Using augmented reality in university education for future IT specialists: educational process and student research work

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Abstract

The article substantiates the feature of using augmented reality (AR) in university training of future IT specialists in the learning process and in the research work of students. The survey of university teachers analyzed the most popular AR applications for training future IT specialists (AR Ruler, AR Physics, Nicola Tesla, Arloon Geometry, AR Geometry, GeoGebra 3D Graphing Calculator, etc.), disclose the main advantages of the applications. The methodological basis for the implementation of future IT specialists research activities towards the development and use of AR applications is substantiated. The content of the activities of the student's scientific club "Informatics studios" of Borys Grinchenko Kyiv University is developed. Students as part of the scientific club activity updated the mobile application, and the model bank corresponding to the topics: "Polyhedrons" for 11th grade, as well as "Functions, their properties and graphs" for 10th grade. The expediency of using software tools to develop a mobile application (Android Studio, SDK, NDK, QR Generator, FTDS Dev, Google Sceneform, Poly) is substantiated. The content of the stages of development of a mobile application is presented. As a result of a survey of students and pupils the positive impact of AR on the learning process is established.

Keywords

augmented reality, mobile application, university training of students, IT specialists

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1. Introduction

The introduction of modern virtual learning tools into the university training of students is the most important condition for enhancing the learning effect, which lies in the interactivity of 3D modeling and using the effect of augmented reality. Having a set of paper markers, it is possible to represent a learning object not only in volume, but also to do a number of manipulations with it, to look at it from different angles. The use of augmented reality is an important condition for the implementation of the modern educational process for students of any specialty. But AR becomes especially important for future IT specialists, who have not only to use, but also to develop AR tools in future professional activities. The relevance of implementing augmented reality technology in the educational process lies in the fact that the use of this innovative teaching tool increases students' motivation, increases the level of information assimilation by synthesizing different forms of its presentation [1].

The use of AR seems to be especially significant in distance learning conditions, which is confirmed by numerous feedback from university teachers during the year 2020 [2, 3, 4, 5, 6]. According to researches [7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23], the advantages of AR are visualization, information completeness, interactivity, which allows to develop students' imaginative thinking and spatial imagination, maintain interest in the learning process. At the same time, there are still insufficiently developed methods for building the learning process using AR, which opens the way to further scientific research.

Theoretical and practical aspects of using AR in the educational process are covered in numerous studies. Akçayır and Akçayır [24] submitted advantages and challenges associated with augmented reality for education. In particular, it has been established that the most reported advantage of AR is that it promotes enhanced learning achievement. Some noted challenges imposed by AR are usability issues and frequent technical problems. We found several other challenges and numerous advantages of AR usage, which are discussed in detail. In addition, current gaps in AR research and needs in the field are identified, and suggestions are offered for future research. Martín-Gutiérrez et al. [25] disclose virtual technologies trends in education. Among them are the following: educational institutions will benefit from better accessibility to virtual technologies; this will make it possible to teach in virtual environments that are impossible to visualize in physical classrooms, like accessing into virtual laboratories, visualizing machines, industrial plants, or even medical scenarios. The huge possibilities of accessible virtual technologies will make it possible to break the boundaries of formal education. Ibáñez and Delgado-Kloos [26] presented a systematic review of the literature on the use of augmented reality technology to support science, technology, engineering and mathematics (STEM) learning.

We consider the perspectives of AR methodological research to be interesting, as researchers need to design features that allow students to acquire basic competences related with STEM disciplines, and future applications need to include metacognitive scaffolding and experimental support for inquiry-based learning activities. Finally, it would be useful to explore how augmented reality learning activities can be part of blended instructional strategies such as the flipped classroom. Syrovatskyi et al. [27] presented the software for the design of augmented reality tools for educational purposes is characterized and the technological requirements for the optional course "Development of virtual and augmented reality software" are defined .

The papers [28, 29, 30] present some theoretical and practical aspects of using augmented reality in the process of professional training of future IT specialists as well as future computer science teachers at the level of leading trends, approaches, principles, conditions, and technologies. Besides, our previous work proves that in the field of physical processes modeling, the Proteus physics lab serves as a popular example of augmented reality. Using Proteus environment allows to visualize the work of functional units of computational system on microlevel. This is especially important for programming resource-limited systems, such as microcontrollers in the process of training future IT professionals [31].

Noteworthy are scientific studies on the use of various aspects of AR in the process of learning mathematics, considering that it is the mathematical training that is basic to the training of future IT specialists: Sollervall and Milrad [32] – implementation of mobile learning in mathematics, Chang et al. [33] – the use of game techniques in teaching mathematics, Bhagat and Chang [34], Kramarenko et al. [35] – application of GeoGebra for teaching geometry, etc. It's worth noting that in many scientific papers the authors analyze the possibilities of both VR and AR for the educational process. We believe that such a comprehensive analysis makes sense, because many modern methods of teaching students combine these technologies.

The *aim of the study* is to reveal the possibilities of AR for the implementation of training and research work of future IT specialists in the university.

In the process of research methods were used: analysis of scientific and pedagogical literature on the selection of theoretical and methodological foundations for the use of augmented reality in the learning process at the university, development of the content of scientific student circle activity; study and synthesis of teaching experience on the use of AR in the educational process; pedagogical experiment to bring the effectiveness of the AR mobile application in the learning process, highlighting by teachers the most popular AR applications, their advantages; methods of mathematical statistics.

2. Results and discussion

Augmented reality is a relatively new technology, gaining popularity in the educational process primarily because of its accessibility and inexpensiveness. To see augmented reality, you need a computer webcam or mobile device camera (smartphone, tablet, AR glasses) and a special application that superimposes digital information (3D models, video, audio, texts) on the real world image from the camera and displays the result on the screen. Using AR you can "animate" almost any educational materials – illustrations in books, diagrams, maps, drawings, create educational projects, explaining the phenomena, the demonstration of which for various reasons is difficult to organize in the classroom (due to lack of equipment, the inability to show in real life, the danger to health, etc.). Different visualization tools are used for different smartphones, for example, for Android – sfb, mtl, obj, fbx fsa extensions, for iOS – sfb, mtl, obj. Today, the technology has four basic techniques:

1. Marker-based – binding to a given element.
2. Markerless – free positioning.
3. Location-based – reading markers and geopositioning.
4. Based on the layer overlay – selecting a model from the device to display [36].

Technologically, the introduction of augmented reality into the learning process is uncomplicated. For example, when pointing the cameras of mobile devices at various objects, corresponding text explanations, photos, video files or a complex of text information and video series appear on the screen. Learning applications with augmented reality are proposed to be built according to the following scheme:

- the use of special tags;
- reading tags by computer or mobile device;
- playback the layer with additional information on the screen.

Our own experience in using augmented reality in the professional training of students allows us to highlight requirements for the use of AR through a mobile device:

- AR mode should be able to be switched off, with the option to switch to normal mode, where any "blank" background or a static 3D scene replaces the environment, and the content is positioned so that it is more convenient to view from the device.
- The text should be displayed on a backing that provides a contrasting and easy-to-read output. Long text should be scrollable.
- The photo gallery should be displayed on a substrate that provides an easy-to-view output and have transition elements to the next/previous photo.
- The audio recording should play through the audio system of the device and visually display the playback control panel with the ability to pause/resume audio playback as well as navigate to an arbitrary recording location.
- The video should play back with sound (if any) on a backing that provides its easy-to-view output and have a playback control panel with the ability to pause/resume the video as well as navigate to an arbitrary recording location.
- The 3D scene is initially prepared by the performer for correct display in AR mode and may have its own individual controls depending on the scenario.

There are different directions of AR research. The first direction is associated with the study of virtual (VR) and augmented reality (AR) technologies as a trend in the information technology industry, the basics of creating applications. The second direction is the pedagogical design of learning tools based on virtual and augmented reality technologies. The third is the definition and experimental verification of organizational and pedagogical conditions and techniques for the effective use of AR in the educational process [36].

Today, augmented reality technology is still developing, but it already has a number of applications, including for education. In October, November 2020 we conducted a survey among teachers at the Boris Grinchenko Kyiv University, the Sumy State Pedagogical University named after A. S. Makarenko, the Alfred Nobel University (Dnipro) and the Pavlo Tychyna Uman State Pedagogical University. A total of 48 teachers were interviewed, they are from physics and mathematics and computer science disciplines and have experience using AR in the educational process. As a result of the survey, the most popular AR applications were highlighted, which allowed to present their main advantages for the educational process.

1. *AR Ruler.* One of the easiest ideas to use augmented reality technology is measurement. Using AR's ability to determine where three-dimensional objects begin and end, you can

measure the distance and easily display it. However, we are not just talking about simple direct measurements - the AR Ruler (aka AR ruler) also measures angles, volume, area, perimeter, etc. AR Ruler is a useful enough application to get approximate measurements when they are needed. According to the teachers, the add-on is most often used in the lessons of Analytical Geometry, Projective Geometry, and Image Methods.

2. *AR Physics (CG)*. The educational complex gives you the opportunity to learn about physical processes and phenomena. It includes more than 50 visual experiments on 9 sections of general physics. The complex allows: to conduct visual 3D demonstrations of physical processes and phenomena without the use of regular laboratory equipment; to organize students' independent work, etc. In the opinion of teachers, the addition has the following advantages: high detail structure and properties of the studied objects; deep immersion of students in the environment of the experiments; the possibility of experiments without laboratory equipment; the possibility of dangerous experiments without risk to life and health; direct user interaction with the virtual objects by augmented reality.
3. *AR Physics*. This app has a game style and full interaction with the learner. In the app it is possible to add various elements, conduct experiments, and monitor real processes. The app is available in different languages with introductory text, voiceover and animated models. It is used in the study of general physics. The application makes it possible to implement inquiry-based learning, provides interaction between teachers and students.
4. *Nicola Tesla*. The app provides access to products with embedded interactive content that comes to life when viewed through a mobile device. Features of the Nikola Tesla AR app include: virtual simulations, including a demonstration of how electricity flows through a Tesla winding, etc. The program promotes a better understanding of the subject and develops imagination and abstract thinking.
5. *Arloon Geometry*. Augmented reality app for learning geometry. Available 3D models with formulas for calculations, unfolding of figures, textual theoretical information. The add-on allows you to calculate the density of shapes, the volume of bodies (cube, cylinder, sphere, pyramid, cone, etc.). The program gives a sense of reality and practical experience, visualizes complex relationships, and concretizes abstract concepts.
6. *AR Geometry*. App with the use of augmented reality technology to the geometry textbook for grades 10-11. Used in classes on methods of teaching mathematics.
7. GeoGebra 3D Graphing Calculator. The application allows you to solve mathematical problems in 3D, build graphs of 3D functions and surfaces, create geometric constructions (bodies, spheres) in 3D, find their sections, store and distribute the results. Use when organizing classes in algebra, mathematical analysis, and analytic geometry.
8. *AR applications for elementary mathematics (AR MATH, Math Worlds AR, Math-O-Matic AR, Math Jumps: Math Games, Math Wiki - Learn Math)* for use in mathematics teaching methods classes.

There are still a significant number of well-known applications: *ModumLab*, *PhysicsPlayground*, *Algorithms: comprehensible and animated*, etc. At the same time, they were not recalled by the experts, opens the possibility of systematization and classification of available AR applications for use in the process of professional training of students.

As a result of the survey of respondents, we highlight the advantages of using AR in the educational process. These advantages are basic in the implementation of professional training of future IT specialists:

1. **Better explanation of complex and abstract concepts**. Practice shows that students understand theoretical concepts better when they can visualize them. This is especially true for complex topics with the use of visual three-dimensional models.
2. **Increased student engagement**. AR provides a playful approach to learning, which makes the class more emotional than a traditional class.
3. **No additional tools are required**, as most modern students have smartphones.
4. **Practice-oriented classes**. Students can perform practical exercises without the need for laboratory equipment.
5. **Accessible learning**. With AR applications, users can learn anytime and anywhere, which is important in a distance learning environment.

In our previous work [36] we solved the problem – the development of an AR application in mathematics in the process of research activities of the students of the specialty "Computer Science" of the Borys Grinchenko Kyiv University. The following methodological foundations were the key to the realization of such a task:

- augmented reality in the process of learning mathematics, first of all, helps to visualize mathematical objects (geometric shapes, bodies of function graphs, etc.). It should also be noted that augmented reality in the process of learning mathematics provides such opportunities as moving, rotating, scaling 3D-models, viewing them at any angles, connecting and disconnecting virtual objects and studying the obtained results, and so on;
- students' research work is an obligatory, integral part of professional training at the university. The development of the system of students' research work is the most important function of the educational system and an important statutory activity of the university as an educational institution.

To further ensure the involvement of students in the development of AR applications as part of the research work, we developed the content of the activities of the student's research group (scientific club) "Informatics studios" of the Borys Grinchenko Kyiv University:

Classes 1–4. Technologies of Virtual (VR) and Augmented (AR) Reality in the Educational Process. The essence of virtual and augmented reality technologies, methods of their implementation and areas of application. Operating principles and functionality of AR and VR applications. Classification and comparison of virtual and augmented reality systems. Analysis of practical experience in the use of virtual and augmented reality systems in the educational process. Mixed reality technology.

Classes 5–8. Design technology of educational VR- and AR-applications. Approaches to the design of applications using virtual and augmented reality technologies. Review and analysis of tools for designing the structure of VR- and AR- applications. Comparative characteristics of VR and AR content development tools in browsers.

Classes 9–10. The use of mobile technologies in digital education. The concept of "mobile learning", opportunities and goals for mobile learning. Characteristics and features of mobile learning. Didactic principles of mobile learning.

Classes 11–12. Application of educational VR and AR applications in mobile education. Mobile applications in the work of the modern teacher. The main problems and limitations of mobile learning technology. Analysis of mobile applications used in the educational process. The use of educational VR and AR applications.

The work of the "Informatics studios" group includes the following tasks:

Assignment 1. An introduction to the technical devices of virtual and augmented reality.
Assignment 2. Ways to design the structure of an AR or VR application.
Assignment 3. Functionality of VR application design tools.
Assignment 4. Software tools for designing AR applications.
Assignment 5. Development of educational AR applications and their use in the learning process.
Assignment 6. Designing educational VR content for use in digital education.
Assignment 7. Development of surveys and quizzes by means of mobile applications.
Assignment 8. Creating interactive learning games by means of mobile applications.
Assignment 9. Development of QR code and its use in the educational process.
Assignment 10. Methodological peculiarities of the use of educational VR and AR applications in mobile learning.

As the practice of using AR in the educational process, there are still not sufficiently developed methods of using AR. There is a lack of methodological and didactic literature on the implementation of training with the help of AR technology. In addition, requires the development of AR applications to ensure the objectives of the educational process. We solved the problem of limited didactic means by involving students in the development of their own augmented reality objects using specialized programs. It should be noted that such activity has a pronounced interdisciplinary character, because it contributes to the effective integration of such branches as information technology and mathematics. We developed a mobile application and a bank of models corresponding to the school mathematics course. Two topics were chosen: "Polyhedrons" for 11th grade, as well as "Functions, their properties and graphs" for 10th grade. These programs were tested in classes on the methodology of teaching mathematics. After testing the materials at the 3rd International Workshop on Augmented Reality in Education (AREdu 2020 workshop, https://aredu.ccjournals.eu/aredu2020/), we decided to update the software toolkit in the context of expanding the visual 3D model base and transferring the standard platform to the game engine based on the suggestions made.

To develop the program, we used the following tools:

- Android Studio (integrated development environment for the Android platform), SDK (a set of development tools, utilities and documentation that allows you to create applications using a particular technology or for a particular platform) and NDK (a set of tools that allow you to implement part of the application using languages such as C/C++/C# to port he application to different devices and code optimization);
- QR Generator is an online tool that allows you to generate tags;
- FTDS Dev is a program that allows you to generate a database and 3D models with labels;
- Google Sceneform (ARCore, Sceneform) is a library and framework for rendering 3D models to devices with control;

- Poly is a library of ready-made 3D models from Google integrated for Daydream. The first step was to load the augmented reality library into Android Studio. After that, import the model with a mathematical description into a specially prepared asset folder.

The first step was to load the augmented reality library into Android Studio. After that, import the model with a mathematical description into a specially prepared asset folder (figure 1).

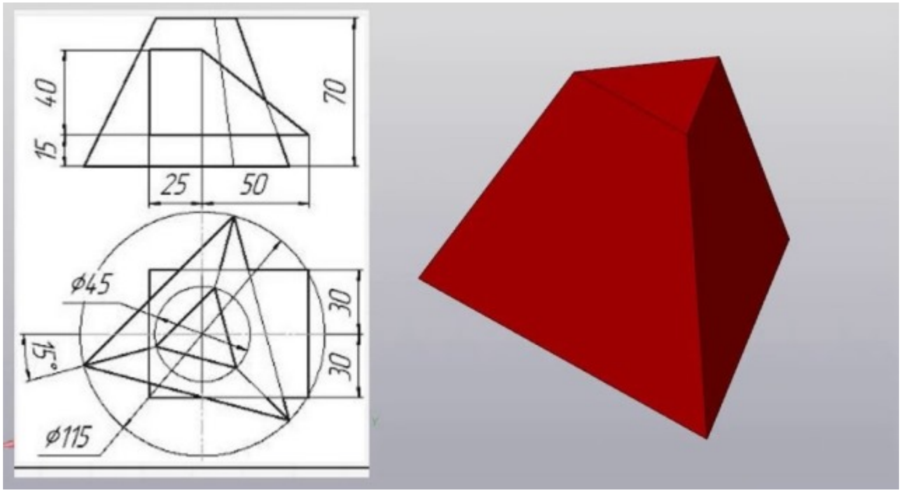

Figure 1: 3D model with parameters.

After generating the processing code, we created a bank of 3D models (figure 2).

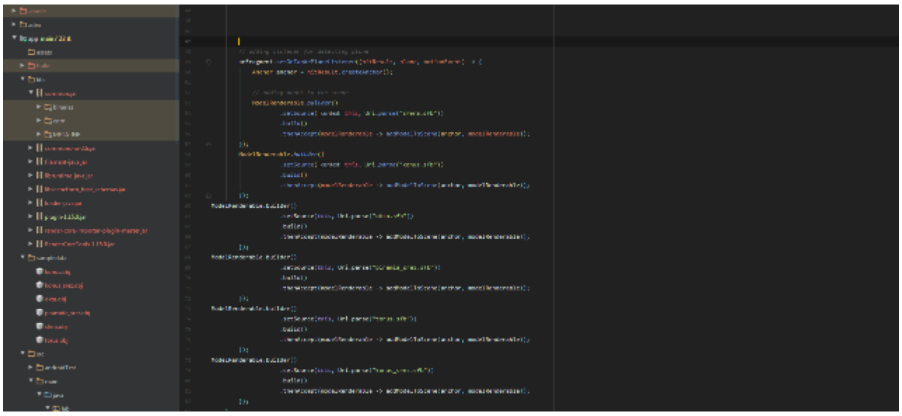

Figure 2: Bank of 3D models with connection without code processing.

The next step was to process the modeling code and render the 3D model. At this stage we created positioning and anchoring to the marker (figure 3).

After compiling the project, we tested it on different devices. Total for 145 Android devices on different OS versions (figure 4).

Smartphone emulation of cone model with parameters in 2D perspective mode without using OpenGL is shown in figure 5.

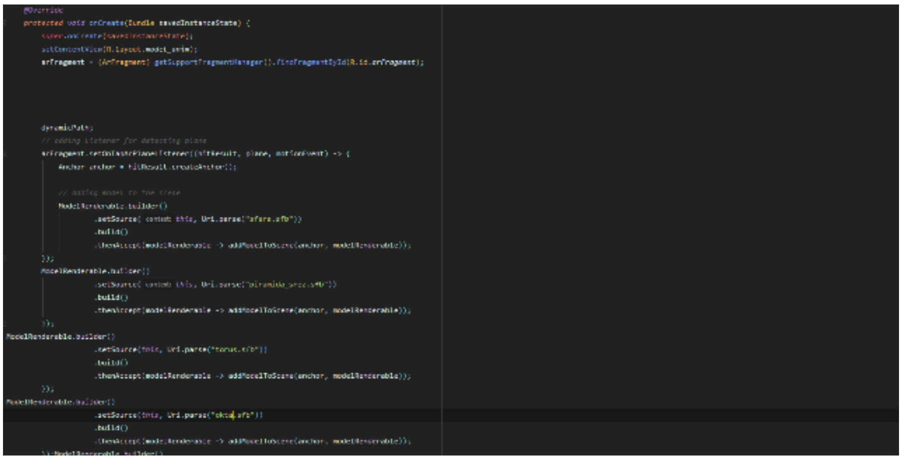

Figure 3: 3D model processing code.

In the February 2021 update, we offered the app to 137 individuals for testing: 50 – 10th grade students, 52 – 11th grade students, and 35 university students. All respondents are students of different schools and programming courses in Kyiv. The results of the survey compared to the results of a similar survey for 2020 (table 1).

Table 1
Results of the survey of AR supplement users

Year	Number of respondents	Convenient to work with the application, the number, (%)	Willingness to learn with AR number, (%)
2020	104	94 (90.4%)	48 (46.2%)
2021	137	126 (90.2%)	71 (50.8%)

As a result of the survey, it was found that 126 people found it convenient to use this addendum, which is 90.2%, this is at the level of last year's figure (in 2020 it was 90.4%). In 2020, we noted that only 46.2% of people were convinced that they would like to do teaching assignments with supplemented reality. This was due to the fact that the vast majority of respondents still do not have experience of using AR in the educational process. This clearly indicates that the problem of organizing the educational process with the help of AR requires scientific and methodological solutions. In 2021, the indicator has increased and will be 50.8%. This increase is due to the fact that in the conditions of distance education teachers began to use AR in the educational process more often.

3. Conclusions

1. The analysis of the main AR techniques (marker-based, markerless, projection based on the overlay layer) and requirements for the use of AR revealed the possibilities of AR for the implementation of training and research work of future IT specialists in the university.

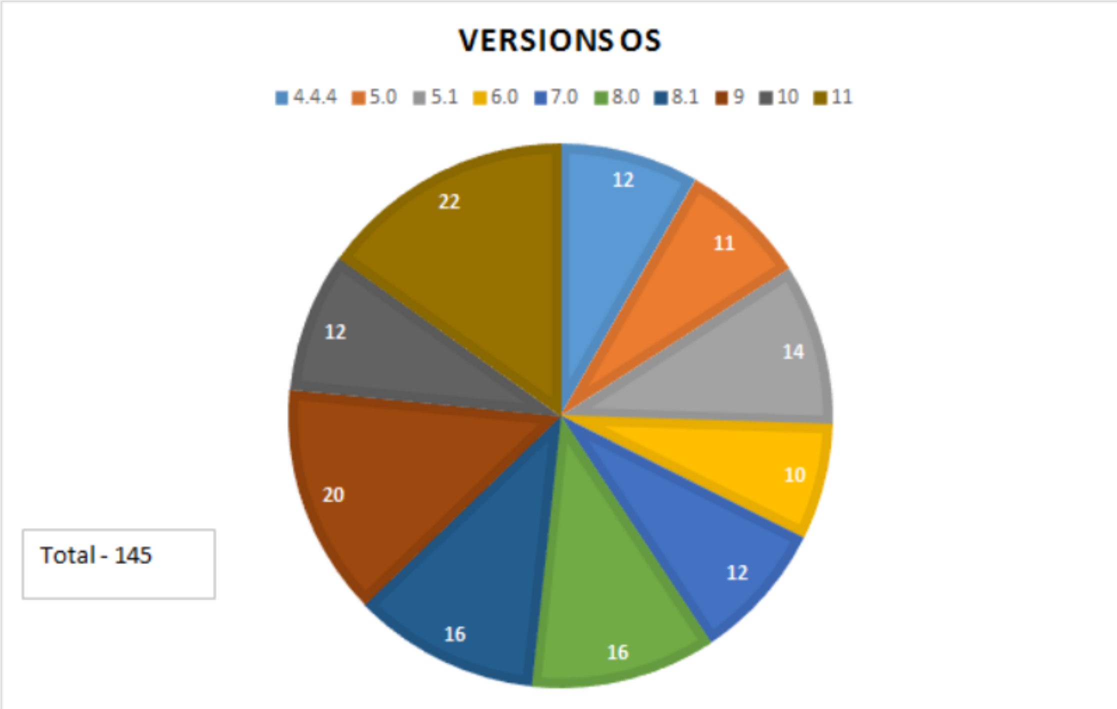

Figure 4: Diagram of the number of tests on the Android OS versions.

Surveys of university teachers allowed to analyze the most popular AR applications for training future IT specialists (AR Ruler, AR Physics, Nicola Tesla, Arloon Geometry, AR Geometry, GeoGebra 3D Graphing Calculator, etc.) And reveal their main advantages (illustration of complex and abstract concepts, accessibility, practice-oriented, increasing student motivation for learning, etc.).

2. To effectively involve future IT specialists in the development of AR applications, the content of the activities of the scientific club "Informatics studios" of the Borys Grinchenko Kyiv University was developed. According to the results of approbation of the previous materials at the the 3rd International Workshop on Augmented Reality in Education (AREdu 2020) within the activity of the scientific circle the students updated the mobile application and model bank corresponding to the topics: "Polyhedrons" for 11th grade, as well as "Functions, their properties and graphs" for 10th grade school mathematics course.
3. The choice of software tools for developing a mobile application (Android Studio, SDK, NDK, QR Generator, FTDS Dev, Google Sceneform, Poly) is justified. The stages of mobile application development (loading the library AR in Android Studio; import models; generation of the processing code; created bank 3D models; processing code modeling and rendering 3D models; positioning and linking to the marker; compilation of the project; testing). As a result of the survey of students and students identified the benefits

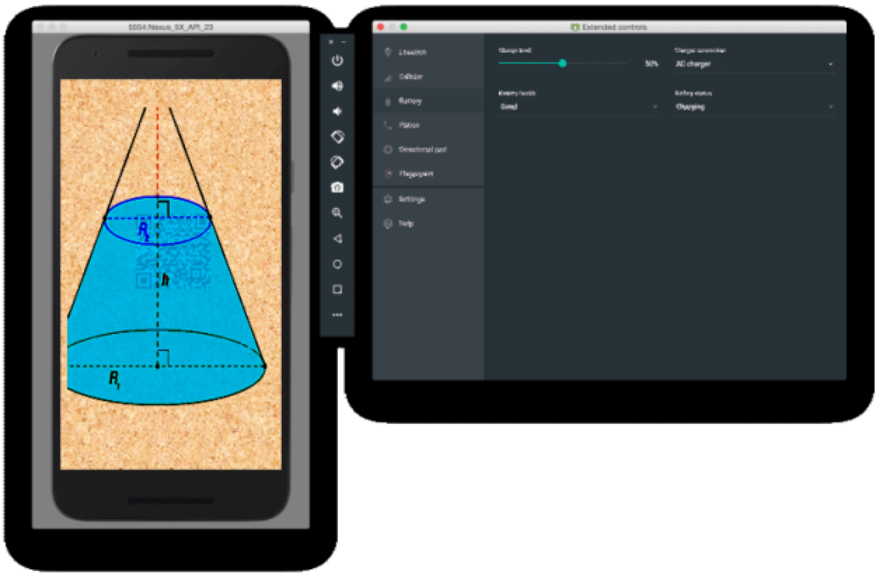

Figure 5: Smartphone emulation.

of using the AR application.

4. Prospects for further research we see in improving the methods of teaching mathematics and computer science disciplines using AR in the process of professional training of future IT specialists.

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