Using augmented reality for early literacy

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Abstract

Currently, augmented reality is one of the most actively developing technologies, which has also found its application in the field of education. Analysis of various publications has confirmed that AR technology opens up new opportunities for teachers and increases the attractiveness of learning for students of different ages. Mobile AR apps allow the student to see a real-world environment with overlaid or composite virtual objects. This is especially true for young children. The article identifies the activities that provide a child's personal experience using AR technology. Comparison of existing AR applications for learning the alphabet is given. A new AR application is described, which was developed using Unity, C#, Vuforia. The developed mobile AR application provides an opportunity to study the Ukrainian alphabet, the names of numbers, the sounds of animals. Thanks to this application, the learning process is accompanied by three-dimensional visualization and sounding of each letter and number. An analysis of a survey of teachers and parents showed that when using an AR application, the interest and self-efficacy of children in learning letters and numbers significantly increased. The use of the AR application increased the speed of memorizing the material and helped to retain the child's attention while learning a new material.

Keywords

augmented reality (AR), mobile application, early literacy, visualization of educational information, AR-application, studying letters, 3D model, Vuforia

1. Introduction

In the modern world, technology development trends dictate the constant introduction of new products in all spheres of life. The technology that is currently being actively developed and implemented is augmented reality (AR). Its main advantage is that a smartphone is enough to use it. With the help of AR technology, virtual objects can be integrated into the material world: an augmented reality camera using AR programs captures reality and looks for predetermined target points in it – markers to which virtual objects are attached. Augmented reality technology allows you to combine the real and virtual world. Supplement existing objects with virtual ones for better visualization. AR apps work with 3D objects, texts, images, videos, and animations.

ICTERI-2021, Vol II: Workshops, September 28 – October 2, 2021, Kherson, Ukraine
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They allow you to combine and enable users to freely interact with events, information and objects [1, 2, 3, 4, 5].

With the development of software and hardware, augmented reality technologies are actively used in many areas: advertising, entertainment (games), marketing, medicine, engineering, and much more. As one know, the best technologies are being introduced into educational processes, as the fundamental facet of the entire development of society [2].

Literacy is a critical aspect of the healthy growth and development of young children. Early childhood education is the period when a child develops skills, knowledge and interest in learning. Including the basics of written and spoken language. Since the problem of reading among elementary school children is especially acute today. According to the standards, by the end of the first grade, the child should read aloud the available texts mainly in whole words (individual words of a complicated structure – in compositions). Which involves knowingly reading 40 words per minute [6]. Consequently, in the case of late literacy, the child during the period of study in the first grade, in addition to the stress due to the mode of life, receives the stress of academic failure. To avoid problems in the process of school education, it is necessary to start learning literacy in a playful way at an early preschool age.

Today, AR's potential for education is being actively explored by Osipova et al. [1], da Silva et al. [2], Santos et al. [3], Syrovatskyi et al. [4], Wojciechowski and Cellary [5], Kiv et al. [7], Thomas et al. [8], Singhal et al. [9]. In the race to improve the memorization of the material by students, teachers are trying to diversify the educational process. That is why the introduction of the ability to interact simultaneously with virtual and real objects will make the learning process more fun and memorable [9]. In addition, the introduction of augmented reality technology into the educational process can increase the creative component of a student's thinking. And it will also help to perceive complex things in a visual way "from all sides", which will make learning more flexible and deep. Therefore, the use of AR in education is an important task. The use of augmented reality technology is a very promising direction for the education system [2, 7, 8]. This requires the appropriate software. Not every teacher can prepare a mobile program [1, 4]. Therefore, the development of the necessary mobile applications is very important [4].

2. Literature review

Each stage of education has its own key characteristics. Augmented reality in higher education is focused on the study of material, which previously could only be studied theoretically on the image in the book. For example, Thomas et al. [8] describe current examples of the use of augmented reality that can improve teaching and learning in various areas of higher education, including, but not limited to, medical education, language learning and science. And also offer possible ways of implementation in the educational process. Nesenbergs et al. [10] offer generalized knowledge of how augmented reality technologies are applicable and affect distance learning in higher education. Namely, identifying the impact on such learning outcomes as academic performance and engagement at all stages of higher education from preparation for the course to assessment and grading of students.

Actual use of augmented and virtual reality to study dangerous to human areas, mechanisms

and instruments. In this case, the use of AR will allow you to consider the process in detail, try to independently perform a number of actions, which increases the level of knowledge and reduces the percentage of risks. The experience of using these modern technologies has already been described in a number of publications. Saravas et al. [11] describes a VR simulator for training workers of metallurgical enterprises in the design of complex mechanisms before starting repair work. At the heart of the simulator, the authors propose a component that can be used for any virtual reality equipment and will be further adapted to augmented reality devices. The use of virtual reality is presented by Song et al. [12] as a set of virtual reality training systems for three different types of cranes for students. The results of a study at the Department of Architecture and Architectural Engineering, Yonsei University, South Korea showed that the VR crane training system significantly improved students' self-esteem when operating the crane. The analysis showed that the change in self-efficacy is due to ease of use, mediated by the sense of presence and perceived usefulness.

Implementation of AR programs was carried out in many subjects. The work of Tosik Gün and Atasoy [13] is devoted to the analysis of learning outcomes in mathematics. The students studied "Geometric objects and measuring volume". Instead of the classical material, didactic materials with AR markers on paper were provided. The results of the study confirm an increase in the comprehensibility of the chosen topic and an increase in academic performance. Also in work by Hung et al. [14] the application of AR in biology lessons is considered, namely the comparison of understanding the material using augmented reality and with the standard use of textbooks. The results showed that the lessons with augmented reality were deeper in the study of the material and more practice-oriented. Which, in turn, is more interesting for children.

Augmented reality in secondary education is focused on supplementing existing knowledge with more visual demonstrations, as well as explaining abstract phenomena with examples that can be detailed. In [15], augmented reality technology was used in physics lessons within the school curriculum, which showed a deeper academic performance, as well as involvement in the academic subject. Salmi et al. [16] came to the conclusion that the use of AR in the learning process is effective for all children, especially for those who previously had low academic performance and learning ability.

Augmented reality in education involves expanding existing knowledge or learning new ones with the help of visual aids, which improves the quality of the study of the material. Today there is experience of using augmented reality for school textbooks, teaching aids, books [17, 18, 19, 20].

Kravtsov and Pulinets [17] describes the use of AR on the example of visualization of models of physical processes in a school physics course. The authors have developed 3D models that appear when hovering over pictures in physics textbooks. Also, visualization of the thermal conductivity of physical bodies using AR allows the student to participate in the experiment.

A particular attraction is the use of augmented reality in the education of young children [21, 22, 23, 24, 25, 26, 27, 28]. Yilmaz et al. [18] examined the understanding of information by preschoolers, as well as whether they enjoy the process. The research results demonstrate the emotional involvement of children in the learning process and their emotional uplift. The use of AR software for studying books made it possible to notice that children remember the plot faster, and then they involve their parents in retelling the story based on "coming to life pictures" [18, 19].

Play as a teaching and learning tool for preschool children is suggested by Chrisna et al. [23]. The aim of the research is to create an educational game about animals for young children. The authors propose an augmented reality app "Kotak Edu" that teaches children to identify three-dimensional animal shapes and helps improve literacy.

Costa et al. [24] also focuses on game-based learning. The paper presents a mobile augmented reality platform for educational purposes. The platform includes a mobile application, which consists of a location game aimed at understanding the universe, and an e-office, which allows teachers to enter information about celestial bodies.

An urgent task for the application of augmented reality is an early literacy [22, 23, 25, 26, 27, 28]. Mahayuddin and Mamat [25] studied the use of a mobile augmented reality application for teaching phonetic literacy to children with autism. At the Malak Autism Education Center, educators used the AR-app to improve literacy in children with autism using a phonetic teaching method. Observations have shown that children with autism are addicted to three-dimensional visual objects, and the application helps to associate graphics with images of the surrounding objects. Visual and sound effects attract children and focus their attention mainly on literacy and learning. But the authors consider the unstable operation of the mobile AR-application to be a negative point, which requires further refinement.

Che Dalim et al. [26] explores how AR technology helps young children learn English that is not their native language. The article describes the experience of children in terms of gaining knowledge and pleasure from learning using a combination of AR and speech recognition technologies. For this, the authors have developed a prototype AR "TeachAR" interface. Experiments have shown that thanks to the combination of AR and the traditional method, young children learn language faster and easier.

The experience of developing and using a mobile application with augmented reality for learning the alphabet by children is described by Nanda and Jha [27]. The authors confirm that the possibilities of augmented reality are a fun new way to involve children in learning the alphabet. The AR-app allows kids to become more familiar with letter recognition, learn letter pronunciation and improve their skills and memorization.

Nigam et al. [28] also presents an augmented reality application that creates an interactive alphabet learning environment for children. The authors report that the app motivates children to self-study.

Thus, augmented reality is widely used at various levels of education such as higher education, secondary education, primary education, and preschool education.

For young children, training is successfully carried out with a playful form. Motivation, fun, and curiosity are important ingredients in any educational game. Publications confirm that this can be achieved using augmented reality technologies.

Augmented reality in preschool education involves the use of colorful images of simple things such as illustrations for a book, simple shapes, animals, numbers, and the beginning of learning the alphabet.

From the age of 3, the child remembers the order of actions with the phone starting from the fourth demonstration. Thus, even without knowing how to read, the child can use the mobile application on his own. The mobile application is seen as an additional element of interest in training and will not replace a fully-fledged training.

However, implementation in early childhood education is still limited as the required software

is required. Therefore, the development of a learning environment with augmented reality for learning Ukrainian letters for young children is very important.

3. Activities that provide a personal experience of the child with the help of AR technology

The characteristic of competence as a personal achievement of a child, as a result of the educational activity of an adult with a child, is considered by us as a sequence: an emotional-value attitude, the formation of knowledge, life skills [29]:

- *Emotional-value attitude*: shows interest in computer and digital technology (computer, tablet, phone); motivated by the value of respectable interaction in the Internet space; has a cognitive need for discussion during computer games (educational, developmental, game), shows respect for other participants in the information space (users), shows a positive attitude towards modern digital technologies, reacts emotionally to the plot of computer games, demonstrates interest in communicating with others through technical means during the game and outside it, determines the value preference in the choice of educational and developmental games, and the like.
- *Formation of knowledge*: has an idea of information, communication and digital technologies as modern technical means that expand information horizons and help to navigate in the world in conditions of high technicalization of life, demonstrates the formation of knowledge about the features of computer technology, ways to control it with the help of peripheral devices, correctly names it components, knows the purpose and names of peripheral devices, deliberately uses computer technology (as intended); possesses the skills of searching, transferring information, is familiar with the basic resources of the Internet and the rules of the information world and knows how, if necessary, to protect himself from various information threats, practically possesses digital tools, knows how to use interactive exercises, performs operations and algorithmic actions of the initial user, which constitute one of the essential components of educational activities, realizes digital technologies contribute to the development of skills necessary for problem solving, analytical thinking, creativity, the formation of interpersonal emotional intelligence, including empathy, cooperation, social awareness).
- *Life skills*: a child is able, independently or with partial help from an adult, to turn on computer equipment and use it while playing, drawing, constructing, modeling. Complies with the safety rules for the use of computer technology. Manages himself while communicating on the Internet and in computer games, discovers the ability to behave safely with strangers on the network; is responsible for respecting computer technology; can deliberately differentiate and select cognitive and game content, characterizes its content; shows the ability to complete computer lessons on time.

The work consists of three stages:

- first is the presentation of the original problem due to the situation – the identification of a friend in a new material;

- second is the presentation of a visual image – forecasting, putting forward hypotheses about the past or future of objects, a situation that needs to be understood;
- third is the implementation of practical actions with cognitive material – the unification of the elements of the understandable as a whole.

The listed activities of a child with AR technologies and stages of work are possible if there are structural components of the learning model. We have defined the construction of a teaching model as an imitation of the educational process of teaching literacy by creating a schematic order. The training model has the following form (figure 1), it reflects all the elements as a single system.

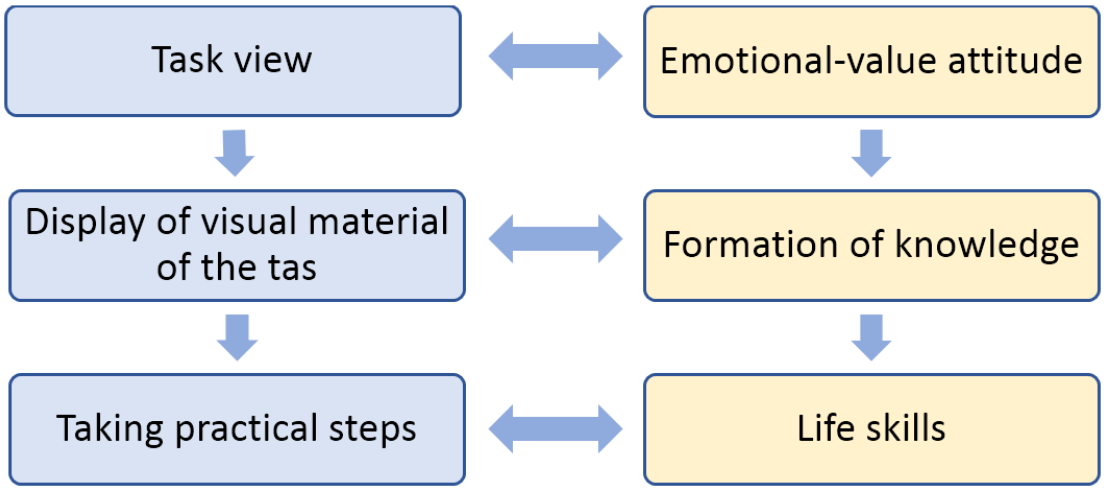

Figure 1: Stages of work with AR technology.

At the center of all work is the child of preschool age as the central object of the influence of many factors: content, pedagogical, didactic, technological and others. When organizing cognitive activity, the following algorithm is advisable: all codes are used that carry a sensory-cognitive, logical-mathematical meaning, elements of research search – a word, a drawing, a physical image, a diagram, a model, and practical actions [29].

The introduction of early literacy is an excellent simulator for the classic literacy that a child will encounter in the senior group of kindergarten and in elementary school. In addition, at an early stage of literacy, the child's interest in learning can be adjusted, the intensity of learning can be smoothly introduced, thereby learning will take place in a healthy and environmentally friendly manner.

In this regard, a more detailed study of this problem made it possible to identify the necessary rules for using AR. We make the following proposals for the promising spread of directions for using AR technologies for teaching preschool children and primary school children:

- Continuous viewing of training exercises – no more than 15 minutes.
- Working with modern technologies in accordance with sanitary requirements is allowed no more than 2 times a week (morning and afternoon).

- Based on the content of teaching literacy under the "Confident Start" program [29] in preschool educational institutions, the mobile AR-application will allow you to adjust the educational process, prepare the child for school: during the pre-literate period, master the elements of literacy, carry out preparatory, propaedeutic work to master the elements of written speech; to get acquainted with the basic units of speech and learn how to correctly use the terms to mean "sentences", "words", "sound", "syllables", "letters".

4. Analysis of similar mobile applications

During the research of analogs existing in the Google Play Store, many applications similar in topic and technical direction were identified. But only those that use augmented reality technology were selected. At the same time, they are aimed at carrying the elements of the game into the process of teaching children language basics.

Alphabet-AR [30] is an addition to the printed alphabet, aimed at capturing children's attention to the process of learning the Ukrainian language. By scanning the pages of the book, the application installs in their place a three-dimensional animated model, endowed with sound in the form of individual sounds, words or verses. The 3D models used in Alphabet-AR are endowed with bright colors and pleasing visual style, which is a definite advantage considering the target audience.

Unfortunately, it was not possible to conduct a full testing of the product, as it is necessary to purchase a special alphabet, a link to which was not found during the inspection of Alphabet-AR. This fact can be attributed to a number of disadvantages, since everyone will not be able to freely use this application.

Another analogue, similar to the program under development, is the *360ed Alphabet AR* [31], aimed at teaching children the English language using augmented reality and linguistic games. Unlike the previous program, in this product there is a link to a demo card with vivid images necessary for displaying models in augmented reality, as well as the ability to listen to the names of cards in different languages. From a technical and graphical point of view, the app is executed on high pebbles. The only drawbacks are the inability to choose the Ukrainian interface language and the need to purchase the full version of the program to open the full range of application capabilities.

The latest analogue of *Kids Alphabet Learning with Augmented Reality* [32] differs from the previous counterparts in its minimalistic interface design and limited functionality. The program has the ability to scan maps, which can be downloaded through the built-in instructions, and display flat drawings based on the scanned image. This is the main and only function available in the application, which is a disadvantage. But it should be noted that the visual style used looks attractive to the target audience.

So, the considered analogs of applications indicate that on the market of free mobile applications there are many similar programs that differ only in the quality of execution, language and territorial characteristics. On the other hand, it should be noted that there are almost no separate applications aimed at the Ukrainian-speaking user. In addition, a combination of skills in learning letters, numbers and animal sounds was not found.

Also, applications, functional and technical elements, which can become a support for further

Table 1
Comparison of the analyzed analogs

Comparison indicator	Application		
	Alphabet-AR	360ed Alphabet AR	Kids Alphabet Learning with AR
Using 3D models	+	+	-
Using AR (augmented reality)	+	+	+
Availability of sound	+	+	-
The presence of the Ukrainian language	+	-	-

development, are analyzed (table 1).

Thus, both the advantages of existing analogues and disadvantages were taken into account. Based on this knowledge, it was decided to develop a new application "Fox Alphabet AR", which maximizes all the advantages and takes into account the disadvantages of analogs.

5. Development of a mobile application "Fox Alphabet AR"

For the development of the application, a free cross-platform environment for developing computer games Unity was chosen. This environment has a rich set of tools for creating 3D measurements in augmented reality. To write program modules, the object-oriented programming language C# was used, since there is support for the latest version of Unity [33]. During the development of the application, an analysis of existing libraries and add-ons was carried out that allow displaying three-dimensional objects in augmented reality. It was necessary to give preference to one of the alternatives: ARCore [34] or Vuforia [35]. We compared the performance of a mobile app with augmented reality based on general performance characteristics based on Vuforia and AR Core (table 2). From the above table, you can see that software applications behave in about the same way, but the launch speed of an application built on ARCore is higher. If we analyze the accuracy of working with the application, and this is the main criterion, since the application is planned for children to work, then Vuforia works better at short distances, and ARCore at further ones. In addition, Vuforia is more efficient than ARCore.

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Thus, in order to ensure the minimum requirements for the hardware component of the future product, it was decided to choose the second possible version of the library. Although the technical potential of the Vuforia package lags slightly behind ARCore, the available functionality will be enough to complete the task. The main function of the application is to study the Ukrainian alphabet. For this, models of letters were created, which are shown in the figure 2. Additionally, the application contains models of numbers and animals. For all letters, corresponding sounds are provided, for numbers – the sound of the name, for animals – their sounds.

Table 2
Testing applications running on Vuforia and ARCore

No	Comparison indicator	Vuforia	ARCore
1	Change screen orientation: vertical positioning	+	+
2	Change the screen orientation: horizontal positioning	+	+
3	Interrupt: call	+	+
4	Interruption: sms	+	-
5	Interrupt: system notification	+	+
6	Interruption: folding	-	+
7	Interruption: sleep mode	+	-
8	Device memory full	-	+
9	Insufficient battery charge (less than 20%).	+	+
10	Display accuracy at a phone angle of 20 to 160 degrees	71%	67%
11	The efficiency of the application when changing the distance of the smartphone to the marker from 10 to 65 centimeters	74%	61%
12	Application launch speed	7 sec	4 sec

To save images, with subsequent recognition by the system, a database was chosen offered by the Vuforia platform, which is available to registered users [35]. Also, in order to provide users with the ability to freely download and use the cards necessary for recognition by the application, it was decided to embed a link to the archive in the Google Drive cloud storage.

Before writing software modules and setting up augmented reality, the first priority is to load images into the Vuforia database that will be used for scanning. For this, two groups of cards (letters and numbers) were selected, which will become the basis for displaying 3D models in subsequent development steps. A total of 47 images were used, sized 3.15 MB. Along with the image, a list of audio signals of the same number is created.

The next step in creating augmented reality is to assign to each image, from a previously created database, the corresponding 3D models. Thus, for each card after successful recognition, its own three-dimensional model will appear. Recognition is implemented by means of the Vuforia library.

The assignment of the image to the corresponding 3D models is done by hand using the Unity editor. For this, a software module is implemented for each image, in which the application receives instructions for actions when the image is recognized by the camera. An example of the object from the development environment is shown in the figure 3.

To increase the speed of the system, it was decided to split the application into two modules. The first module includes only the interface, and the second – the main functionality of augmented reality.

To work with the application, the main menu is provided, where you can select one of the training sets. Also added instructions and additional notification of the need to download the cards on which the training takes place. All actions for the child are also voiced in the application. In addition, when you point the phone at the card and when the 3D model appears, dubbing occurs. Thus, learning takes place on a visual level and on an auditory and tactile level. Since the cards can be printed separately, and the child can play with them outside of training

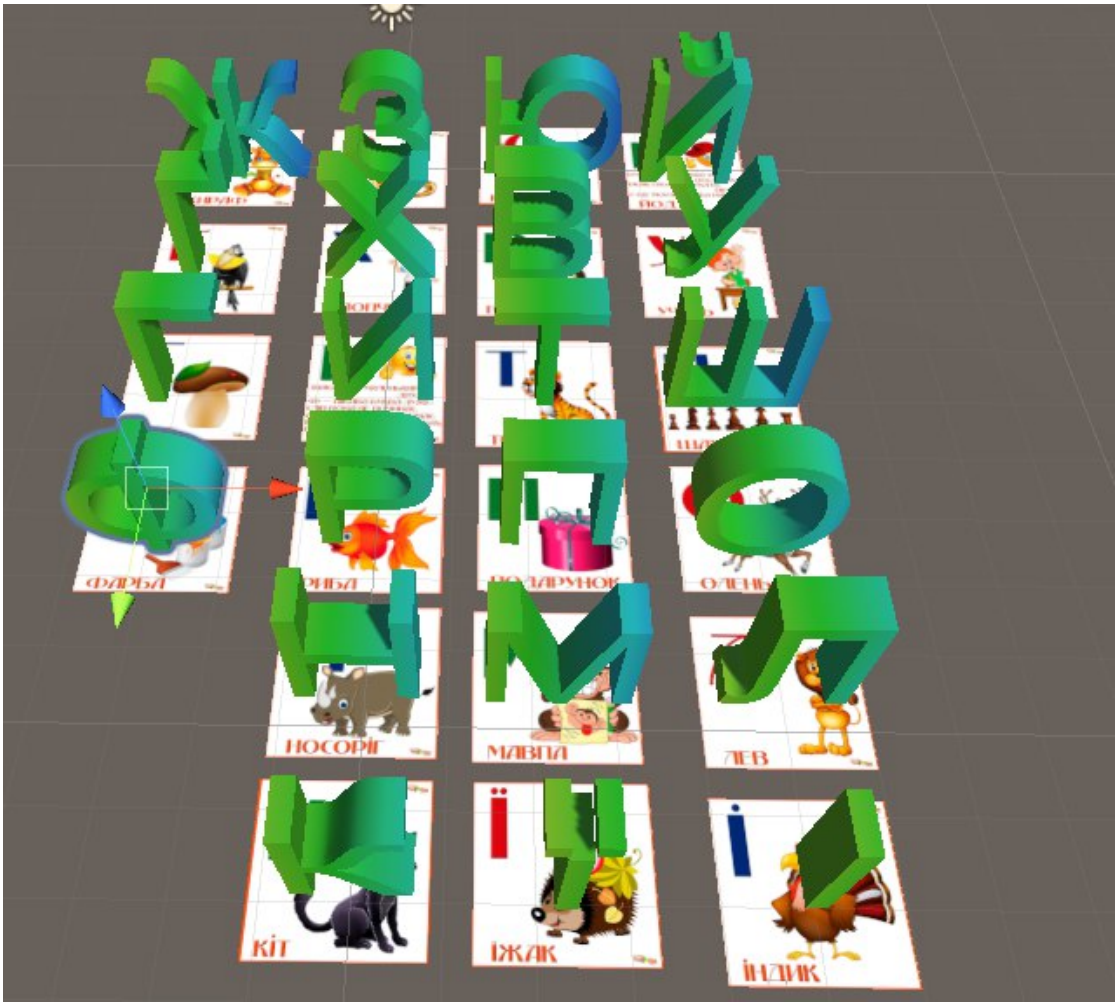

Figure 2: Examples of 3D letter models.

in the application. In order to study the next map, it is enough to point the phone at it. The figure 4 shows an example of how the application works.

6. Results and discussion

The study of letters – the alphabetical period in the modern method of teaching literacy is divided into two stages. At the first stage, the letters denoting vowel sounds are studied and letters denoting consonants. At the second stage – letters that contain several sounds, as well as letters that make the sound softer, in which children move on to reading words of a more complex structure. The division into stages is advisable because it allows you to more clearly define the tasks of the stages of learning and thus develop a system and methodology for the work of teachers and children.

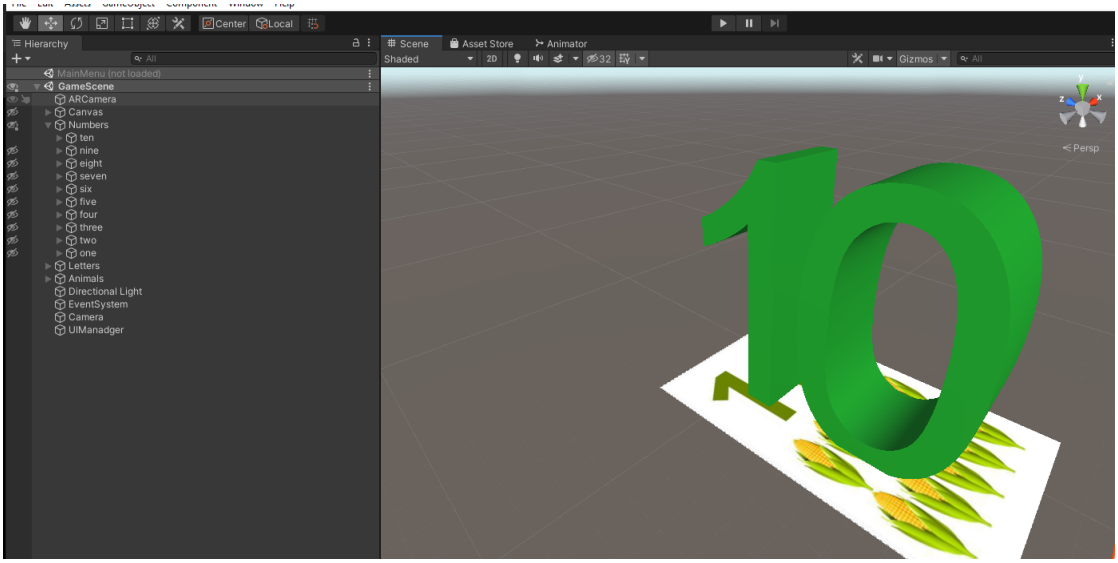

Figure 3: The example screen view of the object from the development environment.

In the experiment, we took into account the new requirements for training in accordance with the Concept of the New Ukrainian School, the main goal of which is to prepare a competent modern Ukrainian. Therefore, it is necessary to change the forms, methods and technologies of teaching. An experiment was conducted on the use of the developed mobile application with augmented reality among children.

We carried out a survey of the participants in the experiment, namely, teachers of educational institutions and parents of the city of Mariupol.

The survey was designed to analyze and support further data collection on the current trend in AR learning adoption. The objective of the survey was to collect enough examples of software applications to determine whether the mobile application was useful.

As the parameters of the survey, we chose the achievement of a certain function and the use of certain capabilities by students. For our study, it was important to identify the interrelated characteristics of learning (the speed of learning – familiarization, the speed of memorization and the frequency of independent use of letters), which affect the learning outcomes. Evaluation of success in terms of indicators was determined by two groups of survey participants: teachers and parents. An analysis of the implementation of an AR application for educational institutions and parents is shown in the table 3.

The table displays the number of days for a child to achieve a certain function before and after using the AR mobile application. The figure 5 shows a diagram of the views of teachers, and the figure 6 – the opinions of parents.

To analyze the use of the developed software according to the first characteristic, it was found that the speed of a child's acquaintance with letters increased, the study became 2.5 times faster than without the use of AR technologies.

According to the second characteristic, the speed of memorization increased according to the observations of parents and teachers from 10 days to 3 days and from 5 days to 3 days,

Figure 4: An example of using the application “Fox Alphabet AR”.

respectively. This demonstrates the effectiveness of the use of AR technologies at different stages of the study of letters. The data of the third characteristic – the frequency of independent use, most clearly demonstrate a well-designed application. This confirms the fact that children tend to independently use the learned letters when performing tasks and in everyday life (respectively, they use the studied material 2 times more often than without the use of AR technologies). Average registered effect size – doubled letter and learning frequency.

Thus, the results showed that the learning system for letters and numbers when using AR significantly increased the interest and self-efficacy of children. The speed of memorizing the material has also increased.

Table 3
Results of the answers of teachers to the question: Do you find this technology affects children's learning?

	opinions of educators (27)			opinions of parents (81)		
	Speed of study by the child (days)	Speed of memorization by the child (days)	Frequency of self-use (days)	Speed of study by the child (days)	Speed of memorization by the child (days)	Frequency of self-use (days)
Before the introduction of AR	5	10	3	10	5	5
After the introduction of AR	2	3	6	2	3	10

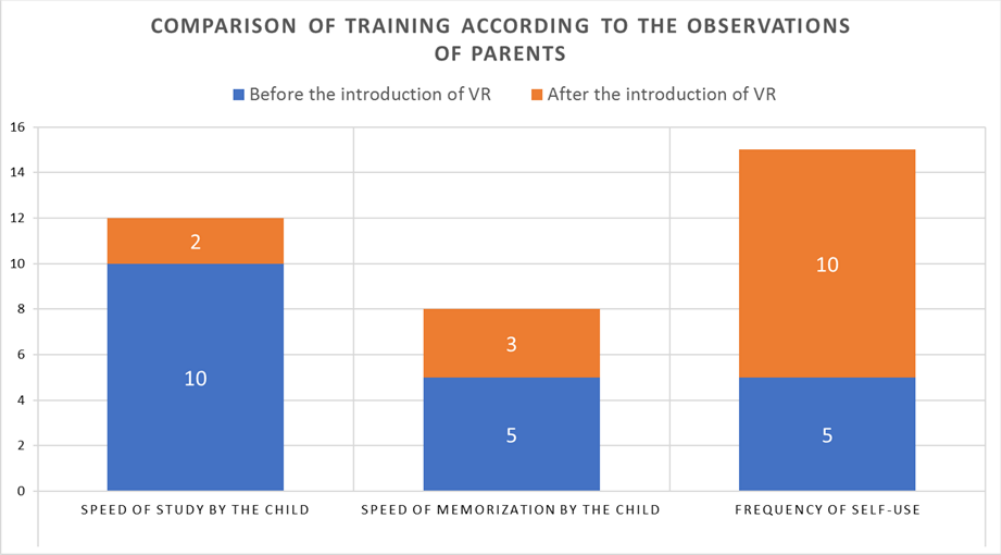

Figure 5: The results of parents' opinions.

7. Conclusions

Currently, augmented reality is one of the most actively developing technologies, which has also found its application in the field of education. AR technology opens up new opportunities for teachers and increases the attractiveness of learning for students of different ages. This is especially true for young children, since 3D models have good visibility and high attractiveness.

The mobile AR application developed by us "Fox Alphabet AR" provides an opportunity to study the Ukrainian alphabet, the names of numbers, the sounds of animals. Thanks to this application, the learning process is accompanied by 3D visualization and sounding of each letter and number.

Children who do not receive early literacy continue to decode new information with less quality in elementary school, which slows down the learning process and contributes to psy-

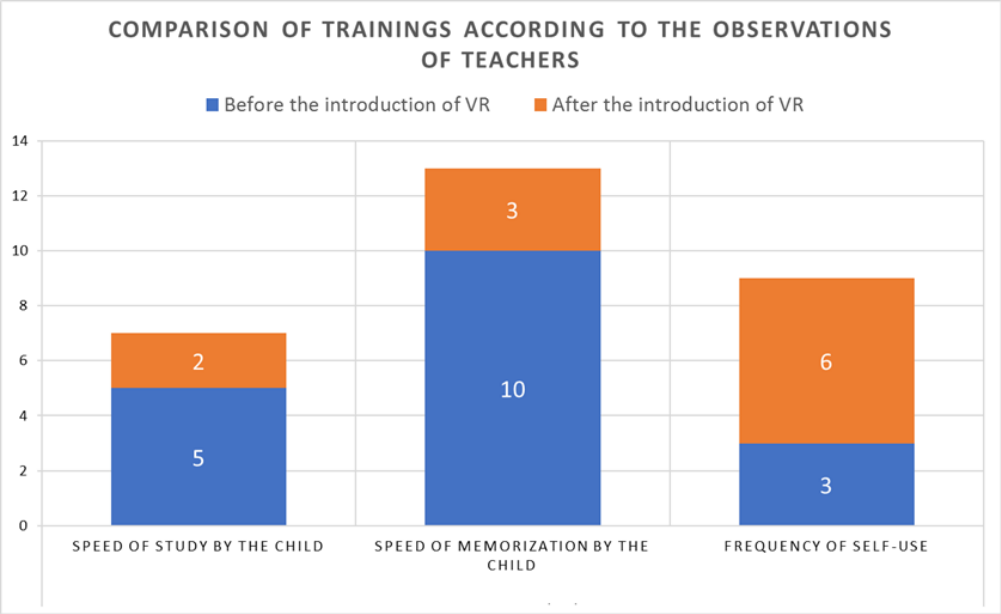

Figure 6: The results of teachers' opinions.

chological difficulties during the period of adaptation to school. This can cause the child to lag behind in the learning process. The study of initial competencies, such as knowledge of the alphabet, allows you to increase the level of decoding of teaching information received from the teacher.

An analysis of a survey of teachers and parents showed that when using an AR application, the interest and self-efficacy of children in learning letters and numbers significantly increased. The use of the AR application increased the speed of memorizing the material and helped to retain the child's attention while learning a new material.

In the future, we plan to add visualization of the study of syllables, shapes, colors to support the early development of children.

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