Augmented Reality in Training Engineering Students: Teaching Methods

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Abstract. *The research aim*. The research is intended to theoretically substantiate, develop and test methods of applying augmented reality to training future engineers. *The research tasks* include adaptation of augmented reality tools to apply them to laboratory classes while training future engineers; visualization of theoretical models of physical phenomena and processes using augmented reality tools; theoretical substantiation and development of methods of applying augmented reality to training future engineers. *The research object* is training future engineers at engineering universities. *The research subject* is methods of applying augmented reality to training future engineers. *The research results* are the following. There are analyzed national and foreign researches into issues of applying augmented reality to training future engineers at engineering universities. The augmented reality tools (HP Reveal) is adapted to be used in laboratory classes in physics while training future engineers. There are created augmented reality objects in the form of educational videos in which the structure of laboratory machines and procedures of working with them are explained. Methods of applying augmented reality to training future engineers at engineering universities are developed.

Keywords: Augmented Reality, Training of Future Engineers, Laboratory Works.

1 Introduction

1.1 Problem statement

Training of future engineers at engineering universities is aimed at forming a competent specialist capable of working under conditions of escalating information flows. Successful solution of this task depends on a student's acquired skills to find, process, understand and use information. Sometimes, students find it difficult to comprehend scientific notions and laws as, in case of traditional training techniques, this material is presented in an abstract form which is difficult to understand. It results into theoretical models not consistent with real-life phenomena and processes.

The augmented reality (AR) technology is one of the modern training means reflecting theoretical notions through visual 2D/3D objects, thus facilitating understanding of abstract notions and models by students.

1.2 Analysis of the latest researches

The authors [9; 15] use augmented reality as a means of arranging students' group and solo work while studying electric machines. This provides an opportunity of arranging interactive training and performing laboratory works without a teacher's assistance. AR tools presented in the research create a link between theoretical material and laboratory works. In designing installations and machines, application of AR tools makes students' training motivating and comfortable as they are available and easy to use.

In [13], D. N. Phon, M. B. Ali and N. D. Halim treat augmented reality as a new technology applicable to implementation of innovative teaching-learning methods. Application of AR methods enhances educational results, yet the principle driver implies treating AR design as a support of the training activity. The researchers [16; 18] think that AR provides new opportunities of developing the training environment that enables students to interact with each other and the training content at the same time. It causes deeper comprehension of educational information and enhances students' motivation.

C. Onime, O. Abiona shows a conceptual reality-virtuality relationship between hands-on, remote and virtual laboratories. The hands-on physical laboratories would be at the Realism end, remote laboratories are in the mixed reality zone and virtual laboratories are at the other extreme. Without any visible view of the apparatus, the user interfaces of most remote laboratories are typically computer-generated environments with the insertion of real data taken from the remote apparatus, which is consistent with an augmented virtuality environment [10, p. 70].

In [11], there are developed methods of training future engineers using AR technologies to present educational materials on engineering subjects for theoretical and laboratory training in an interactive form. The authors' goal is to reduce expenditures by introducing AR technologies while conducting an experiment.

The recent researches into augmented, virtual (VR) and mixed realities developed by the world's largest electronics producers were presented at the conference [5]. Both researchers and practitioners were able to improve their skills of mastering up-to-date AR and VR technologies during courses and seminars conducted at the conference.

A. Striuk, M. Rassovytska and S. Shokaliuk substantiated efficiency of applying the AR app Blipper to professional and practical training of future engineers [17]. In [20], we developed theoretical and methodological foundations of AR application to training students with specific educational needs. Ukrainian researchers developed some components of the training and methodological complex for designing VR an AR systems for future Informatics teachers.

However, currently, there are some issues understudied in Ukraine, namely: adaptation of AR tools to be used in laboratory classes while training future engineers; provision of visualization of theoretical models of physical phenomena and processes by modern ICT tools; application of AR technology to forming future engineers'

competences.

1.3 Research aim

The research is aimed at theoretical substantiation, development and experimental examination of the methods of applying AR to training future engineers.

2 Main material presentation

2.1 Using ICT in laboratory works

The present-day educational system emphasizes training which results in acquired knowledge and skills necessary for professional and research activity. Engineering universities focus their attention on developing research competences in laboratory classes. These classes are noted for application of specific tools and devices requiring mastering specific knowledge and skills by students [21]. A laboratory class that envisages a student's independent experimenting is much more significant in its scale than any other form of class organization as it boosts research competences required for his/her further engineering career.

Ya. Ya. Boliubash distinguishes the following stages in the structure of modern laboratory classes: 1) conducting initial control of students' preparedness to perform a laboratory work; 2) doing relative training tasks; 3) preparing an individual report; 4) teachers' assessing students' work results [4]. In laboratory classes, students follow the instruction that can be considered a basic information source. According to Yu. O. Zhuk, this puts forward some requirements to the content and structure of an instruction. The researcher indicates that the description that is too detailed splits students' attention and makes them master too much information that can cause some errors and inefficient use of the training time [22].

First-year students' questioning conducted by the research author [12] reveals that most students have difficulties during laboratory classes including: 1) inability to apply theoretical knowledge to solving definite experimental problems; 2) underdeveloped skills of experimenting; 3) inability to substantiate experiment results by means of available theoretical knowledge; 4) failure to understand professional direction of the work to be done; 5) difficulties associated with reproduction of the material mastered independently; 6) students' reluctance while performing a work; 7) absence of a teacher's due control of laboratory work results.

Application of modern information technologies can be one of solutions of described problems [1; 3; 14]. The experience described in [22] indicates that visualization of information by ICT tools greatly enhances its perception. To ensure motivation of the training activity and make a laboratory class effective, we use the AR technology.

R.T. Azuma defines augmented reality as a system combining virtual objects and reality, interacting on-line and operating in 3D. AR cannot create an entirely virtual environment, yet, it involves both virtual and real-world elements by adding virtual objects changed as a result of a user's actions to his/her surroundings [2]. Thus, AR

provides a modern solution of the problem of encouraging future engineers to conduct their own researches and experiments.

2.2 Methods of using augmented reality in laboratory classes

While elaborating methods of applying augmented reality to training future engineers, we analyzed a set of software tools of training support which are widely used as educational sources, namely: Amazon Sumerian, AR Flashcards Space Lite, AR-3D Science, Augment, Blippar, Chromville, Elements 4D, HP Reveal, Layar, Magicplan, Quiver, Google Lens. To create AR objects, we chose the HP Reveal platform as the easiest to adapt to educational needs and available [6]. AR objects are treated as a result of adding virtual objects to real-life markers (video instructions to perform laboratory works) that are perceived as real objects. Schematic drawings (schemes) of laboratory machines can be such markers [8] as they enable students to get ready to a laboratory work independently and efficiently.

AR tools are used in laboratory classes according to the BYOD (Bring Your Own Device) approach: students use their own mobile devices to recognize markers. After pointing the camera of a mobile device at the scheme (marker), there appears a video on the screen in which a teacher demonstrates a laboratory machine and its major elements, comments on the experiment conduction and highlights its peculiarities [7]. Thus, AR objects are supplementary to printed instructions. The result is visualized instructions to conduct laboratory works (Fig. 1).

Fig. 1. Visualization of the instruction for the laboratory work "Determination of the liquid tension ratio by the height of its raise in the capillary tube"

The method of applying augmented reality at laboratory classes envisages the following steps: 1) installing the mobile app HP Reveal (Fig. 2); 2) opening and registering (Fig. 3–Fig. 4); 3) searching by the #tag #physicslab (Fig. 5); 4) subsequent to the search results, choosing a laboratory work, for example, mechanics_lab_2_1 (Fig. 6); 5) in the instruction of the laboratory work, finding the scheme – the general view of the laboratory machine. This scheme is a marker identified by the AR tools; 6) when pointing the mobile device at the picture-marker, HP Reveal scans it (Fig. 7). There appears a video in which a teacher shows a laboratory machine, its basic components and comments on conducting the experiment (Fig. 8); 7) watching an educational video, paying attention to the structure of a machine and procedures of working with it; 8) addressing a teacher if any questions arise.

It should be noted that AR application in laboratory physics classes is an efficient method of engaging students into the training process. It is easier for students to understand abstract theoretical models of physical phenomena through their

visualization by using AR tools.

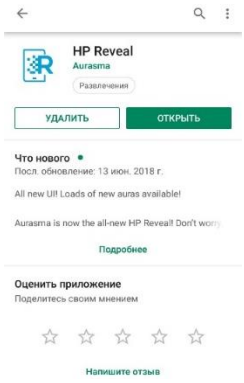

Fig. 2. Install the HP Reveal

Fig. 3. Register the HP Reveal

Fig. 4. Hashtag #physicslab

Fig. 5. Search for mechanics_lab_2_1

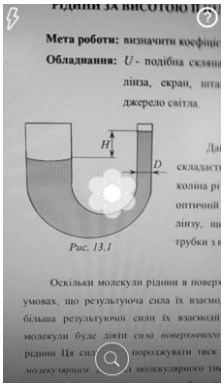

Fig. 6. HP Reveal scans

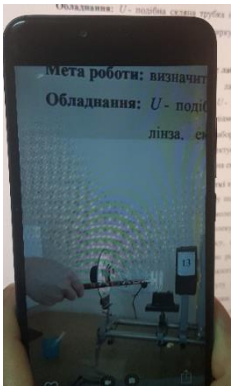

Fig. 7. Educational video

3 Results of experimental examination of the suggested methods

To examine the method, we determine criteria of efficiency of applying augmented reality to training future engineers, their indices and research methods (Table 1).

The pedagogical experiment was conducted at Kryvyi Rih National University during the first term of 2018-2019. First-year students of the speciality Software Engineering were engaged in the experiment comprising 16 students of the experiment group and 17 students of the control group.

The generalized experiment results consistent with the criteria, indices and levels of their formation in the control and experiment groups are given in Fig. 8.

Table 1. Criteria of efficiency of applying augmented reality to training future engineers

Criterion of efficiency of applying augmented reality	Index of efficiency of applying augmented reality	Levels of formation	Research methods
Students' motivation for training activity	Availability of students' desire to study, perform complicated tasks; understanding of significance of studies	High; medium; low	Questionnaire "Motivation for training activity", questionnaire "Augmented reality in laboratory physics classes"
Systematic accomplishment of laboratory works	Timely accomplishment of laboratory works; students' active participation in class	High; medium; low	Results of accomplishment of timely laboratory works
Formation of knowledge and skills	Availability of students' knowledge of the subject; a skill to independently accomplish tasks; objective assessment of students' own results	High; medium; low	Module test in physics

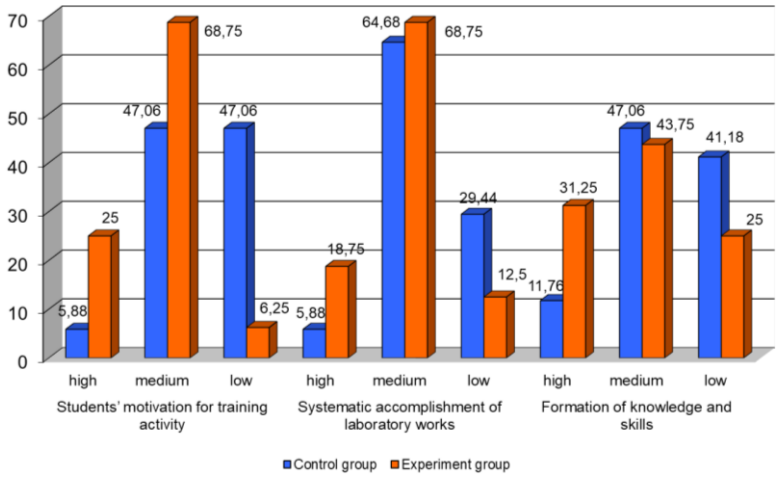

Fig. 8. Generalized results of the experiment

According to the criterion "Students' motivation for training activity", the number of students of the experiment group with high and medium motivation is larger than that of the control group by 40.81%.

The criteria "Systematic accomplishment of laboratory works" and "Formation of knowledge and skills" reveal the number of students of the experiment group with high and medium motivation which is larger than that of the control group by 16%.

After generalizing the results of the pedagogical experiment, we can conclude that the developed methods of applying augmented reality to training future engineers in laboratory classes in physics are quite efficient, especially in terms of raising students' motivation for the training process.

4 Conclusions

While conducting a research into application of augmented reality to training future engineers at engineering universities, we obtained the following results:

1. there are analyzed national and foreign researches into issues of applying augmented reality to training future engineers at engineering universities;
2. the augmented reality tools (HP Reveal) is adapted to be used in laboratory classes in physics while training future engineers and there are created AR objects in the form of educational videos which explain the structure of laboratory machines and procedures of working with them;
3. methods of applying augmented reality to training future engineers at engineering universities are developed;
4. efficiency of the elaborated methods is examined by experiment and proven.

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