DEVELOPMENT OF AUGMENTED REALITY APPLICATION FOR PHYSICS AND GEOPHYSICS LABORATORY

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ABSTRACT:

Augmented reality technologies are widely applied not only for business, but also for education and various fields of science. Due to rapidly growing interest in emerging technologies, augmented reality is taking a leading position in almost all areas of education. Applying augmented reality in physics laboratory can make experiments more efficient in terms of understanding using visualization. The article contains process of development of augmented reality application for visualization and its methods for physics laboratory experiments in terms of maximum efficiency and ways to create visual effects. The article proposes a methodology for creating augmented reality application, which allows students to visualize physics laboratory experiments. This technology is a step towards the development of augmented reality practice, which will reduce the time, cost and difficulty of visualizing physics laboratory experiments.

1. INTRODUCTION

1.1 Theoretical Framework

Augmented reality is applied in various fields of education and science. In education, augmented reality provides a complete immersion of students in a demi virtual environment through their senses. The application of augmented reality in education will ensure good understanding because of visualization support (Kreijns, 2013). One of the reasons to apply in laboratory experiments is to teach invisible particles or waves with supporting visual effects and animations. Therefore, one of the essential goal is to apply in augmented reality in physics laboratory at high school. Augmented reality will help reduce time to visualize physics invisible phenomenon; therefore, this process increases the efficiency of understanding physics experiments. Augmented reality allows students to increase motivation and interest in learning compared to traditional learning approaches such as reading paper materials. In addition, physics experiments with augmented reality allow collecting data about process of performing lab experiments. In this article, possibility of using augmented reality to visualize the unseen effects is systematically analysed. Augmented reality based laboratory experiments help students manage to develop learning skills in order to study physics with more details; therefore, it is highlighting the improvement of the quality of teaching of physics (Dror, 2008). In addition, augmented reality application is in demand for visualization of lab processes. Augmented reality application make it possible to find educational solutions at an earlier stage of lab experiments. They can be active participants in the augmented world, interact with objects in it, and be third-party observers who only see and analyse the student's actions during physics laboratory experiments. To develop the learning scenario, augmented reality application include the presence of various kinds of prompts such as text, sound, graphic. With the help of hints, it is possible to provide the necessary reference information to continue experiment (Martin, 2011). Both active participation and third-party observation in the augmented world can enhance the learning experience in physics laboratory experiments. They allow for interactive and immersive exploration of concepts, while also providing opportunities for analysis, discussion, and evaluation. These roles leverage the capabilities of augmented reality technology to create engaging and dynamic learning environments.

1.2 Related Research

There are various options for requesting hints like using the menu presented in the scene and using predefined scene objects, voice recognition. Students work in the experiment mode, in which any reference information is available to the student and the time for completing tasks is not limited. Augmented reality application provide an examination mode of experiment in which there is no access to reference materials, the time for performing experiments is limited, and all student's actions are logged for further assessment of the correctness of the execution. In addition, the application is counting errors automatically. In augmented reality, it is possible to organize a flexible learning process. In some scenarios of using the augmented reality, it is possible to repeat the same actions endlessly in terms of execution time. Such an experiments scenario is in demand during the initial acquaintance with the physics laboratory. A radically different scenario is developed to assess the quality of acquired skills in learning process. In this scenario, it is possible to limit the number of attempts and time. Physics laboratory experiments should be as capacious as possible, and include methods that affect different channels of perception, and give a volume of understanding. Illustrative, explanatory, practical, creative methods in teaching physics have always been effective. Today, there is open opportunities to reduce theory and increase practice with bright visual content and cognitive tasks (Bronack, 2011). The augmented reality application offers various options for requesting hints and assistance during the physics laboratory experiments. Students can access hints through the menu presented within the scene or by interacting with predefined objects in the virtual environment. Another option is to utilize voice recognition, allowing students to verbally request hints or guidance. During the experiment mode, students have unrestricted access to reference materials and there is no time limit for completing tasks. This mode allows students to explore the experiment at their own pace and seek assistance as needed.

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The focus is on the learning process rather than time constraints. The examination mode in the augmented reality application provides a different experience. In this mode, students do not have access to reference materials, the time for performing experiments is limited, and all of the student's actions are logged. This mode is designed for assessment purposes, allowing for the evaluation of the correctness of the execution. The application also automatically counts errors, providing feedback to the student. The augmented reality technology enables the organization of a flexible learning process. Depending on the scenario, the same actions can be repeated endlessly in terms of execution time. This feature is particularly useful during the initial introduction to the physics laboratory, allowing students to familiarize themselves with the equipment and procedures without time constraints. However, for assessing the quality of acquired skills, a different scenario is developed. This scenario may limit the number of attempts and the available time, providing a more challenging and realistic assessment of the student's proficiency. To ensure an effective physics laboratory experience, it is important to incorporate various methods that cater to different channels of perception and facilitate a comprehensive understanding. The application should include illustrative, explanatory, practical, and creative methods of teaching physics. The use of bright visual content, along with cognitive tasks, can help reduce reliance on theoretical concepts and increase practical engagement. With the advancements in augmented reality technology, there are ample opportunities to create engaging and interactive learning experiences that promote practical learning and enhance understanding in physics education. By leveraging visual content, cognitive tasks, and interactive elements, students can develop a deeper grasp of physics concepts and apply them in a meaningful way.

2. METHOD AND MATERIALS

2.1 Research Model

Educators are trying to make comprehensive learning methods with more innovative methodological materials and textbooks with digital arrangement. The learning process is becoming more streamed with digitalization (Milgram, 1994). In an overview of augmented reality technologies and principles of education provides classification of modern approaches to physics laboratory. All physics experiments can be conditionally divided into two categories such as intellectual activity and physical activity. Digitization of education is a process of transformation education through the introduction of digital technologies that help improve students' knowledge. Successful laboratory activity is associated with the processing of existing data and obtaining new data with no harm to students. Today, students successfully develop their competencies and improve their skills with the help of augmented reality. It is possible to hone the acquired skills in the course of a physics. The situation is different with the category of manual students. Their activities are directly related to constant reading book, since working out the movements and actions of a student to automatism sometimes helps to someone to understand. The probability of emergencies in high schools where physical experiment took place is extremely high (Azuma, 1997). That is due to the unscrupulous experiment of teachers with student and their lack of sufficient competencies. Therefore, high schools are in search of advanced and safe solutions in physics laboratory in high school. Therefore, appropriate methods and approaches to teach students at high schools is necessity. For the physics experiments, a solution is applications of augmented reality. Today they are the most important element of laboratory experiments in such areas of activity, where errors in experiments on real objects can lead to emergency consequences, and their elimination can lead to large financial costs. These applications allow students to simulate physics phenomena in which the students will have to understand phenomena. Application provide the formation of lab skills in an artificially simulated environment. Replacing real physical phenomena, they can significantly shape and supplement the student's experience in their interaction with the experiment. Educators are actively exploring innovative methodologies and digital resources to enhance comprehensive learning. The digitalization of education has led to a more streamlined learning process. Augmented reality technologies offer a classification of modern approaches to physics laboratory experiments, which can be categorized into intellectual activities and physical activities. The digitization of education involves the integration of digital technologies to improve students' knowledge and learning experiences. In the context of physics laboratory activities, successful experimentation requires the processing of existing data and the acquisition of new data, all while ensuring the safety of students. Augmented reality has proven to be a valuable tool for students to develop their competencies and improve their skills in physics. However, there is a difference in the learning process for manual students who rely on reading books extensively. For them, the repetition and practice of physical movements and actions are crucial for understanding and achieving automatism. The risk of accidents and emergencies in high schools where physical experiments take place is relatively high. This is often due to the lack of sufficient competencies and unscrupulous experimentation by teachers and students. As a result, high schools are actively seeking advanced and safe solutions for physics laboratories. Augmented reality applications provide a viable solution for physics experiments in high schools. They have become essential elements of laboratory experiments, particularly in areas where errors or mishaps in real-world experiments can have serious consequences or require significant financial resources to rectify. These applications allow students to simulate physics phenomena, enhancing their understanding and skills in an artificially simulated environment. By replacing real physical phenomena, augmented reality applications can greatly shape and supplement students' experiences in their interactions with the experiments. Augmented reality applications offer a safe and effective means of conducting physics laboratory experiments in high schools. They provide opportunities for students to simulate and understand complex physics phenomena while developing their lab skills. Augmented reality technology plays a critical role in shaping students' experiences and enhancing their interactions with the experiments, ensuring a comprehensive and engaging learning environment.

2.2 Data Collection Tools,

Augmented reality application have been added in the second decade of the twenty first century, which are currently developing quickly. Perhaps this is the most promising technology in education. Today, among teaching methods, game learning is very common. This is the concept of learning, derived from education and entertainment, which means the distribution of educational content through an entertainment approach. The main goal is to educate the audience of student while entertaining them. The main idea behind playful learning is that when learning content is entertaining, it is more likely to be remembered. Competent, highly qualified and quickly trained student is the key to success and competitiveness of the high school. The problem is that the knowledge gained by student in high school is rapidly becoming obsolete; therefore, there is a growing need for their significant renewal. At present, the rate of obsolescence

of knowledge is approximately ten times higher than the rate of their update. To maintain knowledge at the level of requirements is to spread unique ideas in science, art, technology. Indeed, augmented reality applications have experienced rapid development in the past decade and have shown great promise, especially in the field of education. This technology provides immersive and interactive experiences that can enhance learning outcomes. It combines educational content with entertainment elements, resulting in a concept known as game-based learning. Game-based learning leverages the principles of both education and entertainment to deliver educational content in an engaging and enjoyable manner. The main objective is to educate students while entertaining them. The underlying idea is that when learning is fun and entertaining, it is more likely to be retained and remembered by the students. In the context of high school education, having competent and highly qualified students who can quickly adapt to new knowledge is crucial for their success and competitiveness. However, the challenge lies in the fact that the knowledge gained by students in high school becomes outdated at an accelerating pace. The need for continuous updating and renewal of knowledge is becoming increasingly important. The rate of obsolescence of knowledge is currently much higher than the rate at which new knowledge is being generated. To keep up with the evolving requirements and maintain knowledge at the desired level, it is essential to foster the dissemination of unique ideas in various fields such as science, art, and technology. Augmented reality applications, along with other emerging technologies, can play a significant role in facilitating this process by providing dynamic and up-to-date educational experiences that reflect the latest advancements in these fields. By incorporating augmented reality into educational practices, students can engage with cutting-edge ideas and explore concepts in a hands-on and interactive manner during the physics learning as shown in Figure 1.

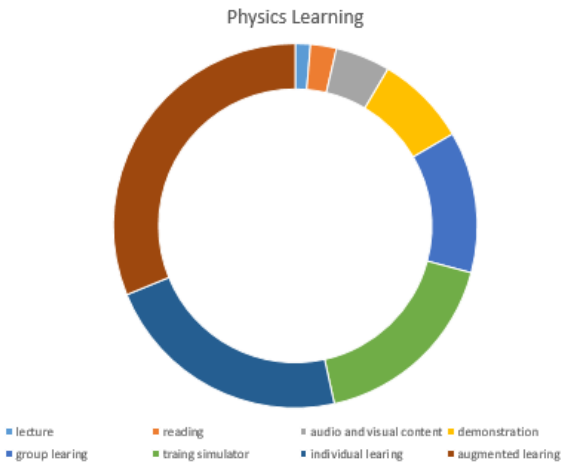

Figure 1. The effectiveness of the main teaching methods.

This not only helps them develop a deeper understanding of the subject matter but also cultivates critical thinking, problem-solving skills, and creativity. The integration of augmented reality applications in education, along with the concept of game-based learning, offers a promising approach to address the challenges of knowledge obsolescence and keep students well-equipped for the demands of the future. By combining education and entertainment, these technologies have the potential to revolutionize the learning experience and prepare students for the ever-changing landscape of knowledge and innovation.In addition, since the staff is changing, the approaches to its experiments should also change (Höllerer, 2004). According to study, students are now interested in increasing augmented learning. Augmented reality application are able to achieve these requirements to the fullest. Today augmented reality is not only for gamers, but also for students. All this brings us closer to expanding our capabilities in the augmented world. Augmented reality is relatively new concepts, which was invented in 1950s; however, they began to be mainstream only ten years ago. Nowadays augmented reality technologies immediately began to be used in student educational activities. For example, augmented reality application are developing at a tremendous pace for education from studying to teaching (Kaufmann, 2003).

Augmented reality application have many following advantages:

1. Ability to create any environment for students that is as close as possible to real conditions;
2. Ability of dividing a complex algorithm of action into simple stages for their consistent development with a gradual complication of studying conditions;
3. Ability to see any design from the inside;
4. Ability to show all processes from mechanics to the interaction of substances literally at the atomic level;
5. Ability of an immediate objective assessment of the quality of the experiment, fixing the mistakes made, simultaneously demonstrating the correct actions and the exercise until students fully understand the lab experiment;
6. Ability of learning in a semi-game form naturally attracts the attention of the student;
7. Ability of learning in emergency situations; complete safety of experiments, providing the student with the opportunity to independently make decisions and act in critical and emergency situations;
8. Ability to immerse of the student in the process;
9. Ability to interact with the subject of physics laboratory experiments using the position of the head and the controller located in the hand.

Augmented reality applications are already being used in education in order to improve their efficiency and quality. Demonstrating that digestibility and memorability of data is better than during the traditional experiments with student by teacher. It is not in the form of monitoring, but in tutoring, which implies complete control and direction of the student's actions. In traditional learning, it is impossible to organize in large classes with a large number of students. In contrary, the learning process is almost completely automated with the help of augmented reality application, while the effectiveness of physics laboratory experiments remains at a high level. During the research, I discover that:

1. The use of augmented reality develops emotional intelligence, since visual effects and animations in augmented reality allow you to evoke a greater empathic response than watching experiment.
2. The use of augmented reality technologies reduces the level of anxiety and negative self-esteem during experiments. The study confirmed a 31% reduction in anxiety in experiments augmented reality teacher compared to an 11.7% reduction in traditional physics laboratory experiments.
3. Augmented reality application shows a higher testing ability compared to the traditional paper test and surveys.
4. Augmented reality is effective in laboratory experiments to compare with manual of experiments. Because of the study, it turned out that augmented reality is more effective for gaining knowledge than textual materials. Students using augmented reality showed results above 33%. 95% of teachers who participated in augmented reality physics laboratory experiments would prefer to continue using the technology.

The ideal physics laboratory experiments, which show maximum efficiency, turned out to be a combination of two types of learning. Augmented reality and methodological materials in such a sequence that the student is learned first methodology and then augmented reality. Most likely this is due to immersion in the situation at the first stage. The student is included in what is happening and analyses everything with examples, and then consolidates knowledge. The result of such a mixed learning format, where a rigorous theory in a laboratory experiments manual is accompanied by impressions in augmented reality. These studies perfectly demonstrate the effectiveness of the use of augmented reality application in laboratory experiments as shown in Figure 2. By setting goals correctly, building a competent testing structure and design, and carefully analysing the results, I finally create an ideal mobile application that would meet the specifics of an augmented reality for physics laboratory experiments.

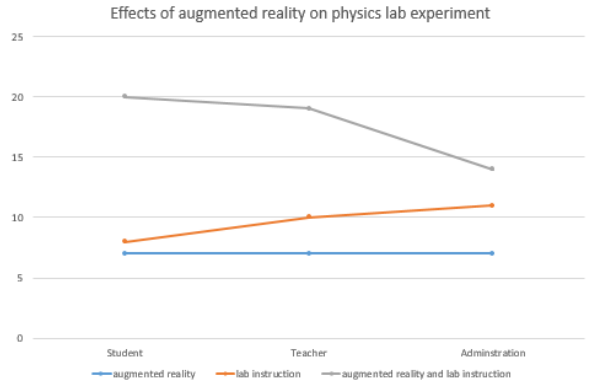

Figure 2. The effectiveness of the three types of teaching styles.

The augmented reality application is a beautiful unique product, the development of which requires a lot of app developers, time and financial resources; therefore, the use of augmented reality is not common in high schools. To spread the use of augmented reality in high schools, it is necessary to learn how to create application. Most teachers in high school use game engines to create laboratory environment for augmented reality. Their significant disadvantage for use in laboratory experiment is the difficulty of converting 3D models to augmented reality. To add 3D models of tool to the physics laboratory, it is necessary to perform the procedure of texturing and optimizing the model in order to ease the cost of drawing in augmented reality. These procedures are similar in time and cost to creating a new copy of the model. However, in there is a platform for creating augmented reality concept, which supports loading 3D models. Augmented reality concept provides a wide range of tools to experiment with virtual prototype at all stages of its development from visualizing an experimental idea to conducting augmented tests and making changes at the design stage.

The main advantages of augmented reality concept are the following:
- The presence of its own engine, the algorithms of which can reduce the requirements for resource performance, which makes it possible to experiment in augmented reality on average computers.
- Seamless integration, which manifests itself in the ability to load 3D models into augmented reality without pre-processing.
- Simple and intuitive interface makes it possible to quickly start without programming skills

Experiment has developed a prototype of the application, outlined the general steps for creating a mobile application in augmented reality. For the development of a mobile application for any type of laboratory, the same steps can be distinguished. Methodology of the same steps allows you to create a pipeline development prototype, in which the templates that need to be configured are defined. The sequence of the same elements is developed in advance. Modules have been developed the functionality of supporting various types of prompts for physics laboratory and general scenario for teaching the process of experiments on laboratory. This approach allows mass creation of application with similar functionality for different types of lab equipment.

An approach involving the use of the augmented reality concept platform to develop a lab mobile application with augmented reality involves the following steps:
1. Collection of information about the mobile application object, obtaining a technological map for regulatory documentation, 3D models of experiment.
2. Creation of an experiment tested scenario, which includes a sequence of steps that must be performed to simulate equipment.
3. Loading 3D models of experiment and auxiliary elements into the scene of the augmented reality concept editor.
4. Setting up the scene in the augmented reality concept editor.
In the process of creating a lab, the initial data on the sequence of lab is converted from one format to another. At the first stage, unstructured data is present, such as repair worksheets, process records.

At the third stage, an instruction for testing the experiment is formed in the form in which it is loaded into the mobile application program. The augmented reality mobile application accepts file as input, consisting of an array of elementary instructions. The main advantage of developing augmented reality application for lab experiment with augmented reality concept environment using universal modules is that the creation of a mobile application does not require knowledge of programming languages and experience with visualization engines. Mobile application development consists of setting up a physics laboratory scene in a graphics editor and creating mobile application instruction files using a desktop application.

3. RESULTS

To create application using augmented reality technology requires software modules that develop common functions. To use the technology, a system has been developed, the conceptual architecture of which is shown in Figure 3. Two independent subsystems can be distinguished in the system being developed. The first subsystem is a program for launching and operating an augmented reality mobile application for lab.
Namely, this program develops a general algorithm for the scenario of physics laboratory experiments in which includes processing student actions in augmented reality, launching the necessary prompts, and moving elements.

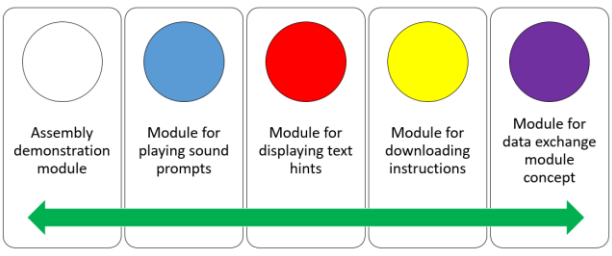

Figure 3. Logical modules for augmented reality application.

When the program is launched, configuration files are loaded with a description of the prompts, with a sequence of experiments for assembling the lab. If the files are successfully uploaded, the student can start using the augmented reality simulation lab. The core of augmented reality concept regularly sends a packet with the states of the levers responsible for triggering hints. The second subsystem is a program for creating configuration files for running the mobile application and disassembly instructions. To develop the modules, the C++ programming language was chosen, which is used in the core of augmented reality concept as shown in Figure 3**.** To create an augmented reality application, the cross-platform framework chosen, which provides classes for creating custom graphical interfaces. The advantage of the technology for the rapid creation of application in the augmented reality concept environment is that a student does not need to know programming languages. Algorithms for managing prompts are developed to use them for a specific type of equipment. To facilitate the creation of configuration files, generation of files using on-screen forms is used. Thus, to create effects, animation in the field of programming and experimenting augmented environments is not required. The author has developed a prototype of a high-performance technology for the development of augmented reality application. As initial data for the development of the simulator, the drawings of the pump, a set of technological documentation for repair, and design 3D models of the lab were received from the teacher.

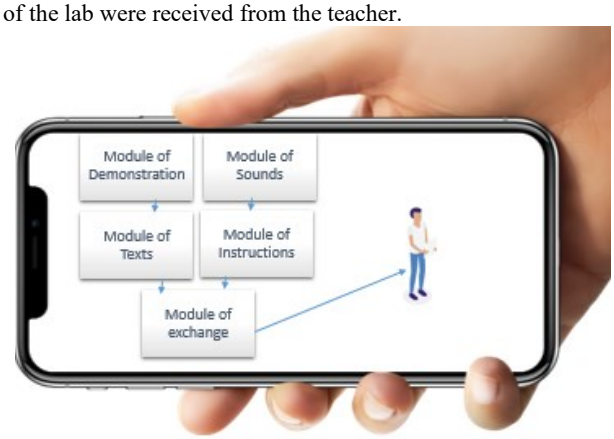

Figure 4. Application design algorithm.

The paper considers a simplified version of the lab, the degree of detail of which elements is reduced, only the key elements of the lab are presented in Figure 4. The creation of a physics laboratory application for lab assembly was carried out in accordance with the proposed rapid development technology in the concept augmented reality environment. The first stage of mobile application development is the preparation of initial data for the subsequent creation of a physics laboratory experiment in the augmented reality concept editor. At this stage, the analyst, based on the data from the technological documentation for the repair, prepared a detailed scenario for lab. In the scenario, the element numbers correspond to the designations in the drawings. The received detailed disassembly scenario and the transferred 3D models of the equipment served as the source materials for creating an augmented reality application in this final qualifying work. Based on the disassembly scenario, reference materials were prepared. Audio files were recorded with a description of the stages and sounding of elementary experiments, graphic tips were compiled, including pump drawings and a disassembly scenario. Objects for managing hints were also selected. After preparing reference materials, the augmented reality concept physics laboratory experiment was created. Models of the pump, hint control levers, a slider for changing stages and text hints were added to the physics laboratory experiment. The required properties have been added to the objects. For effective physics laboratory, a phased demonstration of the assembly of the pump and direct actions on the elements of the student's equipment are separately developed. The student can watch a demo of assembly for each individual step with stops and repeats, listen to audio prompts, read reference materials, and perform disassembly on their own.

In addition to the student, teacher can observe the physics laboratory experiments process. Observation can be external, where teachers watch a display of what the student sees in augmented reality. In addition, teachers can connect to the physics experiment from another computer using the shared access mode. To do this, they must have augmented reality application. Observers see the entire physics laboratory experiments scene. They can communicate with the student and interact with objects in the scene without restriction. The focus is on creating an immersive and interactive experience for students, allowing them to assemble and disassemble laboratory equipment in a virtual environment. The development process follows a rapid development technology, and the initial stage involves preparing the necessary data for creating the laboratory experiment. The analyst utilizes technological documentation for the equipment repair to create a detailed scenario for the lab. This scenario includes references to specific elements and their corresponding numbers in the equipment drawings. Additionally, 3D models of the equipment are transferred to serve as source materials for the augmented reality application. To enhance the learning experience, reference materials are prepared based on the disassembly scenario. These materials consist of audio files describing the stages of the experiment and elementary experiments, as well as graphic tips such as pump drawings and the disassembly scenario itself. Objects for managing hints, such as control levers and a slider for changing stages, are also included. The augmented reality physics laboratory experiment is created by incorporating the 3D models of the equipment, hint control levers, slider, and text hints. Properties relevant to the objects are added to ensure effective functionality. The experiment allows for a step-by-step demonstration of the assembly process, including stops and repeats. Students can listen to audio prompts, read reference materials, and perform the disassembly on their own. In addition to the student's perspective, the teacher has the ability to observe the physics laboratory experiments. The teacher can choose between an external observation mode, where they view a display of what the student sees in augmented reality, or a shared access mode, where they connect to the physics experiment from another computer using the augmented reality application. In both modes, the teacher has a comprehensive view of the entire physics laboratory scene and can interact with objects and communicate with the student without any limitations. The development of an augmented reality physics laboratory application provides an immersive and interactive learning experience for students, with the added benefit of teacher observation and interaction.

4. CONCLUSIONS

An analysis of technological development of education needs that many augmented reality applications will be in demand, since augmented reality allows to students to learn to experiment with physics laboratory by applying visualization. The main agenda in the development of modern augmented reality application is the time consuming and costly process of creating mobile application. This article proposes a technology for creating inexpensive, but genuine application for the physics lessons. The

augmented reality concept tool was chosen to develop the technology in physics lessons. The developed technology makes it possible to facilitate and speed up the process of creating a mobile application. The evaluation of a generalized scenario of the learning process and prepared functions for processing hints allows to create an mobile application only by setting up a physics laboratory experiment in the augmented reality concept editor and configuration files that contain information about the types of hints used and their indices. The authors not only invented a theoretical technology, but also tested practical examples of creating application in augmented reality. Thus, a display of the physical world in augmented reality was created with 3D models correspond to the physical objects. In this case, students can learn how to experiment with this lab experiments, detailing to the smallest disassembly elements of experiment. When immersed in augmented reality, the student develops skills in working with laboratory experiments similar to the skills formed during physics laboratory experiments on real physics lab equipment. This is achieved due to the correspondence of virtual models to real physical objects, the possibility of moving equipment parts only according to scenarios that are feasible in real life, the possibility of sound accompaniment of the interaction of objects with each other. It is possible to develop program blocks that are responsible for capturing data during physics experiments. In automatic mode, it is possible to obtain the time spent on completing the physics laboratory experiments course. Subsequent analysis of the types of errors will allow you to adjust the learning process for each student, which will increase the effectiveness of physics laboratory experiments. Further development of the technology for the rapid development of augmented reality application is associated with the inclusion of modules for logging student actions for subsequent student assessment, analysis of the learning process, and mistakes made. It is also possible to build a physics laboratory experiments system that will include auxiliary applications for maintaining a database of student who have completed physics laboratory experiments.

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