








# Augmented Reality in the Literary Education of Primary School Children: Specifics, Creation, Application

Liudmyla L. Nezhyva<sup>1</sup><sup>a</sup>, Svitlana P. Palamar<sup>1</sup><sup>b</sup>, Halyna O. Vaskivska<sup>1</sup><sup>c</sup>, Olha V. Kotenko<sup>1</sup><sup>d</sup>,  
Liudmyla A. Nazarenko<sup>2</sup><sup>e</sup>, Maryna S. Naumenko<sup>1</sup><sup>f</sup> and Andrei V. Voznyak<sup>3</sup><sup>g</sup>

<sup>1</sup>*Borys Grinchenko Kyiv University, 18/2, Bulvarno-Kudriavska Str., Kyiv, 04053, Ukraine*

<sup>2</sup>*Mykolayiv Regional Institute of Postgraduate Pedagogical Education, 4-A Admiralska Str., Mykolayiv, 54000, Ukraine*

<sup>3</sup>*Kryvyi Rih State Pedagogical University, 54 Gagarin Ave., Kryvyi Rih, 50086, Ukraine*  
{l.nezhyva, s.palamar, o.kotenko, m.naumenko}@kubg.edu.ua, avvozyak76@gmail.com


**Keywords:** Augmented Reality Technology, 3D Visualisation, Creative Thinking, Emotional Intelligence, Interactive Travel Game.


**Abstract:** The authors worked on expanding the methodological basis for the use of augmented reality on the examples of alphabets in accordance with the objectives of the school program of the 1st-grade of the New Ukrainian School, namely the content lines: “Interact orally”, “Exploring the media”, “Exploring linguistic phenomena”. The methodological aspect of the application of augmented reality on the basis of interactive art books has also been expanded. In particular, within the line “Theatricalize” it is proposed to involve students in stage art, in the conditions of which they gained experience of performance, tried to improvise. Observation of artistic expression through augmented reality, work with interactive coloring pages and stickers, expression of appropriate emotions through acting ensures the development of the child’s emotional intelligence, creative thinking, initiative, self-awareness, self-control, ability to overcome barriers associated with uncertainty and risks, effectively cooperate with and understand one another. The result of the research characterizes different directions of application of augmented reality in the literary field of primary education: visualization, observation and research of artistic image, demonstration of its expression; visualization, observation and research of the artistic world of a literary work; organization of the reader’s interaction with the literary hero; organization of game activities in the lesson of literary reading (study of the work with the help of a game developed by means of augmented reality); organization of theatrical performances with the help of interactive bracelets and stickers with AR applications. This study is devoted to the creation of an augmented reality appendix to the topic “Ukrainian folk tales”. Due to the fact that the leading activity in primary school is gaming, the AR application based on a fairy tale as a game-trip was created. The development of the application provides for the implementation of further tasks: analysis of the work, interpretation of the work, activation of the emotional impact of works on the reader. The augmented reality for the accompaniment of the creative reading of the fairy tale was created with the help of Unity programs and the Vuforia plugin. The basis of the game-trip is a fairy-tale map with stations and special interactive tags. A specially designed program attaches a virtual AR object to the label and activates the image of the hero, the episode of the fairy tale, the text of the question on the screen.


## 1 INTRODUCTION


### 1.1 The problem statement


New virtual (VR) and augmented reality (AR) technologies have quickly gained popularity around the world. Currently, visualized content on various topics is used with the help of modern electronic devices in various fields, such as: science, production processes, technology, marketing, design, entertainment,


<sup>a</sup>  <https://orcid.org/0000-0001-9520-0694>


<sup>b</sup>  <https://orcid.org/0000-0001-6123-241X>

<sup>c</sup>  <https://orcid.org/0000-0002-8714-8512>

<sup>d</sup>  <https://orcid.org/0000-0001-8967-8130>

<sup>e</sup>  <https://orcid.org/0000-0001-6560-5252>

<sup>f</sup>  <https://orcid.org/0000-0001-8927-4427>

<sup>g</sup>  <https://orcid.org/0000-0003-4683-1136>

medicine, education, etc. VR and AR applications are already actively used as teaching aids in schools in America and Europe. Augmented reality technology has become especially popular due to its easy and convenient use. The availability of smartphone or tablet, which can be used for individual tasks, observations, research, as well as for group projects, is enough to work with AR. With the help of AR applications with smartphones in hands, foreign and domestic primary school students have the opportunity to explore the solar system, water molecules, flora and fauna, travel, enliven the pages of the alphabet, visualize artistic images and the world of literature, etc. By extrapolating the world experience of activating augmented reality in school practice, scientists-methodologists and teachers-practitioners in Ukraine develop their own AR applications and substantiate methodological models of their implementation in education.

Modern development of information and communication technologies allows to modernize the educational process in primary school as much as possible in accordance with the challenges of the time and the requirements of the reformed education. The linguistic and literary branch of primary education was no exception. In particular, the “Living Alphabet” has appeared on the desks of first-graders in Ukrainian schools, the visualization of which is provided by the FastAR Kids application in smartphones or tablets (iOS, Android, iPhone). The interactive edition contains a game platform with special labels on the pages of the edition, which activate augmented reality in 3D format based on the plots of poems with amazing stories and animated characters. Some teachers use the alternative edition of the “Kobzar’s Alphabet” in the practice of teaching literacy to first-graders. This interactive book contains works by Taras Shevchenko for each letter of the alphabet, the illustrations of which come to life, move and talk with the help of the same FastAR Kids application. However, the methodology of teaching with the help of such books remains undeveloped, so the use of augmented reality in literacy lessons in the first-grade is not systematic, but rather situational.

The specificity of fiction, its imagery, organic integration into the multimedia space also suggest the need for partial revival of the artistic picture with the help of augmented reality technology in the reading process. While developing lifelong learning skills in primary school students, it is important to form an interest in books, to teach to feel the beauty that is embedded in the artistic word. The depth of perception of the work depends not only on the development of critical thinking and aesthetic sense, associated with

a sense of beauty, understanding of the values accumulated in the artistic image, but also on emotional intelligence. Therefore, the development of dialogic interaction with works of art will be greatly facilitated by the use of augmented reality technology, which causes its visualization primarily emotional resonance and promotes the activation of the creative imagination.

## 1.2 Literature review

We analyzed the current state of research on the use of AR applications in education (Chen et al., 2017); studied the experience of combination of AR with learning based on games in primary school (Makhachashvili et al., 2020; Pellas et al., 2019), the impact of integrating game approaches with augmented reality on learning (osvitoria.media, 2019; Sáez-López et al., 2019), improvement of learning efficiency and students’ motivation through the use of AR applications on smartphones (Chen, 2019).

Possibilities of application of AR technologies in different fields of education were considered by Pochtoviuk et al. (Pochtoviuk et al., 2020). The authors noted the great impact of presentation of educational material by augmented reality on the development of facial expressions, attention, stimulating thinking and increasing the level of understanding of information. Among the benefits, scientists point to realism, clarity, completeness, information and interactivity. The didactic potential of virtual information learning environment is determined by Bondarenko et al. (Bondarenko et al., 2020). Scientists emphasize such features of VR and AR as immersion, dynamism, sense of presence, continuity, causality, intensification of the process of cognition, saving time for processing the material. While acknowledging the effectiveness of learning with the help of VR and AR, the authors also point out the disadvantages, including low computerization, low number and low quality of software products (Bondarenko et al., 2020), difficulties in applying these technologies, such as: small experience in using this technology, lack of methodological literature, lack of developed methods of AR implementation (Iatsyshyn et al., 2020). Lacunae of augmented reality educational products are filled by practitioners who create mobile applications to visualize educational material, including the chemical structure of water and display video data from laboratory experiments to study subjects of the natural cycle in the primary school. Innovative is the experience of developing a mobile application LiCo.SolarSystem, designed to visualize the solar system using AR technology and study the alphabet using astronomical def-

initions (Midak et al., 2020a). According to the authors of the LiCo.STEM and LiCo.SolarSystem applications (can be downloaded from a publicly available Google Play Market resource), its contributes to the development of cognitive motivation of primary school students and educational energy, their imagination, creative initiative and research activity (Midak et al., 2020b).

Walsh et al. (Walsh et al., 2019) offer the development and implementation of educational tools using virtual and augmented reality for language learning in primary school. Sekerin et al. (Sekerin et al., 2017) outlined the prospects for the implementation of the latest educational technologies that allow to increase the effectiveness of teaching. Thus, in the course of the study, they found that 20% of students are ready to receive educational information from conventional sources, and 80% of students need inter-active perception of information based on augmented reality. Carrying out lessons with the help of virtual reality tools, according to scientists, contributes to the full involvement of students in the educational process and, accordingly, successes in the acquisition of knowledge (Sekerin et al., 2017). For primary school students in Ukraine, a textbook and universal didactic material from AR for the integrated course “I explore the world”, aimed at developing research skills (Honcharova, 2019), has already been created.

The most of the publications on the identified problem (Amelina et al., 2022; Babkin et al., 2021; Burov et al., 2020; Kiv et al., 2020; Kolomoiets and Kassim, 2018; Lavrentieva et al., 2020; Mintii and Soloviev, 2018; Palamar et al., 2021; Petrovych et al., 2021; Rashevskaya et al., 2020; Semerikov et al., 2021; Shepiliev et al., 2021; Striuk et al., 2018; Tarasenko et al., 2021; Vakaliuk and Pochtoviuk, 2021; Zelinska et al., 2018; Zinonos et al., 2018) testify to the possibility of using VR and AR technologies in the educational field for the purpose of visual modeling of educational material; supplementing its visualization; developing students’ spatial ideas; research and experimentation skills; three-dimensional design, which saves time for learning information, accelerates learning and makes the process fun and engaging.

### 1.3 The aim of the research

Thus, augmented reality is increasingly used in primary education, special educational applications have been developed in the field of natural sciences, AR text-books have been created for primary school students for the course “I explore the world”.

Among the many tools of augmented reality technologies in the educational process of primary school

one use AR applications such as “Animals 4D” in the integrated course “I explore the world”. Encyclopedias of the Ukrainian manufacturer with augmented reality iEXPLORE, which transfer the animal world from the pages of the book to reality, are designed to instill curiosity in children, to acquaint them with the magical world of animals, insects, beetles and dinosaurs.

The authors of this article outlined the prospects for the application of augmented reality in the linguistic and literary field of primary school. Several editions of works of art by Ukrainian and foreign writers with AR applications, which should be used in reading lessons, are named. We conducted a study of the effectiveness of the use of AR applications in reading lessons in primary school with the definition of their benefits for enhancing the reading activities of students (Nezhyva et al., 2020). However, there is a need for the systematic development of methods for applying augmented reality in literacy and reading lessons in 1st-4th grades and testing its effectiveness for the development of the subject and key competencies of primary school students.

The recommendations of the European Parliament and the Council “On the basic professional skills required for lifelong learning” refer to the formation of basic competencies that help individuals to socialize successfully. For the main competencies, among others, such reference frameworks as critical thinking, creativity, initiative, the ability to constructively manage emotions are named (ec.europa.eu, 2018). We believe that such personality qualities are formed during reading activities, which will be enhanced by augmented reality.

The study aims to develop a mobile AR application on the Android platform, designed to organize play activities of primary school students during reading lessons while studying fairy tales and modeling of methods of application of augmented reality technologies in the linguistic and literary field of primary education, which can be used by teachers and students for effective training on methods of literary reading in primary school.

## 2 DISCUSSION AND RESULTS

AR technologies provide a three-dimensional field of human perception of virtual information, which can be perceived as elements of real life. With the help of augmented reality, images, videos, text and graphics are projected beyond the screens of smartphones or tablets with the AR function. In this way, virtual objects are combined with the real environment.

With the help of a 360° picture, the boundaries of the creative imagination of a junior school-child can be maximally expanded. Quality augmented and virtual reality content blurs the line between the artificial world and the real one. With the help of gadgets, as if through a window, the student observes an amazing image of the world (scientific, technical, artistic, etc.), explores, cognizes its laws, learns to change it for the better. Therefore, the use of these technologies causes maximum expression in students, and most importantly allows them to actively interact with various objects of study in three-dimensional space. Thus, augmented reality technologies allow students to perceive artistic images in an entertaining form of the game, to get closer to understanding the artistic world of a literary work. In this study we will take into account the most important advantages of immersive technologies, namely:

- clarity, which allows to easily examine in detail any process or object;
- concentration, which allows not to be distracted by external stimuli and focus on the lesson material;
- maximum involvement of students in the learning process;
- the effectiveness of awareness and memorization of important educational information, etc. (osvitoria.media, 2019).

Primary school students have the opportunity to begin their acquaintance with augmented reality in the 1st-grade. Today, many Ukrainian schools are provided with an interactive edition of “Living Alphabet” with the application FastAR Kids for smartphones and tablets (iOS, Android, iPhone). The pages of this alphabet can be revived from the first literacy lessons (figure 1). While working with this alphabet, we offer first-graders not only to listen to poems, fairy tales, useful information, but also advise teachers to set the following tasks for students: observe the heroes of stories, learn to interact with them, explore their appearance and emotional state, pay attention to the environment, orally describe what was seen and heard, etc.

A more complex, but not less interesting format of the interactive edition “Kobzar’s Alphabet” (Kyiv, 2019) with the application FastAR Kids (figure 2). In special literacy lessons, this alphabet can be used as an alternative. Students are invited to get acquainted with the works of the classic of Ukrainian literature Taras Shevchenko in an interesting and relaxed way by means of “reviving” highquality illustrations to these works.



Figure 1: Demonstration of augmented reality according to the publication “Living Alphabet”.

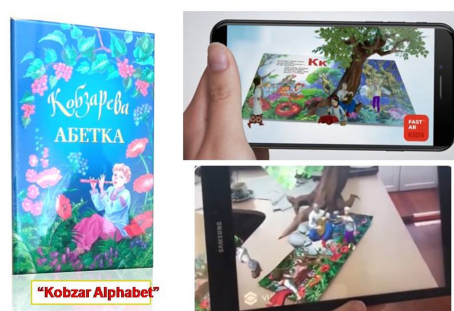


Figure 2: Demonstration of augmented reality according to the publication “Kobzar’s Alphabet”.

It is important that such an alphabet effectively helps first-graders with different levels of readiness to learn to read and understand words and sentences, provides an opportunity not only to update knowledge about the letters of the Ukrainian alphabet and corresponding sounds but also to hear the clear reading of Kobzar’s poetic lines accompanied by augmented reality. The teacher is invited to draw students’ attention to the melodiousness of the native language, to the beauty of Ukrainian landscapes, activated by the AR application, to emphasize the spiritual values of Kobzar’s poetry. Thus, with the help of augmented reality, the tasks of the main semantic lines of study according to the current school program of the 1st-grade of the New Ukrainian School are realized, namely:

- “Interact orally”. Students perform actions to activate augmented reality following the listened instructions; answer questions on the content of what is heard and seen (who? what? where? when? how?); tell what is said in the text, activated by augmented reality; share their feelings and emotions from what they have heard and seen; tell what has interested them; reproduce emotionally in roles (with students or teachers) the dialogue of the characters; learn to use non-verbal means (gestures, facial expressions, etc.) according to the communication situation;

repeat samples of coherent utterance (2–3 sentences) while preserving its content and intonation features; retell a short listened text based on augmented reality; independently build a short coherent statement based on the listened text or augmented reality.

- “*Exploring the media*”. Younger students, working with media products, learn to perceive the content and form of simple media products, among which there is not only the usual pictures, comics, cartoons, but also augmented reality, participate in its discussion; share their impressions of listened to / viewed media products.
- “*Exploring linguistic phenomena*”. Students explore speech sounds, their correct pronunciation by activating augmented reality applications, learn the correspondence of sounds and letters; observe the lexical meaning of words.

Thus, there is another effective means of teaching literacy to primary school children – augmented reality, which contributes not only to the successful study of the Ukrainian alphabet but also a casual acquaintance with classical examples of literature and spiritual values reflected in it, ensures the development of speech, imagination, critical thinking, emotional intelligence of primary school students.

In primary school, it is appropriate to conduct interactive reading lessons using art books for children with augmented reality, in particular a series of books “Read and Play” by the Ukrainian publishing house Art Nation Publishing. One has confirmed the effectiveness of the use of augmented reality (Wow-Box AR) in the process of studying of Lewis Carroll’s fairy tale “Alice in Wonderland” and “Alice Through the Looking-Glass”, as well as the application of The Pumpkin’s Year during the creative reading of a short story for children called “Pumpkin Year” by Ukrainian writer K. Babkina. In the extracurricular reading lesson, the model of studying E. Hoffman’s work “The Nutcracker and the Mouse King” was successfully applied with the activation of the WowBox AR application. The use of interactive pages of this edition and additional bracelets contributed to the activation of readers in the virtual art world and thus the implementation of the tasks of the content lines of the program of the New Ukrainian School. In particular, within the line “Theatricalize” students had the opportunity, wearing bracelets and playing the roles of the heroes of the fairy tale, to observe unfamiliar (spectator) and to express their own (actor) expression. Thus, students were curiously involved in stage art, in which they gained experience of performance, tried to improvise. Observation of artistic expression through augmented reality, work with inter-

active coloring pages and stickers, expression of appropriate emotions through acting ensures the development of the child’s emotional intelligence, creative thinking, initiative, self-awareness, self-control, ability to overcome barriers associated with uncertainty and risks, effectively cooperate with and understand one another.

It is becoming increasingly difficult to draw the attention of a young reader to a book in the modern conditions of informatization of society. From an early school age, children get used to gadgets, which are gradually becoming one of the leading ways of learning about the world. This problem has become even more acute in a pandemic, when the distance learning format has become more active in the education system. At the same time, we should remember the importance of the art book, reflected in the fiction aesthetic, spiritual, moral values for the formation of the personal image of the world of the student. The art of the word enriches with new knowledge, has a powerful educational potential, develops speech, figurative thinking, creative imagination and emotional intelligence, promotes awareness of national identity and socialization of the individual, causes unforgettable impressions, gives aesthetic pleasure. Therefore, there is a need to open the value of fiction for younger students, to form the interests of readers, to demonstrate the uniqueness of literary reading.

This study is devoted to the creation of an augmented reality application to the topic “Ukrainian folk tales”. Due to the fact that the leading activity in primary school is gaming, the AR application for a fairy tale was created as a game-trip to the very same story. The development of the application provides for the following tasks:

- *Analysis of the work*. Describe the place and time of events, characters (motives of behavior, causes of feelings and emotions, relationships between characters);
- *Interpretation of the work*. Conduct dramatization, creative translation, continuation of the text; evaluate the experiences and emotions of the characters;
- *The emotional impact of works on the reader*. Describe the mood, feelings of the characters of the work and one’s own emotions caused by reading a fairy tale; compare these emotions with the feelings caused by events in one’s own life; characterize the favorite character, substantiate the sympathy, the reasons of empathy to the character.

Thus, with the help of the Unity program (Haranin and Moiseienko, 2018; Katsko and Moiseienko, 2018; Kuznetsov et al., 2022) and the Vuforia plugin,

an augmented reality was created to accompany the creative reading of the fairy tale “Kotygoroshko” (figure 3).

The basis of the game-trip is a fairy tale map with stations and special interactive tags – circles of different colors (figure 4).

In order to activate the augmented reality on the map and complete the lesson tasks, students form groups. For convenience, students in each group receive stickers of the same color (red, blue, green, yellow). To animate the interactive parts of the travel map (colored circles), one needs to download a specially designed AR application (figures 5, 6) on the smartphone or tablet and point the gadget to the color wheel of the command of the respective station. A specially designed program attaches a virtual AR object to the label and activates the image of the hero, the episode of the fairy tale, the text of the question on the screen. Each group of students “animates” it with the help of AR applications on each of the four stations of the circle of the corresponding color.

The first stop of the game-trip is dedicated to the retelling of a fairy tale. According to the name of the stop, it is suggested to perform the actions “Look and tell”. Each group of students “animates” the circle of the corresponding color and a fragment that needs to be transferred appeared on the smartphone. The group of students is offered the task to make a plan for the retelling of a fragment of a fairy tale visualized with the help of an AR application and to determine the speakers according to the plan. The teams were offered the following fragments: “Red” – a fragment of “Brothers and sister have disappeared”; “Yellow” – a fragment of the “Appearance of Kotygoroshko”; “Green” – a fragment of “Battle”; “Blue” – a fragment of “Betrayal of brothers”.

The task of the second stop “Who is who” of the fairy-tale travel game is the characterization. Each team “revives” its hero from the fairy tale “Kotygoroshko”, watches him, remembers the text of the fairy tale and characterizes it by features: the appearance of the hero; emotions experienced by a fairy-tale hero; positive and negative features; mistakes or achievements of the hero; one’s own attitude to the hero (figure 6).

The next stop of the fabulous game-trip is “Think”. At this stop, students visualize the questions based on the fragments of the fairy tale told by the students. While activating the red label, the students answered the question: What happened in Kotygoroshko? Explain why, after Olenka’s disappearance, the brothers also disappeared? Name the reasons for the return of the brothers. Why did the brothers lose the battle? What advice would you give them

to win? Evaluate the actions of the brothers. While activating the yellow label, students pondered the following questions: When did Kotygoroshko appear in the family? Explain why people were afraid of his power? In what way do you think one can use Kotygoroshko’s force? Complete the preparation for the battle of Kotygoroshka and the brothers? Explain why Kotygoroshko was so confident in his strength? What would you do recommend to Kotygoroshka when he was preparing for the battle? Consider what influences the victory? While activating the green label, the students analyzed the fairy tale in the following directions: Who has Kotygoroshko met, when he came to the snake? Explain Olenka’s behavior during the meeting with Kotygoroshko? Consider whether Kotygoroshko could negotiate with the snake and not fight? Suggest possible solutions in the fight between Kotygoroshko and the snake. How do you feel about Kotygoroshko’s act? Name the advantages of Kotygoroshko in contrast to his brothers. While activating the blue label, the students answered the following questions: Was Kotygoroshko able to free his brothers and sister? For what reasons Kotygoroshko did not admit to the boys that he was a brother? Why did the brothers decide to get rid of Kotygoroshko and then freed him from their trap? Advise Kotygoroshko how to act in the situation that developed at the end of the fairy tale? What would you tell your brothers to do in the current situation? Try to model the other possible end of the fairy tale.

### 3 CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

The presented research actualizes the use of AR applications in the practice of literary education of primary school students. According to the authors of the study, augmented reality technology meets modern social and educational challenges, contributes to the successful implementation of the tasks of literary education of the New Ukrainian School, allows younger students to fully immerse themselves in the space of art and activates their figurative thinking.

Given the specifics of fiction and the leading principles of methods of teaching literary reading in primary school, this article describes the different areas of application of augmented reality in the literary field of primary education:

- visualization, observation and research of the artistic image, demonstration of its expression;
- visualization, observation and research of the

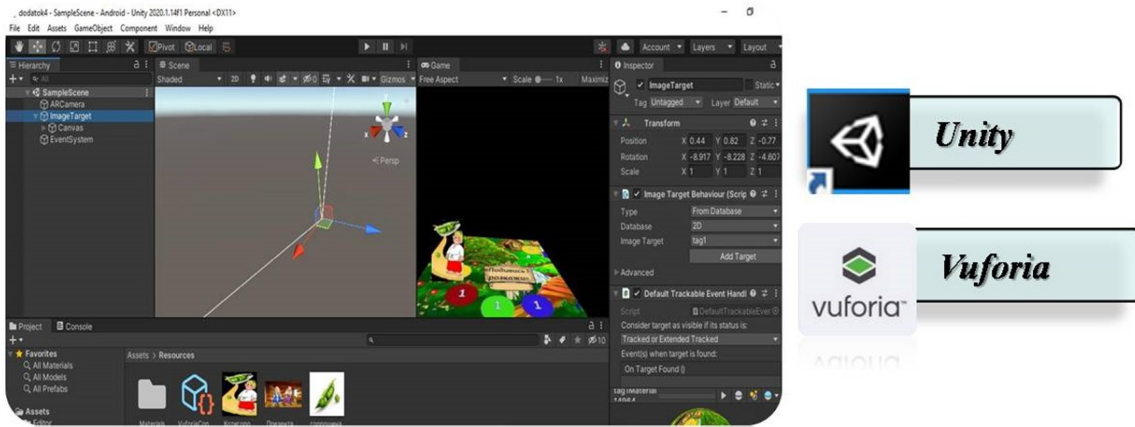


Figure 3: The process of the development of the application to “Kotygoroshko”.



Figure 4: Interactive map of the game-trip for the activation of the AR applications under the fairy-tail “Kotygoroshko”.

artistic world of a literary work;

- organization of the reader’s interaction with the literary hero;
- organization of game activities in the lesson of literary reading (study of the work with the help of a game developed by means of augmented reality);
- organization of theatrical performances with the help of interactive bracelets and stickers with AR applications.

In order to organize effective play activities of primary school students in the lesson of reading while studying a fairy tale, a mobile application (on the Android platform) of a travel game using AR technology has been developed. The development of the application provides for the implementation of the content

of the current school program of the New Ukrainian School of Literary Reading: analysis and interpretation of the work, activation of the emotional impact of the work on the reader. The use of augmented reality objects in the methodology of literary reading allows the teacher to deepen the emotional resonance of reading a fairy tale, motivate to read oral folklore, develop the creative imagination of primary school children, the quality of their emotional intelligence, including the ability to understand and analyze emotions, empathy, interaction in a team, manage emotions, etc. In addition, AR applications qualitatively visualize the world of art, promote easy memorization of works by students, the development of critical and figurative thinking of primary school children in an interesting game form, their creativity and initiative.

All in all, we see the continuation of scientific



Figure 5: Activation of the interactive part of the travel map “Look and tell”. Fragment “Battle”.



Figure 6: Activation of the interactive part of the travel map “Look and tell”. Fragment “Appearance of Kotygoroshko”.

research on a particular problem in the direction of studying the readiness of future teachers to apply augmented reality in the linguistic and literary field of primary education.

## REFERENCES

- Amelina, S. M., Tarasenko, R. O., Semerikov, S. O., and Kazhan, Y. M. (2022). Teaching foreign language professional communication using augmented reality elements. In Semerikov, S., Osadchyi, V., and Kuzminska, O., editors, *Proceedings of the Symposium on Advances in Educational Technology, AET 2020*, Kyiv. University of Educational Management, SciTePress.
- Babkin, V. V., Sharavara, V. V., Sharavara, V. V., Bilous, V. V., Voznyak, A. V., and Kharchenko, S. Y. (2021). Using augmented reality in university education for future IT specialists: educational process and student research work. *CEUR Workshop Proceedings*, 2898:255–268.



- Bondarenko, O. V., Pakhomova, O. V., and Lewoniewski, W. (2020). The didactic potential of virtual information educational environment as a tool of geography students training. *CEUR Workshop Proceedings*, 2547:13–23.
- Burov, O. Y., Kiv, A. E., Semerikov, S. O., Striuk, A. M., Striuk, M. I., Kolgatina, L. S., and Oliinyk, I. V. (2020). AREdu 2020 - How augmented reality helps during the coronavirus pandemic. *CEUR Workshop Proceedings*, 2731:1–46.
- Chen, P., Liu, X., Cheng, W., and Huang, R. (2017). A review of using augmented reality in education from 2011 to 2016. In Popescu, E., Kinshuk, Khribi, M. K., Huang, R., Jemni, M., Chen, N.-S., and Sampson, D. G., editors, *Innovations in Smart Learning*, pages 13–18, Singapore. Springer Singapore.
- Chen, Y.-C. (2019). Effect of mobile augmented reality on learning performance, motivation, and math anxiety in a math course. *Journal of Educational Computing Research*, 57(7):1695–1722.
- ec.europa.eu (2018). Council recommendation on key competences for lifelong learning. [https://ec.europa.eu/education/education-in-the-eu/council-recommendation-on-key-competences-for-lifelong-learning\\_en](https://ec.europa.eu/education/education-in-the-eu/council-recommendation-on-key-competences-for-lifelong-learning_en).
- Haranin, O. M. and Moiseienko, N. V. (2018). Adaptive artificial intelligence in RPG-game on the Unity game engine. *CEUR Workshop Proceedings*, 2292:143–150.
- Honcharova, N. (2019). Technology of augmented reality in textbooks of new generation. *Problems of the modern textbook*, 22:46–56.
- Iatsyshyn, A. V., Kovach, V. O., Romanenko, Y. O., Deinega, I. I., Iatsyshyn, A. V., Popov, O. O., Kutsan, Y. G., Artemchuk, V. O., Burov, O. Y., and Lytvynova, S. H. (2020). Application of augmented reality technologies for preparation of specialists of new technological era. *CEUR Workshop Proceedings*, 2547:181–200.
- Katsko, O. O. and Moiseienko, N. V. (2018). Development computer games on the Unity game engine for research of elements of the cognitive thinking in the playing process. *CEUR Workshop Proceedings*, 2292:151–155.
- Kiv, A. E., Shyshkina, M. P., Semerikov, S. O., Striuk, A. M., and Yechkalo, Y. V. (2020). AREdu 2019 – How augmented reality transforms to augmented learning. *CEUR Workshop Proceedings*, 2547:1–12.
- Kolomoiets, T. H. and Kassim, D. A. (2018). Using the augmented reality to teach of global reading of preschoolers with autism spectrum disorders. *CEUR Workshop Proceedings*, 2257:237–246.
- Kuznetsov, V. S., Moiseienko, M. V., Moiseienko, N. V., Rostalny, B. A., and Kiv, A. E. (2022). Using Unity to teach game development. In Semerikov, S., Osadchyi, V., and Kuzminska, O., editors, *Proceedings of the Symposium on Advances in Educational Technology, AET 2020*, Kyiv. University of Educational Management, SciTePress.
- Lavrentieva, O. O., Arkhyrov, I. O., Krupskyi, O. P., Velykodnyi, D. O., and Filatov, S. V. (2020). Methodology of using mobile apps with augmented reality in students' vocational preparation process for transport industry. *CEUR Workshop Proceedings*, 2731:143–162.
- Makhachashvili, R. K., Kovpiuk, S. I., Bakhtina, A. O., and Shmeltser, E. O. (2020). Technology of poetry presentation via Emoji Maker platform: Pedagogical function of graphic mimesis. *CEUR Workshop Proceedings*, 2643:264–280.
- Midak, L. Y., Kravets, I. V., Kuzyshyn, O. V., Berladyniuk, K. V., Buzhdyhan, K. V., Baziuk, L. V., and Uchitel, A. D. (2020a). Augmented reality in process of studying astronomic concepts in primary school. *CEUR Workshop Proceedings*, 2731:239–250.
- Midak, L. Y., Kravets, I. V., Kuzyshyn, O. V., Pahomov, J. D., Lutsyshyn, V. M., and Uchitel, A. D. (2020b). Augmented reality technology within studying natural subjects in primary school. *CEUR Workshop Proceedings*, 2547:251–261.
- Mintii, I. S. and Soloviev, V. N. (2018). Augmented reality: Ukrainian present business and future education. *CEUR Workshop Proceedings*, 2257:227–231.
- Nezhyva, L. L., Palamar, S. P., and Lytvyn, O. S. (2020). Perspectives on the use of augmented reality within the linguistic and literary field of primary education. *CEUR Workshop Proceedings*, 2731:297–311.
- osvitoria.media (2019). Virtual and augmented reality: how new technologies inspire learning. <https://osvitoria.media/opinions/virtualna-ta-dopovnena-realnist-yakoyu-mozhe-buty-suchasna-osvita/>.
- Palamar, S. P., Bieliienka, G. V., Ponomarenko, T. O., Kozak, L. V., Nezhyva, L. L., and Voznyak, A. V. (2021). Formation of readiness of future teachers to use augmented reality in the educational process of preschool and primary education. *CEUR Workshop Proceedings*, 2898:334–350.
- Pellas, N., Fotaris, P., Kazanidis, I., and Wells, D. (2019). Augmenting the learning experience in primary and secondary school education: a systematic review of recent trends in augmented reality game-based learning. *Virtual Reality*, 23(4):329–346.
- Petrovych, O. B., Vinnichuk, A. P., Krupka, V. P., Zelehenka, I. A., and Voznyak, A. V. (2021). The usage of augmented reality technologies in professional training of future teachers of Ukrainian language and literature. *CEUR Workshop Proceedings*, 2898:315–333.
- Pochtoviuk, S. I., Vakaliuk, T. A., and Pikilnyak, A. V. (2020). Possibilities of application of augmented reality in different branches of education. *CEUR Workshop Proceedings*, 2547:92–106.
- Rashevskaya, N. V., Semerikov, S. O., Zinonos, N. O., Tkachuk, V. V., and Shyshkina, M. P. (2020). Using augmented reality tools in the teaching of two-dimensional plane geometry. *CEUR Workshop Proceedings*, 2731:79–90.
- Sekerin, V. D., Gorokhova, A. E., Scherbakov, A. A., and Yurkevich, E. V. (2017). The interactive alphabet with augmented reality as a form of involving children in educational process. *Open Education*, 21(5):57–62.

- Semerikov, S. O., Mintii, M. M., and Mintii, I. S. (2021). Review of the course “Development of Virtual and Augmented Reality Software” for STEM teachers: implementation results and improvement potentials. *CEUR Workshop Proceedings*, 2898:159–177.
- Shepiliev, D. S., Semerikov, S. O., Yechkalo, Y. V., Tkachuk, V. V., Markova, O. M., Modlo, Y. O., Mintii, I. S., Mintii, M. M., Selivanova, T. V., Maksyshko, N. K., Vakaliuk, T. A., Osadchyi, V. V., Tarasenko, R. O., Amelina, S. M., and Kiv, A. E. (2021). Development of career guidance quests using WebAR. *Journal of Physics: Conference Series*, 1840(1):012028.
- Striuk, A., Rassovytska, M., and Shokaliuk, S. (2018). Using Blippar augmented reality browser in the practical training of mechanical engineers. *CEUR Workshop Proceedings*, 2104:412–419.
- Sáez-López, J.-M., Sevillano-García, M.-L., and Pascual-Sevillano, M.-d.-I.-Á. (2019). Aplicación del juego ubicuo con realidad aumentada en Educación Primaria (Application of the ubiquitous game with augmented reality in Primary Education). *Comunicar*, 27(61):71–81.
- Tarasenko, R. O., Amelina, S. M., Semerikov, S. O., and Shynkaruk, V. D. (2021). Using interactive semantic networks as an augmented reality element in autonomous learning. *Journal of Physics: Conference Series*, 1946(1):012023.
- Vakaliuk, T. A. and Pochtoviuk, S. I. (2021). Analysis of tools for the development of augmented reality technologies. *CEUR Workshop Proceedings*, 2898:119–130.
- Walsh, J., McMahon, D., Moriarty, P., O’Connell, M., Stack, B., Kearney, C., Brosnan, M., Fitzmaurice, C., McInerney, C., and Riordan, D. (2019). Virtual reality explorers. In *8th Edition of the New Perspectives in Science Education International Conference. Florence, Italy. 21–22 March 2019*. <https://conference.pixel-online.net/NPSE/files/npse/ed0008/FP/2473-EST3735-FP-NPSE8.pdf>.
- Zelinska, S. O., Azaryan, A. A., and Azaryan, V. A. (2018). Investigation of opportunities of the practical application of the augmented reality technologies in the information and educative environment for mining engineers training in the higher education establishment. *CEUR Workshop Proceedings*, 2257:204–214.
- Zinonos, N. O., Vihrova, E. V., and Pikilnyak, A. V. (2018). Prospects of using the augmented reality for training foreign students at the preparatory departments of universities in Ukraine. *CEUR Workshop Proceedings*, 2257:87–92.