are limited exclusively to the school physics course.

Semerikov et al. [17] developed a training course "Virtual and Augmented Reality Software Development". Thus, the researchers solved the problem of developing augmented and virtual reality applications [18, 19, 20]. In [21, 22], we also reviewed the development of mobile AR

applications for performing laboratory work on projection drawing and physics.

The possibilities of using ICT in teaching students and pupils were discussed by Kharchenko et al. [23], Stepanyuk et al. [24], Scaravetti and Doroszewski [25], Midak et al. [26], Kovalchuk et al. [27], Ferrario et al. [28], Shepiliev et al. [29], Chiappe [30], Mourtzis et al. [31], Gezgin [32], Striuk et al. [33], Ivanova et al. [34], Katzis et al. [35], Campos-Pajuelo et al. [36], Mamolo [37] and others. The use of educational mobile ICT in the educational process has increased significantly during the quarantine due to COVID-19. Tkachuk et al. [38, 39, 40] conducted a comprehensive study, which included theoretical substantiation, development and experimental testing of the methodology for using mobile technologies in teaching students in quarantine. As a result, a cloud-based immersive learning environment was developed as an open multi-dimensional technological and pedagogical system. This system includes mobile ICT, VR/AR technologies and provides interaction, cooperation, development of university teachers, students and administration in solving educational, technological and scientific problems.

According to Marienko et al. [41], a promising trend in education is the introduction of teaching methods that combine adaptive technologies with VR/AR. Integration of adaptive cloud-based systems, augmented reality technologies and modern pedagogical methods will be an effective solution to the problem of adaptability of the education system.

Burov and Pinchuk [42, 43, 44] believe that the role of research and development in the use of ICT in education remains extremely important. Augmented, mixed, virtual and augmented reality are becoming part of everyday human life in all spheres of activity. But the synthetic virtual environment is not natural for humans and its impact on their mental and physiological processes remains insufficiently studied [45]. The authors believe that the control of operating parameters in AR/VR/MR/XR is important to mitigate cyber-exposure, especially in the learning process, which can take hours of human activity. Therefore, a methodology was developed to assess the impact of AR/VR/MR/XR in the form of short tests with the registration of informative physiological parameters.

Thus, the analysis of literature sources has shown that ICT, in particular mobile applications, are widely used in the educational process: in teaching mathematics in preschool and secondary schools; engineering graphics, physics, chemistry, history and other disciplines of higher education. But, despite this, the issue of using ICTs in remote laboratory work in technical disciplines in the training of future engineers is not widely disclosed. Therefore, this issue is relevant and requires further research.

3. Description of the program

During the training of future engineers, an important place is occupied by the acquisition of practical skills in the use of measuring instruments, including micrometers. Students acquire these skills during the laboratory work on the topic "Measuring parts with a micrometer" of the disciplines "Interchangeability, standardization and technical measurements" and "Physics". This can be realized only through the use of a micrometer in real conditions in direct contact with the tool.

During distance learning, students do not conduct real experiments. Therefore, such work cannot be called a full-fledged laboratory. Despite the fact that students have the opportunity to

observe real experiments in video, record and process data, they are not directly involved in the experiment. While watching the videos, students, in fact, observe a demonstration experiment. Obviously, in this version, they are often presented only successfully completed attempts. In real demonstrations of experiments, the teacher can repeat the attempt and explain the reason for failure. In a remote experiment, such an opportunity is available only in online experiments. As a result, there was a need to develop a mobile educational information system that allows the student to independently conduct a step-by-step study of the device structure and the basics of working with a micrometer in real conditions. As a result, it became necessary to develop a mobile educational information program that allows the student to independently conduct a step-by-step study of the structure and basics of working with a micrometer in real conditions.

A micrometer (figure 1) is a tool used to measure the external dimensions of parts, the thickness of sheets and tapes and pipe wall thickness in engineering work and research [46, 47]. It consists of a bracket 1 with a heel 2. In the right part of the bracket, a stem 5 with smooth and threaded guide belts is fixed, which serve as a support for the micrometer screw 3, which has a thread pitch of 0.5 mm. At the curved end of the screw there is a belt on which the drum 6 is seated. Tight connection of the drum with the belt is obtained by screwing the cap 7 on the end of the drum. The rotation of the drum and the micrometer screw 3 is carried out by a ratchet 8, which creates a measuring force within 7 N. To fix the micrometer screw reading, a lock 4 is used.
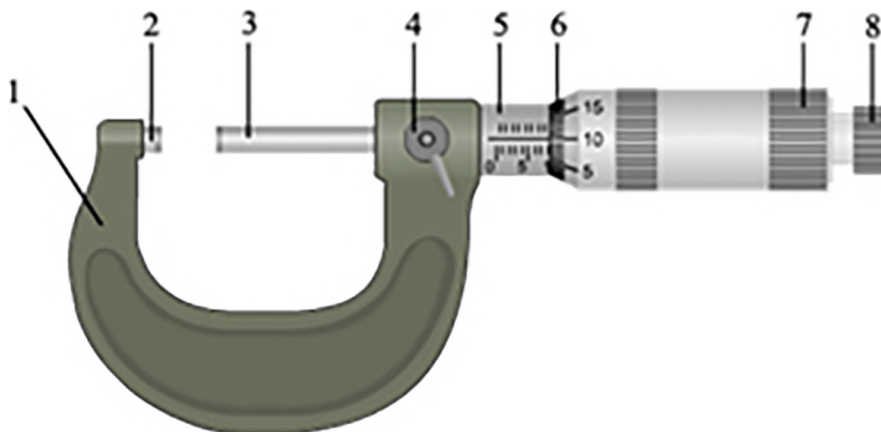

Figure 1: Micrometer of MK series.

The development of the mobile educational information program was conditionally divided into stages:

1. Justification of the functionality and interface of the program;
2. Development of an electronic micrometer model;
3. Writing of scripts;
4. Development and compilation of the program in Unity;
5. Approval of the mobile application.

The mobile application was developed as a methodical and practical educational information program. It should have information on theoretical training of work with the micrometer, video

instruction and practical simulator of the micrometer. The main screen of the program (figure 2) shows the appearance of the micrometer with the main elements signed. On the right side of the screen there are buttons "Practical training", "Knowledge test" and "Information about authors" to switch to additional scenes of the application. The button "Theoretical preparation" activates the departure of the information panel from the top of the screen.

Figure 2: Main program screen.

The object of study of this program is the micrometer itself. Therefore, the development of the program continues with the design of an electronic model of the micrometer. To make an electronic model, you can use various three-dimensional modeling programs. Figure 3 shows the electronic model of the micrometer developed in CAD system Compass 3D. This assembly consists of the following parts: 1 – bracket; 2 – heel; 3 – micrometer screw; 4 – stopper; 5 – stem; 6 – drum; 7 – cap; 8 – ratchet. Each micrometer part is designed as a separate element. The parts are assembled and the model is saved in obj.

The educational information program was developed in the Unity 2021.3.9f1 game engine [48]. To compile mobile applications for the Android system, we additionally installed the latest versions of Android SDK [49] and JDK from Oracle [50].

To layout the main screen of the application (figure 4), create a new scene called "MenuMain-New". In the tab "Hierarchy" load the component "Canvas". This component serves as the basis for placing all the elements of the application. On the "Canvas" add the UI object "Panel" called "PanelMain". As the background image of object "Panel" we set the picture of micrometer model. Using command "Button" we add the menu buttons "Theoretical training", "Practical training", "Knowledge test", "Information about authors" and information buttons of micrometer elements. All buttons are placed as shown in figure 4.

Theoretical information about each micrometer detail is placed in the "ScrollView" com-
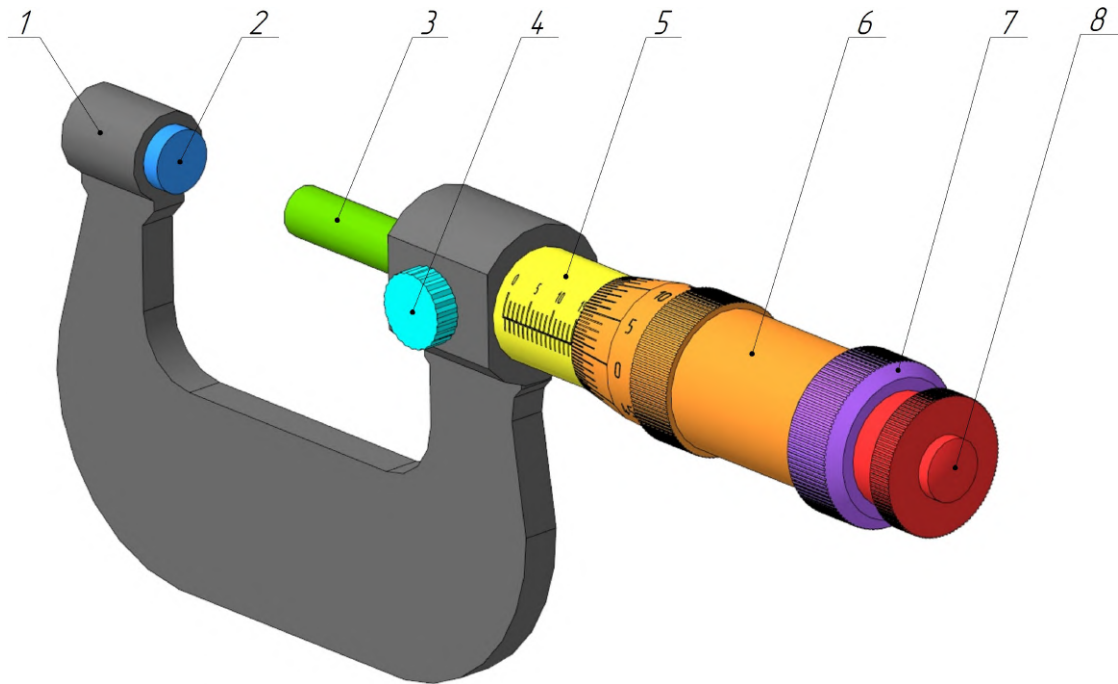
Figure 3: Electronic micrometer model.

ponents. The "ScrollView" objects are located at the top of the scene and are invisible to the observer's eye. The implementation of the effect of "ScrollView" moving from the top to the middle of the screen after pressing the corresponding button is created using the "Animator" component. For this purpose, two animations of departure and arrival of theoretical information were recorded. The "Animator" component was added to each "ScrollView" and the corresponding animation controller was selected. Similarly, the effect of lifting the "ScrollView" objects after pressing the "Back" button was implemented.

Figure 5 shows the final result of the "ScrollViewPiatka" component with information about the "Heel" part. The animation of this object is performed after clicking on the "ButtonPiatka" object called "Heel". In this case the animation controller is activated and the information panel moves from the top of the screen to the center. When you click on the "Back" button, the animation controller is also triggered to return the panel outside the screen upwards. Similarly, information panels for all parts of the micrometer and the "Theoretical preparation" button are implemented.

To go to the stage of practical training, press the button of the same name on the main screen of the program. Practical training is a training video [51] that explains all the details of working with the micrometer. Figure 6 shows the implementation of this scene on the mobile phone screen. The main part of the screen is occupied by the video. The bottom of the screen shows control buttons to start, pause, stop the video and a slider to rewind it. At the bottom right is the "Back" button to return to the main menu.

Setting the control buttons in this scene is similar to the buttons of the previous scene. The
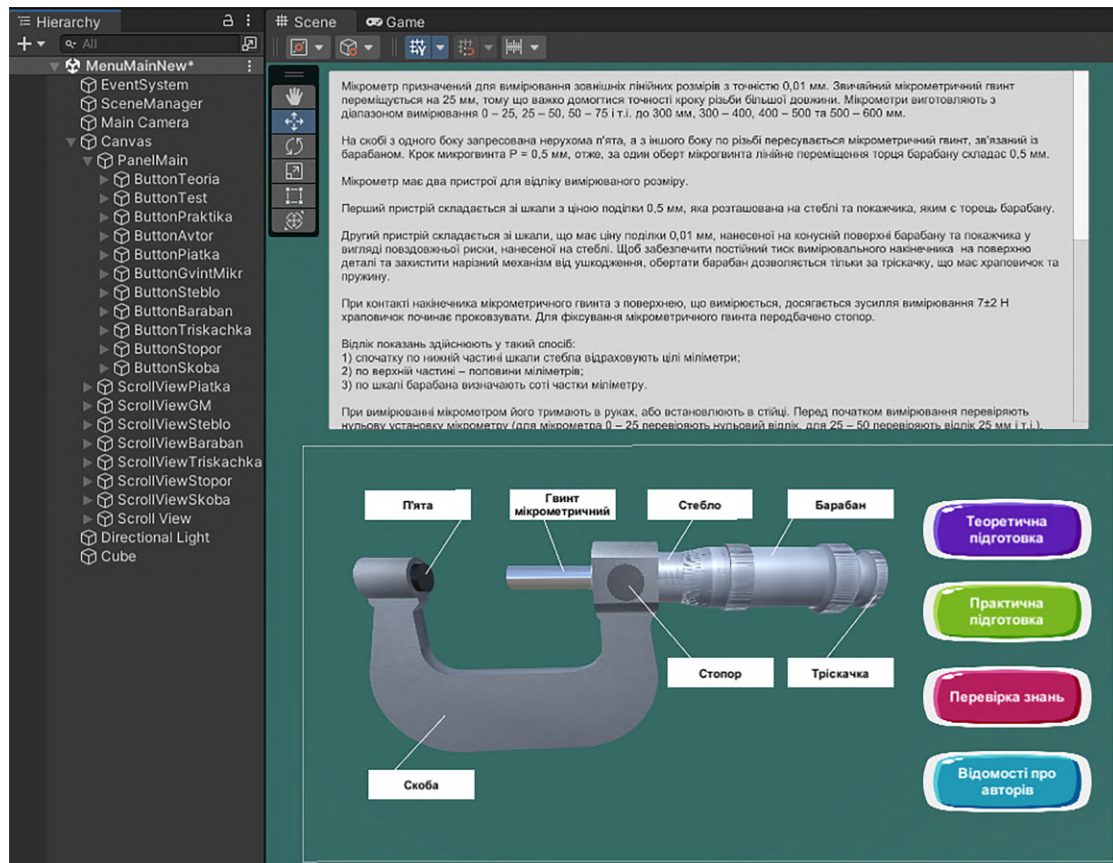
Figure 4: Developing the main screen program in Unity.

functional action of the control buttons is implemented using the corresponding script. The main object of this scene is the training video. The video is displayed using the video player built into Unity 2021.3.9f1.

Figure 7 shows the "Knowledge test" scene. Most of the screen is occupied by an electronic micrometer model and a cube model for measurement. The drum is designed as a moving assembly of parts – the drum itself, the cap and the ratchet. It rotates around its own axis and simultaneously moves left or right, i.e. screws or unscrews. During the movement of the drum, the micrometric screw also moves. Thus, the work of the micrometer is simulated. After stopping the drum, you can determine the micrometer readings on the stem scale.

The corresponding script is responsible for the operation of the drum rotation buttons. The operation scenario of the "Screw the drum" button is as follows:

```
public class UserInterfaceButtons : MonoBehaviour {
  public float rotationSpeed = 70.0f;
  public float translationSpeed = 5.0f;
  bool repeatRotateUP = false;
```
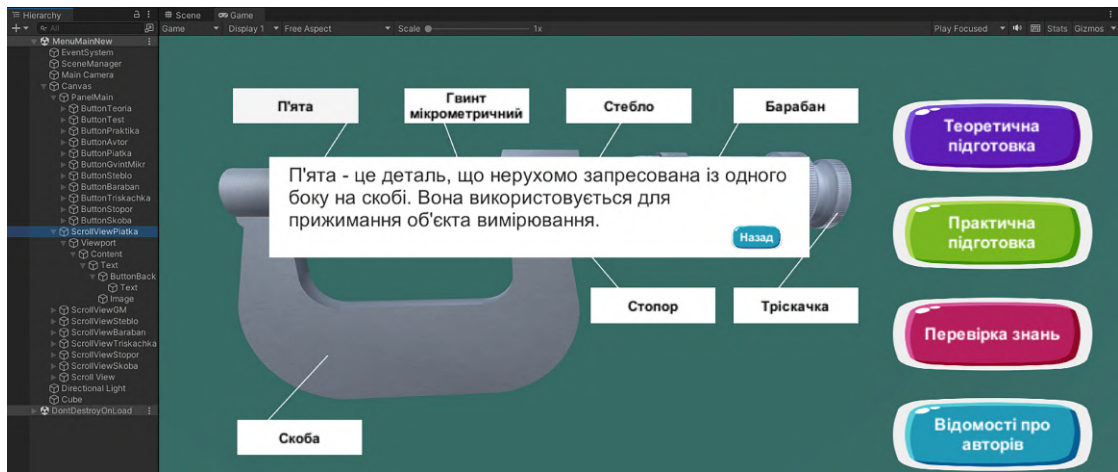
Figure 5: Implementation of the component "ScrollViewPiatka".
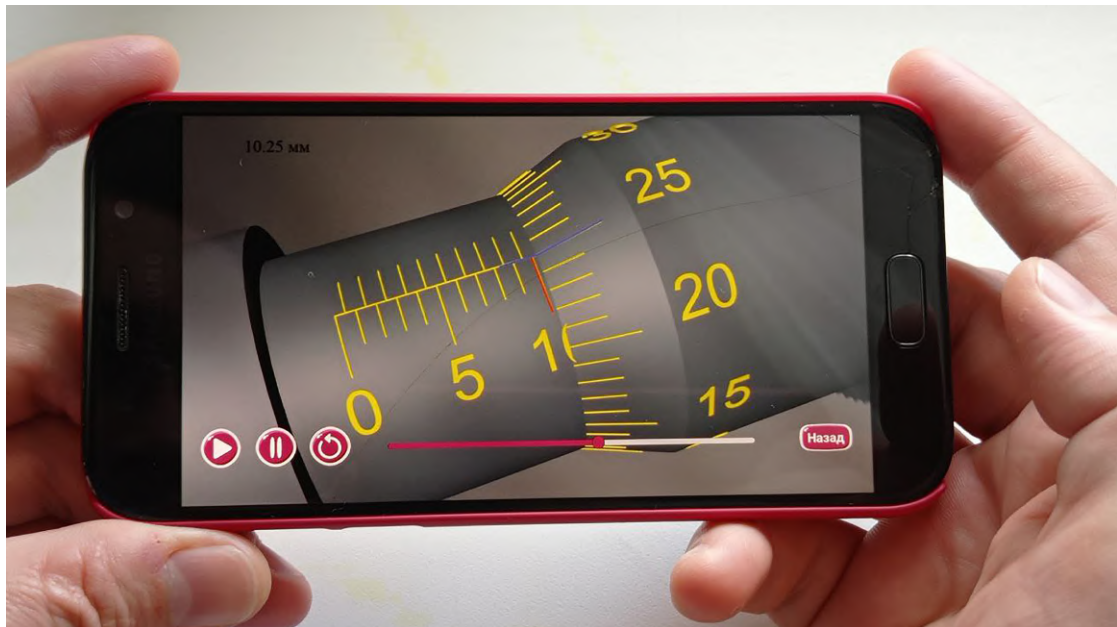

Figure 6: The scene of practical training.

```
void Update () {
  if (repeatRotateUP) RotationUPButton();
}

public void RotationUPButton () {
  GameObject.FindWithTag ("baraban").transform.Rotate
                          (-rotationSpeed * Time.deltaTime, 0, 0);
```

Figure 7: Scene "Knowledge testing".

```
  GameObject.FindWithTag ("baraban").transform.Translate
                         (translationSpeed * Time.deltaTime, 0, 0);
  GameObject.FindWithTag ("VintMetrich").transform.Translate
                         (translationSpeed * Time.deltaTime, 0, 0);
  }

  public void RotationUPButtonRepeat () {
    repeatRotateUP=true;
  }

  public void RotateUPButtonOff () {
    repeatRotateUP = false;
    Debug.Log ("Unscrew the drum");
  }
}
```

Writing the script of the "Screw the drum" button, we begin with the introduction of variables: "public float rotationSpeed = 70.0f", which is responsible for the speed of the rotation process; "public float translationSpeed = 5.0f", which is responsible for the speed of the translation process; "bool repeatRotateUP = false" – a boolean variable that determines whether the rotation button is pressed or not (by default, this parameter has the value "false", that is, the button is not pressed).

The "void Update ()" method constantly checks whether the "repeatRotateUP" variable has

changed its value to "true", if so, the "RotationUPButton" public method is triggered. Through this method, the program accesses the GameObject properties of the model and has access to its other components.

The prefabricated drum model used in the program consists of three smaller models that need to be rotated and moved. To do this, we call the "Tag" of the prefabricated model "baraban". In the code, we write a component for finding tags with the name "baraban" – "FindWithTag ("baraban")" for their further transformation by the components "transform.Rotate" and "transform.Translate". Simultaneously with the rotation and movement of the drum, the micrometric screw moves. We assign the tag "VintMetrich" to the screw and search for it for transformation by the component "transform.Translate".

The public methods "public void RotationUPButtonRepeat ()" and "public void RotateUP-ButtonOff ()" determine the position of the pressed and released rotation button. To track the button release, the following line was written in the system messages: "Debug.Log ("Screwing finished")". A similar script is written for the button "Unscrew the drum". When the micrometer screw touches the cube, the drum stops completely. This effect was implemented using a trigger.

Figure 8 shows the last scene of the mobile application "Information about the authors". It shows the participants who were directly involved in the development of the application – from planning the interface to compiling the finished program. Since the application was tested in Poltava State Agrarian University, this tab has an important motivational and encouraging value for both students and teachers-developers.
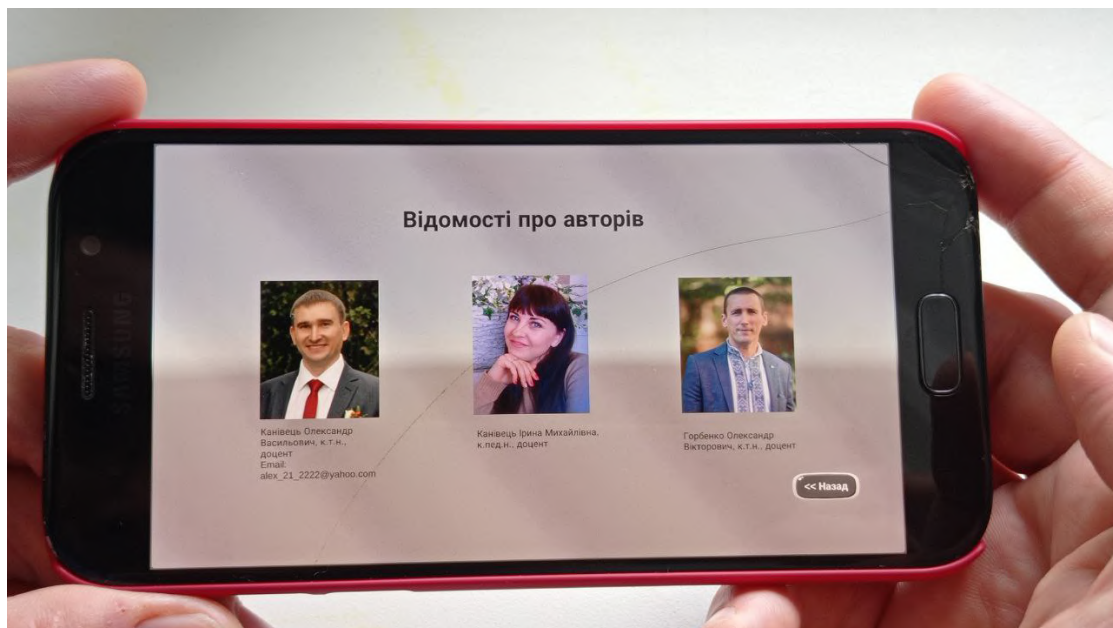

Figure 8: Scene "Information about authors".

Transitions between scenes of the program are implemented using the "SceneManager" script:

```
public class LoadScene : MonoBehaviour {
```

97

```
public void SceneLoader (int SceneIndex) {
    SceneManager.LoadScene (SceneIndex);
  }
}
```

This code has a child public class "LoadScene". The public method "void SceneLoader ()" contains the variable "int SceneIndex", which makes the script universal for switching between all scenes of the program by setting the variable to the corresponding scene number. When you click on the button, the "SceneManager" command is triggered, which implements the transition to the specified scene number.

4. Implementation of the application in the educational process

Performing laboratory work on the topic "Measuring parts with a micrometer" by students majoring in 208 "Agroengineering" and 133 "Industrial Engineering" is of great initial importance. During direct work with the equipment, students acquire practical skills and form the program learning outcomes presented in table 1.

Table 1
Program learning outcomes.

№	208 Agroengineering
1	Evaluate and argue the significance of the results of agricultural machinery tests
2	Reproduce machine parts in graphic form in accordance with the requirements of the design documentation system. Apply measuring tools to determine the parameters of machine parts

№	133 Sectoral engineering
3	Carry out engineering calculations to solve complex problems and practical problems in sectoral engineering
4	Select and apply the necessary equipment, tools and methods
5	Apply means of technical control to assess the parameters of objects and processes in sectoral engineering

To analyze the research, the data on student performance after studying the topic "Measuring parts with a micrometer" during 2019-2022 on the basis of Poltava State Agrarian University and Poltava Polytechnic College of the National Technical Kharkiv Polytechnic Institute were used. In total, 394 students from different higher education institutions (HEIs) took part in the study.

The study was conducted in three stages:

- the first stage: the analysis of the state of development of the problem in scientific, methodological literature and practical activities of higher educational institutions; substantiation of the research problem; questioning of students;
- second stage: development of a mobile application on the topic "Measuring parts with a micrometer" of the disciplines "Interchangeability, standardization and technical measurements" and "Physics";

- the third stage: implementation, processing, verification, systematization and generalization of the research results were carried out.

In order to determine the readiness of students to work with mobile applications during their studies, a survey was conducted before the study. In the process of conducting the study, a survey of students was carried out.

The questionnaire contained the following questions:

1. What is the format of classes in academic disciplines during distance learning?
   a) The teacher sends the materials of his lectures for self-study and gives assignments;
   b) The teacher asks to watch video lectures on the Moodle platform and complete assignments;
   c) The teacher conducts lectures, practical and laboratory classes online on the Moodle platform using video communication programs.
2. How do you use your smartphone in the learning process?
   a) As a calculator;
   b) Information search;
   c) View social networks.
3. On which platform is your smartphone built?
   a) Android
   b) iIOS
   c) Windows
4. Do you have experience in using any mobile application, including AR, VR, MR?
   a) Yes
   b) No
5. Are mobile applications used in the educational process of your higher education institution?
   a) Yes
   b) No
6. Would you use a mobile application when studying the topic "Measuring parts with a micrometer"?
   a) Yes
   b) No

As the results of the survey to the first question showed: 94% of the respondents said that the teacher conducts classes via video communication; 1% of students reported that the teacher sends educational materials through messengers, 5% – the teacher asks to view educational materials on the Moodle platform and complete the appropriate tasks. Students' answers to the second question were distributed as follows: 64% of the surveyed students use smartphones as calculators, 17% – to search for educational content, 19% – for correspondence in social networks, including in the classroom. The statistics of answers to the third question showed that 98% of respondents use smartphones with Android system and only 2% – smartphones on iOS platform. Smartphones with Windows mobile system were not used by any of the surveyed students and teachers. Answering the following questions, all students (100%) noted

that they have experience in using any AR application, but do not use such applications in the educational process. Answering the last question, all respondents expressed a desire to use a mobile application to acquire practical skills in working with a micrometer.

Thus, the survey of students helped to increase motivation to develop an application for smartphones on Android and iOS platforms. The interview with teachers also showed interest in developing such an application. In their opinion, the application should help to improve the process of distance learning and increase students' interest in learning.

To conduct the study, a sample of students was formed. It included students of specialties 208 "Agroengineering" and 133 "Sectoral Engineering". Upon completion of the study of the topic "Measuring parts with a micrometer" by students, an analysis of their progress during 2019-2022 was carried out.

Students were divided by levels of academic achievement on the topic "Measuring parts with a micrometer" in accordance with a 4-point grading system. Thus, according to the evaluation, the grade "(A)" or "excellent" corresponded to a high level of academic achievement, respectively, the grade "(B, C)" or "good" - to a sufficient level, "D" – to an average level and "F, FX" or "unsatisfactory" – to a low level.

During the second stage, the application was developed. Organizational measures necessary for the practical implementation of the study were also planned. Consultations were held for students and teachers to familiarize them with the features of the application.

At the third stage, the process of implementing the mobile educational information program in the educational process was carried out. For practical work with the program, the compiled application file was placed in the Moodle system of the discipline along with the theoretical material. Thanks to this, students had the opportunity to download this file to their phones and install the mobile application. Thus, this program is a separate complete application for the study of the topic "Measurement of parts with a micrometer", and each student had the opportunity to remotely perform a laboratory lesson independently under the guidance of a teacher.

The results of students' progress were recorded step by step in the journal for further analysis. The summary results of students' performance on the topic "Measuring parts with a micrometer" of the disciplines "Interchangeability, standardization and technical measurements" and "Physics" are shown in figure 9.

In the 2019-2020 academic year, the study of the topic "Measuring parts with a micrometer" was carried out under the guidance of a teacher using laboratory equipment in a specialized laboratory in the presence of students. During the training, students gained practical skills and abilities to use a micrometer. As can be seen from the diagram (figure 9), during this period students had the following performance indicators: excellent – 12.9%; good – 46.2%; satisfactory – 38.7% and unsatisfactory – 2.2%. The qualitative performance is 59.1%.

With the transition to distance learning in 2020-2021, laboratory classes were conducted by teachers in the form of demonstrations of micrometer measurements during video conferences. During this period, students did not have the opportunity to learn the basic principles of working with a micrometer in practice. The level of success of students on this topic is as follows: excellent – 5.4%; good – 42.4%; satisfactory – 45.7% and unsatisfactory – 6.5%. The qualitative performance is 47.8%.

When studying the topic "Measuring parts with a micrometer" in 2021-2022 in the conditions
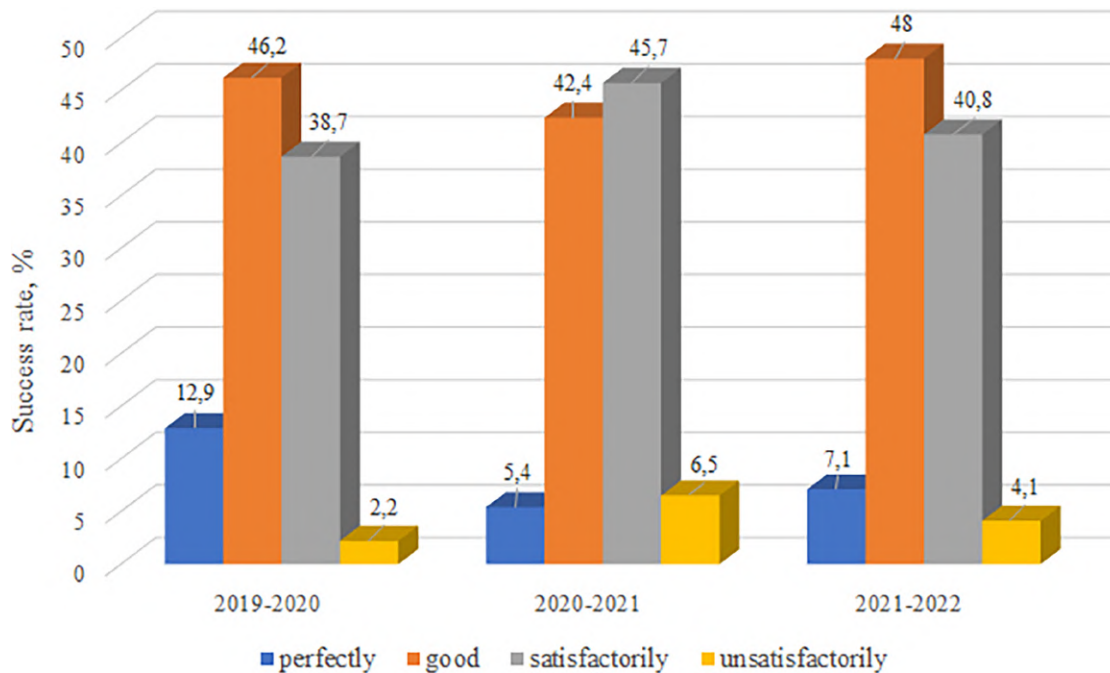
Figure 9: Graph of students' knowledge on the topic "Measuring parts with a micrometer".

of distance learning, a mobile application developed by us was introduced into the educational process. Thanks to this application, students independently measured a virtual model with a micrometer, took screenshots of the phone screen with the measurement results and sent them to the teacher for verification. The results of academic performance in this period are as follows: excellent – 7.1%; good – 48.0%; satisfactory – 40.8% and unsatisfactory – 4.1%. The qualitative performance is 55.1%.

Thus, based on the results obtained, it can be concluded that during the study period 2021-2022, the percentage of qualitative performance of students on the topic "Measuring parts with a micrometer" of the disciplines "Interchangeability, standardization and technical measurements" and "Physics" increased by 7.3% compared to the study period 2020-2021.

5. Conclusions and perspectives of further research

The transition to distance learning in today's conditions has changed approaches to the basic principles of the educational process, which involves the search for new methods and means of teaching, including the use of ICT. During distance learning, there is an urgent issue of laboratory work, where students must independently conduct experiments on the appropriate equipment and take the necessary indicators. To solve this issue, we have developed and implemented a mobile application on the topic "Measuring parts with a micrometer" of the disciplines "Interchangeability, standardization and technical measurements" and "Physics".

The main object of the laboratory lesson is a micrometer. Therefore, its electronic model

consisting of 8 parts was developed in CAD system. The mobile application was developed in the Unity game engine. It contains scenes with theoretical information about the micrometer, a video with its practical use and a scene with an electronic model of the micrometer. The ability to measure a virtual cube is implemented using scripts. To perform remote laboratory work on the above topic, students downloaded the installation file from the Moodle system to the phone and installed the application.

The performance of the program was checked during the laboratory work on this topic. As a result, during distance learning with the use of the application developed by us, the percentage of qualitative success of students in laboratory work on the topic "Measuring parts with a micrometer" increased by 7.3% compared to the same period of distance learning without the use of this application. Thus, the educational process in distance learning, which involves the use of mobile devices, stimulates independent work of students in preparation for the class, increases their cognitive activity, creates conditions for the development of creative abilities.

In the process of using the application in the educational process, a number of tasks have arisen that need to be further addressed: to analyze the operation of the program on mobile phones of different resolutions and screen sizes and make the necessary adjustments; for better visual perception of the material by students, it is necessary to add a video with a real micrometer to the theoretical part of the program; expand the practical part to test students' knowledge, in particular, add parts of different thicknesses for measurement and consider the inverse problem in which the teacher sets the value of the corresponding parameters.

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