

# VR simulator for studying the structure of tractors

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## Abstract

The intensive development of agricultural engineering and agricultural technologies requires a future engineer to have thorough knowledge of the structure and purpose of modern agricultural machinery. In the educational process of training future engineers at higher agricultural educational institutions, the problem has arisen, which is the lack of such equipment as training models. Smart technologies of Industry 4.0, such as artificial intelligence, digital twins, virtual and augmented reality, allow to optimize the educational process, increase its efficiency and reduce the time spent on learning due to a new stage of automation. The purpose of the article is to highlight the main stages of VR application development and the possibilities of using virtual reality to study the structure of tractors. The main object of study is a tractor, so the issue of developing a digital twin has been resolved separately. The VR application has been developed as a smartphone program using a Google Cardboard headset, and the Unity game engine has been chosen as the development environment. The main scene shows a hangar with electronic models of a John Deere 6195M tractor and a virtual avatar. One model of the tractor is disassembled into separate components to study its internal structure. A script was written for the virtual avatar to allow it to move. In particular, the avatar moves when the camera is tilted down to a certain angle. Red markers are placed near the tractor units, which interact with the avatar's sight and display information panels. The information panels tell about the name of the unit, its purpose, and technical characteristics. The capabilities of the developed program have been tested on a sample of students, which included 53 applicants of the speciality 208 Agroengineering. During teaching the Technologies and means of the agroindustrial complex discipline, a practical lesson was developed where students studied the structure of the John Deere 6195M tractor and the controls located in the cab. Evaluation and measurement of user perception of the developed virtual reality application has been determined by a survey based on a questionnaire on technology acceptance. The data obtained using the Likert scale have been analyzed by calculating the mean, median, and standard deviation. The median is close to the mean. This fact indicates a normal distribution of responses, meaning that most respondents rated the mobile application about the same. The results of calculating the standard deviation have shown that these indicators do not exceed one. This indicates the homogeneity of the respondents' answers, which are close to the average value. The use of the program we developed in the educational process has shown that higher education students liked the process of gaining knowledge in the game form, but it should be noted that the movement of the virtual avatar sometimes caused dizziness in some users.

## Keywords

VR application, VR simulator, virtual reality, the structure of a tractor, Unity

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## 1. Introduction

Successful planning of the educational process at higher education institutions, including agricultural ones, requires the education system to use new teaching technologies. In the modern digital era, smart education is understood as a form of education that is becoming increasingly recognized and is enthusiastically accepted by younger generations [1]. At the same time, due to the introduction of the fourth industrial revolution, the educational process is undergoing rapid and continuous changes. Learning models are deeply transformed with the development of digitalization. Smart technologies, such as artificial intelligence, digital twins, virtual and augmented reality, allow to optimize the learning process, increase its efficiency and reduce the time spent on learning thanks to a new stage of automation [2]. Industry 4.0 technologies are used to train competent workforce that is able to cope with the introduction of new business models and technological developments [3], [4].

The quality of educational services has always been a priority for any educational institution. Lectures, material from literary sources, independent work assignments and preparation of students for practical and laboratory classes make up the theoretical part of the training. Thus, theoretical training is based solely on the student's desire and motivation. The consolidation of theoretical knowledge in practice in laboratories is the basis for the acquisition of learning skills and controlled learning outcomes. Involving students in experimental work encourages them to learn new material. This creates an inseparable combination of theory and practice.

Personal training with a teacher in practice is the most effective training format. Accordingly, such training deserves a certain price, namely, time and money are spent on the work of teaching staff, their business trips, and repairing equipment breakdowns caused by students in the process of practicing skills. This is usually too expensive for educational institutions. A virtual reality simulator can help to reduce costs, reduce the risks of emergencies, danger to students' lives and health, and increase the effectiveness of training by expanding the range of modern machines. So, the purpose of the article is to show the main stages of VR application development and the possibilities of using virtual reality to study the structure of tractors.

## 2. Literature review

High-quality training of future engineers depends on the visibility and practical content of the educational process. Classes in laboratories allow students to see agricultural machines, study their external and internal structure, take part in disassembling and assembling mechanisms, and learn how to adjust them.

The practical training of students depends on the quality and modern material support of the laboratories of the educational institution. Figure 1 shows the models and posters used to study the structure of a tractor during the training of students of technical specialities at the Faculty of Engineering and Technology of Poltava State Agrarian University. In the classroom, students have the opportunity to study the structure and principles of engines, brakes, gearboxes and other mechanisms of tractors and cars. Of course, it should be noted that the models available in the laboratories are not taken of modern tractors, but even today they look decent and can be used to learn basic concepts.



**Figure 1:** The training model “The frame of the MTZ-80 tractor”.

On the other side, there is a difficult task: to organize high-quality training for students during their independent and remote work. These types of learning activities allow access to laboratory equipment exclusively in text and video formats through the Moodle system.

The intensive development of agricultural engineering [5], [6] and agricultural technologies [7] requires a future agricultural engineer to have thorough knowledge of the structure and purpose of modern agricultural machinery. The problem with training specialized engineering personnel is the lack of such equipment as training models. For example, students can get acquainted with the appearance of a modern tractor at agricultural exhibitions or during their internship at an agricultural enterprise in their senior year. It is necessary to find modern approaches to solving this problem, and virtual reality can help with this.

The results of the research by Oleksandr Burov, Veleriy Bykov and Svitlana Lytvynova [8] have shown that virtual reality in education can be used almost everywhere. They note that VR creates an infinite number of opportunities for people to gain experience. Today, there are several categories of educational experiences using VR:

- virtual tours;
- high-tech training;
- internships;
- group training;
- distance learning;
- pedagogical design.

On the other side, Oleksandr Burov [9] emphasizes the high cost of VR technologies, which is a significant barrier for many users. In its turn, Google has focused on affordable hardware. To

make VR education accessible to the majority of users, it is important to focus on creating VR applications for devices that users already have, such as smartphones, and use them as powerful learning tools. A phone in your pocket and an inexpensive Google Cardboard headset is all that is needed for students to have a good experience with virtual reality.

Thus, a virtual reality simulator is a software and hardware complex consisting of a VR headsets from one of the key manufacturers (Oculus, HTC Vive, Samsung, etc.) and interactive content – a digital environment created by reproducing and programming an imaginary or real space within which the user can move and interact with virtual objects [10].

There can be several scenarios for the user in a VR simulator, and they can be updated and created depending on the user's goals and objectives. The programming component is responsible for the set of opportunities to interact with the immersive environment that will be included in the virtual training system.

Real-time information from AR/VR devices can be especially useful in specific scenarios for professionals [11]: 1) a head-mounted AR headset assists surgeons during surgery by providing data from wearable devices and other sensors; 2) through VR devices, a user studies a digital simulation of a twin of an industrial layout in virtual reality.

The VR simulator acts as a powerful tool for gamification of the educational process. The problem of gamification of educational activities is studied by a number of scientists such as Stamatios Papadakis [12], [13], Michail Kalogiannakis [14], [15], Carina Gonzalez [16] and others. Gamification in education has proven to be a good strategy for motivating students and promoting their active participation. Gamification methods can be implemented both in virtual environments and in traditional classrooms.

The education of people with special needs has to be highlighted separately. Carina Gonzalez talks about ICT [17] as a convenient tool to help meet the educational needs of such people. Virtual, augmented, and mixed reality are proven to be powerful tools for minimizing the impact of disability and the challenges posed by special educational needs, for educational support, school advancement, and social inclusion. Thus, ICTs enable students with special needs to learn in different educational environments to which they would otherwise not have access.

Successful examples of virtual and augmented reality applications have been implemented for courses in engineering graphics [18], descriptive geometry [19], physics [20], and control and measuring instruments [21]. The Ukrainian researchers Tetiana Vakaliuk [22], Olha Pinchuk [23], Viacheslav Osadchyi [24], Serhiy Semerikov [25], Maiia Marienko [26], Mariya Shyshkina [27], Hennadiy Kravtsov [28], Iryna Mintii [29], Andrii Striuk [30], Oleksandra Sokolyuk [31], Vladyslav Bilous [32], Tetiana Vakaliuk [33], Nataliia Dotsenko [34] and others, consider the current directions of introducing augmented and virtual reality in education and the use of ICT in professional training and retraining. The results of the study by Yun Wen and Longkai Wu [35] also show that the use of augmented reality helps to improve the performance of elementary school students who are weaker in the natural sciences.

The research by Daniel Thalmann [36] concerns the development of multi-user VR applications where computer agents and avatars interact, exchange, and collaborate with each other using objects. This application uses realistic animation to simulate the human movements of computer agents as they interact with avatars to enhance the sense of social presence in the virtual reality environment.

Tetiana Misiuk and Yuriy Kondratenko [37] have shown their own methodology for develop-

ing a mobile computer vision system using augmented reality technology, which allows users (for example, students) to receive additional virtual information about the object of study and be able to interact with it. Independent teams of authors led by Serhiy Semerikov [38] and with the participation of Hennadiy Kravtsov [39] created training courses on virtual and augmented reality software development. In doing so, the researchers have solved the problem of teaching the development of augmented and virtual reality applications.

### 3. Results

The curricula of the “Technologies and means of the agro-industrial complex”, “Technological processes in agricultural engineering” disciplines and the training practice on the preparation and operation of machine-tractor units provide for the study of the structure, maintenance, simple repair, adjustment and aggregation of agricultural machinery and power vehicles (tractors) by students majoring in “208 Agroengineering”. To help students prepare for independent work and distance learning, a decision has been made to develop a VR application.

The virtual reality program has been developed in accordance with the principles of designing multimedia messages by Richard Mayer [40]:

- the multimedia principle – text explanations are displayed together with the corresponding element of the tractor;
- the principle of spatial continuity – text explanations are displayed near the object of explanation;
- the principle of temporal continuity – audio explanations are turned on when the scene is displayed;
- the principle of consistency – there are no extraneous words, images, or sounds that interfere with the perception of information;
- the principle of modality – the display of the scene is accompanied by audio explanations;
- the principle of redundancy – there are no text explanations in scenes with audio explanations;
- the principle of personalization – words are colloquial, not formal;
- the principle of interactivity – students can control the sequence of scenes, audio and text explanations;
- the principle of signaling – places with audio and text explanations are labelled with appropriate markers.

In their study [41], Viktoriia Tkachuk and Yuliia Yechkalo argue that any system developed according to Richard Mayer’s principles is a mobile multimedia development tool, and their use can increase the effectiveness of controlling students’ concentration and motivation.

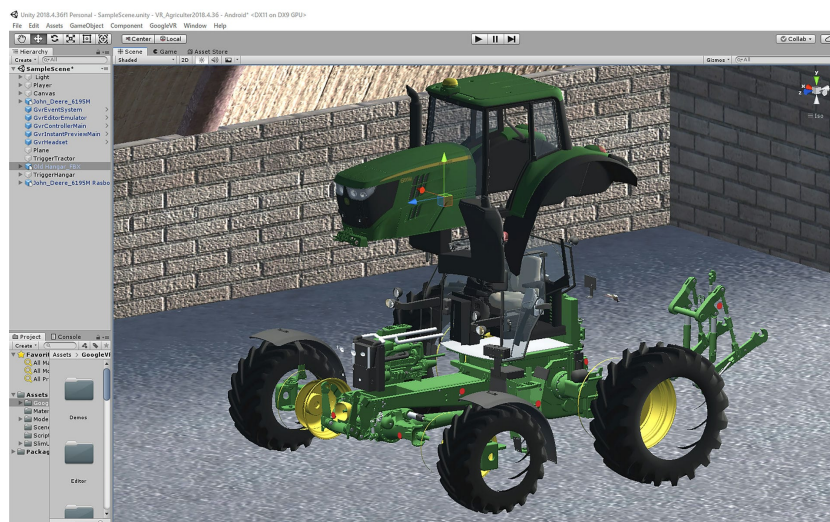
We developed the educational information program in the Unity 2018.4.36f1 game engine [42]. To compile mobile applications for the Android system, we additionally installed the latest versions of the Android SDK [43] and the Oracle JDK [44]. We are developing a virtual reality application for a hardware device such as Google Cardboard, so we installed the Google VR SDK for Unity [45]. This open source package allows users to create a stereoscopic image. Now

the screen in the application will be divided into two parts with a fish-eye effect. In combination with the distortion of plastic lenses, Google Cardboard allows us to create the illusion of depth and immersion in virtual reality.

We select the GvrEventSystem, GvrEditorEmulator, GvrControllerMain, GvrInstantPreviewMain, GvrHeadset, Player elements in the Project Browser panel and drag them to the scene. These prefabs control all VR mode settings, such as screen adaptation to Cardboard lenses. In addition, they receive data from the smartphone gyroscope to track head tilts and turns, so when a user turns their head, the Camera in the video player will turn as well.

At the model development stage, we faced the challenge of building an exact copy of an electronic tractor model. As it turned out, in addition to such Industry 4.0 technologies as the Internet of Things, artificial intelligence, and big data, one of the most prominent recent technological concepts is the Digital Twin. According to Sven Hartmann [46], the digital twin is one of the key concepts of the future.

The developed VR application studies the structure and purpose of the John Deere 6195M tractor. Creating a digital twin of any agricultural machine, especially a tractor consisting of a very large number of parts, is an extremely difficult technical and technological task. Therefore, for our educational project, we used a free 3D electronic model of the John Deere 6195M tractor [? ]. The educational purpose of the VR app is to show both the appearance of the tractor and its internal structure. The disassembled model of the John Deere 6195M tractor for studying the structure, purpose, and maintenance of individual components and parts is shown in figure 2. The virtual user (avatar) has the ability to get closer to any unit and examine it closely. The red dots on the model show markers. Their task is to activate the dashboards for a particular unit or part at the right time.



**Figure 2:** Digital twin of the John Deere 6195M tractor.

Dashboards are developed using the Canvas and Panel components. The panels are deactivated by default. The display of the corresponding panel is implemented using the following script:

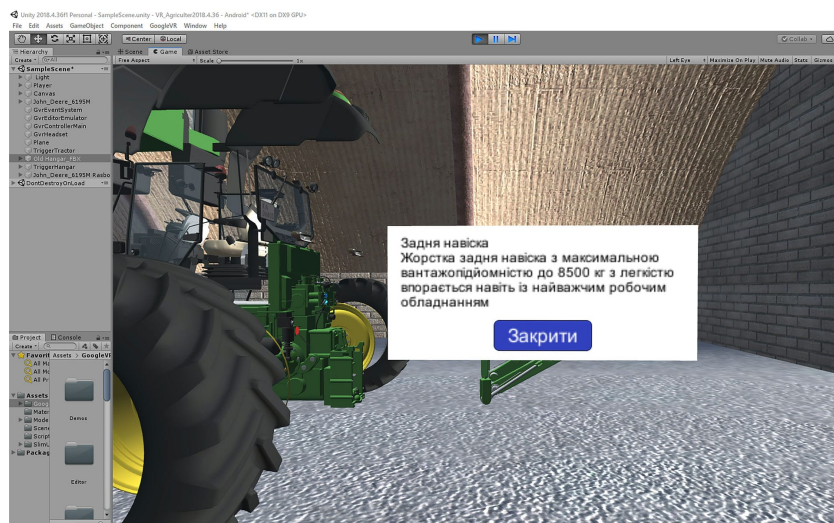
```

public class ShowHideInfo : MonoBehaviour {
public GameObject InfoObject;
private bool Show = false;

public void ShowHideInfo1()
{
    if (!Show)
    {
        InfoObject.SetActive(true);
        Show = true;
    }
    else
    {
        InfoObject.SetActive(false);
        Show = false;
    }
}
}
}

```

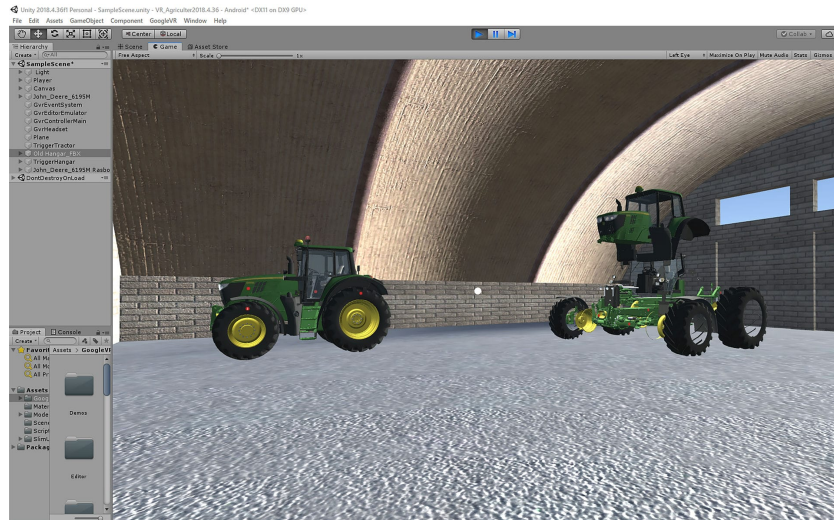
The information panel has a “Text” component that contains general information about the purpose and rules of use of a particular unit or part. Figure 3 shows an information panel with information about the rear suspension of a tractor, from which students learn about the name of this unit, its purpose and technical characteristics. The information panel can be deactivated using the “Close” button.



**Figure 3:** Realization of dashboards.

The main scene of the program (figure 4) consists of two electronic models of John Deere 6195M tractors: a whole one and a disassembled one (figure 2). Both 3D models are placed in an

improvised hangar. Usually, agricultural machinery is kept in hangars or garages, so it is of great educational value. Future engineers need to get used to this kind of tractor storage. The tractor model on the left shows the appearance of the tractor and allows users to imagine its dimensions. It also has red markers to activate the dashboards.



**Figure 4:** Hangar scene layout with tractor models.

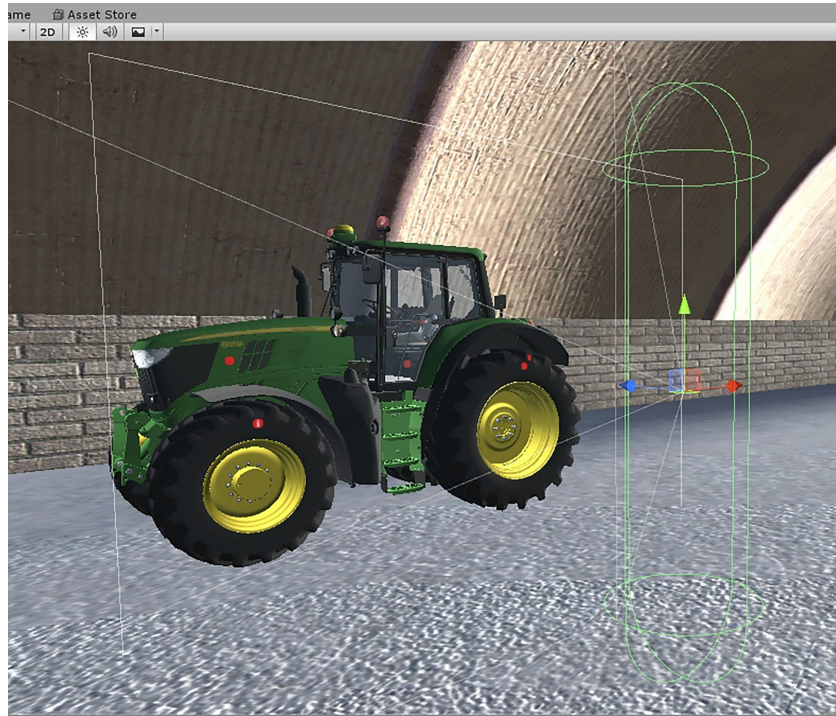
The Player virtual avatar (figure 5) is shown as a green capsule. It contains the Main Camera component and the GvrControllerPointer controller. A white dot is visible in the center of the scene (figure 4). This is the user avatar's sight. It is needed to interact with other elements of the application. The sight allows users to perform interactive actions in the program, such as displaying information panels. To do this, users need to move the white sight over the red marker.

The avatar controller already allows users to rotate around its own axis. At the moment of the program development, the avatar cannot walk yet. We are developing a VR application for mass use by students for educational purposes. We plan to use VR glasses for a mobile phone, without additional joysticks. Such simple glasses can be bought in a store or made from cardboard. For simple VR glasses, the avatar can be moved in the following ways:

- teleporter;
- movement of the avatar when the camera is tilted.

Each method has its advantages and disadvantages. Teleport moves instantly to a specific location and does not allow any adjustments, but it allows users to turn their heads in all directions. Users can also move their avatars by tilting the camera down to a certain angle. In this case, users can set the angle and speed of movement programmatically. This method gives more freedom of movement and allows users to see all the details and components of the tractor better, but it takes some getting used to. In our program, we will use the second method. To implement the movement of the avatar, we use the following script:





**Figure 5:** Layout of the user's VR avatar.

```

public class VRLookWalk : MonoBehaviour {
    public Transform vrCamera;
    public float toggleAngle = 30.0f;
    public float speed = 3.0f;
    public bool moveForward;
    private CharacterController cc;
    void Start()
    {
        cc = GetComponent<CharacterController>();
    }
    void Update()
    {
        if (vrCamera.eulerAngles.x >= toggleAngle && vrCamera.eulerAngles.x < 90.0f)
        {
            moveForward = true;
        }
        else
        {
            moveForward = false;
        }
    }
}

```

```

    if (moveForward)
    {
        Vector3 forward = vrCamera.TransformDirection(Vector3.forward);
        cc.SimpleMove(forward * speed);
    }
}
}

```

In the script, the “toggleAngle” variable defines the maximum angle of the VR headset when the script is triggered and the avatar starts moving. The variable “speed” indicates the speed of the character’s movement. These parameters can be adjusted and defined personally for you.

The VR application was tested during the study of the “Technologies and means of the agro-industrial complex” discipline (figure 6). The students had the opportunity to study the external and internal structure of the John Deere 6195M tractor, the controls in the cab, and estimate its dimensions.



**Figure 6:** Using the program in the educational process.

The evaluation and measurement of user perception of the developed virtual reality application was determined by a survey based on a questionnaire on technology acceptance. Before the survey, users were provided with instructions on how to use the virtual reality program. A total of 53 students of Poltava State Agrarian University majoring in 208 Agroengineering took part in the experiment.

The survey contained 10 questions:

- Q1. It was easy to understand the instructions on how to use the virtual reality app;

- Q2. It took little time to learn how to use the virtual reality app;
- Q3. This virtual reality app is easy to use;
- Q4. Using the virtual reality application made it easier to learn the external and internal structure of the tractor;
- Q5. My interaction with the virtual reality application is clear and understandable;
- Q6. Interacting with the virtual reality application does not require much mental effort;
- Q7. This virtual reality app is fun to use;
- Q8. It is easy for me to make the virtual reality app do what I want it to do;
- Q9. I am confident that the virtual reality app gives me the right instructions;
- Q10. The virtual reality app has no obvious drawbacks.

Answers were given on a 5-point Likert scale: 1 – strongly disagree; 2 – disagree; 3 – find it difficult to answer; 4 – agree; 5 – strongly agree. The data obtained using the Likert scale were analyzed in the following ways: calculation of the mean; calculation of the median; calculation of the standard deviation. The results of the Excel calculations are presented in table 1.

**Table 1**

Results of user perception of the developed virtual reality application.

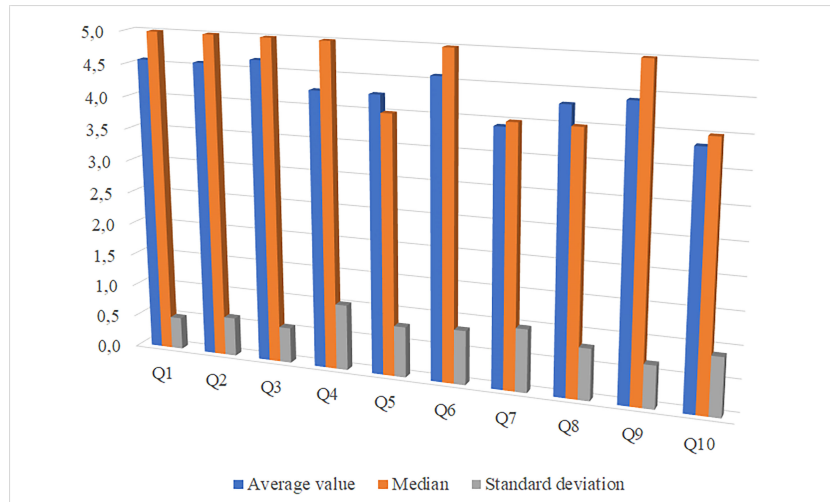
Question number	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Average value	4,6	4,6	4,7	4,3	4,3	4,6	3,9	4,3	4,4	3,8
Median	5	5	5	4	4	5	4	4	5	4
Standard deviation	0,50	0,60	0,55	0,79	0,79	0,84	0,98	0,80	0,66	0,91

The average of all respondents' scores was calculated for each question separately. To do this, we added up all the numerical values of the scores received from all respondents on this question and divided them by the total number of participants. As a result, we have obtained a high average value, which indicates that the majority of respondents have a positive attitude towards the questions asked. It should be noted that the average value does not provide information on how the answers are distributed. For this purpose, we have used other statistical indicators, such as median and standard deviation.

By calculating the median along with the mean, one can get more information about the distribution of responses and assess the sample skewness. The median can be useful for understanding how the scores are distributed on the scale. As it can be seen from the graph in figure 7, the median is close to the mean. This fact indicates a normal distribution of responses, meaning that most respondents rated the mobile app about the same.

A characteristic that shows how much data obtained after the survey deviates from the mean is the standard deviation. High values of the standard deviation indicate that the opinions of survey participants differ, while low values show that the answers are close to the average.

The results of calculating the standard deviation for a particular question in Table 1 show that these indicators do not exceed one. This indicates the homogeneity of the respondents' answers, which are close to the average.



**Figure 7:** Results of the students' survey.

Question Q1 was about the ease of understanding the instructions and the mean was calculated as 4.6 with a median of 5. This indicates that the instructions were simple and easy to understand. The answers to question Q2 of 4.6 showed that little time was needed to learn how to use the application. Question Q3 asked about the ease of use of the app and the result was positively confirmed with a score of 4.7. The average scores of 4.3 for questions Q4 and Q5 indicate a clear interaction with the app, which can help to learn the external and internal structure of the tractor. The result of 4.6 points for question Q6 indicates a low expenditure of mental effort when using the application. The answer to question Q7 is 3.9. Thus, most of the respondents were interested in using the app in the educational process. The result of 4.3 points for question Q8 shows that most of the students surveyed were able to get the app to do the right thing. Question Q9 was about confidence in receiving correct instructions, and the result was 4.4 with a median of 5. Thus, the students surveyed confirmed that they received the correct instructions from the program. The result of Q10 was 3.8 points, with a standard deviation of 0.91, which indicates that the respondents' answers were not disadvantaged by the app.

Students were happy to support the virtual learning format. They especially liked the gameplay of gaining knowledge. Students were interested in walking around the virtual hangar, getting up close and personal with the tractor, studying its design, and getting interesting and useful information about the purpose and maintenance of components from the dashboards. Along with the positive aspects of using the app, it is necessary to highlight the disadvantages of VR technology, namely dizziness and eye fatigue due to the low resolution of the phone screen. Eye strain and fatigue are main disadvantages of using virtual reality devices, as looking directly at the screen can cause eye exhaustion. When using such devices, users tend to blink less frequently, which leads to drying of the eye surface, causing visual exhaustion and fatigue. Ramón Fabregat [47], Olga Pinchuk, and Oleksandr Burov [48] in their own research noted that one of the problems associated with the use of virtual reality technologies is motion sickness. They noted that the brain receives the same signals regardless of whether the observation is

based on an image that suggests movement or on real movement, so the use of virtual reality devices can cause dizziness. We also observed a similar effect in users, and therefore limited the time spent with the application to 15 minutes.

## 4. Conclusion and Future Challenges

Using a VR simulator as an important tool in the process of teaching engineering skills, along with practical training in laboratories, can significantly improve the study of the structure and purpose of agricultural machinery. Of course, the use of such simulators should be part of a special training course that includes a test of the user's knowledge and skills and is designed to meet the individual characteristics of the student.

The most complex and important element of the VR app is the digital twin of the tractor, which is the object of study. Future research will focus on developing exact copies of electronic models of modern tractors from various manufacturers and brands. Thus, VR and AR can play an important role in the education of future agricultural engineering specialists in studying the structure of agricultural machinery. These technologies have the potential to acquire new engineering skills while reducing the educational costs of buying new equipment or renting it. Sometimes the gap between theoretical training and practice is several months. This program allows users to quickly update their knowledge before working on real tractors.

It should also be noted that an important and promising area of research in this field is to determine the impact of VR/AR technologies on students' cognitive load during study. Due to the significant impact on the eyes and brain, virtual and augmented reality technologies cannot replace traditional forms of education, but they are an important complement and assistant in addressing the limitations that arise when using traditional forms of education.

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