

The course “Development of virtual and AR software” for STEM teachers

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Abstract. The article looks into the experience of development and using of learning resources for design of virtual reality (VR) and augmented reality (AR) systems for future STEM teachers. Unity environment for visual design, Visual Studio as a programming environment, platform of VR (Google VR) and AR (Vuforia) were chosen for development of teaching materials. The article describes the content of the created course. The research analyzes the impressions of the course participants. The research data were collected using interviews as the method of qualitative data collection. To conclude, the created course promotes the development of digital competence in the design and use of innovative learning tools.

1 Introduction

The technology of AR is well-known for most of people. It was under the close attention of Gartner analysts for many years. On July 2019, the Gartner Hype Cycle for Customer Service and Support Technologies reflected the increasing attention for such technologies as Blockchain, Field Service Drones, Mediated Interaction Matching, Things as Customers. At the peak of Hype Cycle are AR, Customer Psychographics, Workforce Engagement Management, IoT, Customer Journey

Analytics, Digital Experience Platforms, Engagement Hub, 360-Degree View, Chatbots, Conversational User Interfaces, Consumer Messaging Applications, Emotion Detection/Recognition, NLP, some disappointment is observed in VideoCalling, In-App Mobile Customer Service, Robotic Process Automation Software, Voice of the Customer. According to analysts at Gartner, it will take 5-10 years for AR to reach the performance plateau (when a new technology becomes established) (Fig. 1) [1].



Fig. 1. The Gartner Hype Cycle for Customer Service and Support Technologies.

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According to [2], among the Top 10 Strategic Technology Trends for 2020 are:

– multi-experience – in the future, this trend will become what’s called an ambient experience, but currently, multi-experience focuses on immersive experiences that use AR, VR, mixed reality (MR), multichannel human-machine interfaces and sensing technologies. The combination of these technologies can be used for a simple AR overlay or a fully immersive VR experience;

– human augmentation is the use of technology to enhance a person’s cognitive and physical experiences.

There are high expectations for AR and VR in education. Unfortunately, in Ukraine the technology of AR in the educational environment for training future teachers is almost absent. Despite the significant potential of AR for laboratory studies in Science and Math in secondary and high school in secondary and high school [4, 5, 6, 7, 8, 9, 10], for the training of future engineers [11, 12, 13], for extracurricular educational and research activities of students [14, 15], for foreign students’ adaption [16] and even for teaching global reading of preschool children with autism spectrum disorders [17].

These and other issues were discussed at the 1st [18] and 2nd [19] International workshops on AR in Education which took place in Kryvyi Rih.

Based on the current experience of using VR and AR technologies in education and the prospects for their release into the masses in next 5-10 years, it is necessary to think about the problem of preparing for the use of these innovative technologies in the professional activities of future STEM teachers. After all, in just a few years, today’s students will have to manage this process: both as software engineers and as teachers. Therefore, the main purpose of our research is to develop a training course on designing VR and AR systems for future STEM teachers, adapted to Ukrainian users and to the current level of technology development.

2 The research tasks

The object of the research is the professional training of future STEM teachers for the design of VR and AR technologies.

The subject of the research is the learning resources for the design of VR and AR systems for future STEM teachers.

The purpose of the research is to develop the learning resources for the design of VR and AR systems adapted for different types of learners.

To achieve the purpose of the research such tasks were solved:

1) an analysis of the experience of using AR tools for the development of educational materials was done;

2) the software for the design of AR tools for educational purposes were identified and the technological requirements for the course “Development of VR and AR software tools” were characterized;

3) individual components of the training complex for the design of VR and AR systems for future teachers majoring in STEM disciplines were developed.

3 Results and discussion

In the context of the study, AR is understood primarily as a synthetic environment, a kind of virtual environment in which real objects are complemented by their computer models. Therefore, among the professional requirements for developers of AR tools there are computer modeling, computer programming, computer graphics and computer ergonomics.

While solving the first problem, it was found out that at the present stage of development of information technologies, the leading means of implementing AR are mobile Internet devices – multimedia mobile devices that provide wireless access to information and communication Internet services for the collection, systematization, storage, processing, transmission, presenting all kinds of messages and data.

The use of AR technology in a mobile-oriented learning environment of higher education institutions:

– expands the capabilities of laboratory facilities used to prepare students for work with real systems;

– makes complex and expansive systems available;

– contributes to the improvement of vocational training by providing laboratory simulators with AR;

– motivates students for experimental and educational research work.

The creating of interactive training materials with the use of AR systems can be done in two main directions:

a) the use of utilities or linking markers with user-developed models;

b) the development of VR and AR software for educational purposes.

In the first direction, the developer does not require good programming skills, however, the functionality of the created tools is significantly limited by the relation to proprietary software. In the second direction, the developer needs develop tools himself. However, the functionality and adaptability of the developed tools are significantly increased.

Characterizing the technology of AR, one should point out the simplicity of reflection of virtual objects in it comparison to VR. Stages of developing an object for AR system are: 1) creating a visual model of the AR component in a 3D environment; 2) creating a simple marker in a 2D environment; 3) linking the marker with a 3D model in a software tool to maintain AR.

When the marker is recognized by software for maintaining AR, the corresponding 3D model is shown. This process is implemented according to the scheme shown in Fig. 2 [20].

To solve the second purpose of the study, we reviewed the tools for developing VR and AR and chose the most suitable for achieving the goal of the study. Among the reviewed, we note both the “old” Wikitude SDK [21] (since 2008) and the relatively new (since 2017) Apple tool – SDK ARKit [22]. The current version of ARKit allows you to develop multiplayer games with AR. ARCore [23] is a relatively new (March 2018) tool from Google, a kind of response to ARKit. Supported platforms: Android 7.0 and above, iOS 11 and above.

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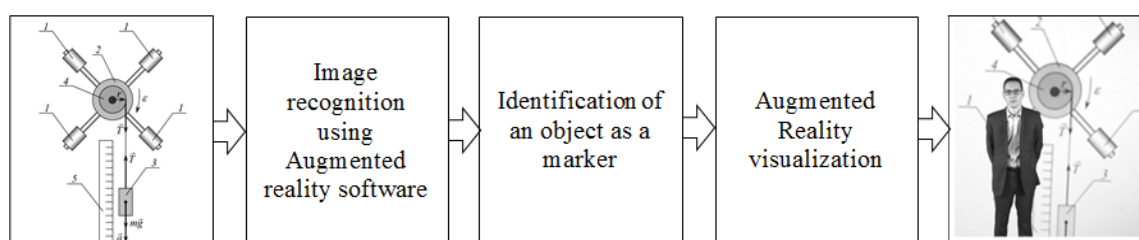


Fig. 2. AR schema.

ARCore comes with three main possibilities of combining VR and real worlds: 1) tracking the position of the phone in the environment; 2) “recognizing the environment” provides the ability of the phone to determine the size and location of horizontal surfaces; 3) lighting assessment allows the phone to evaluate the actual lighting conditions.

ARtoolKit [24] is the oldest (since 1999) SDK for the development of AR tools. It is available on Android, iOS, Linux, Windows, Mac OS, “smart glasses”.

Maxst [25] is the South Korean SDK. It offers advanced tools for recognizing images and environments. Maxst is freely distributed for non-commercial use, and the free version differs from the paid version only with a watermark.

Vuforia [26] is one of the most popular platforms for developing AR. SDK implements the following functionalities: recognition of various types of visual objects (box, cylinder, plane), recognition of text and surroundings, VuMark (combination of image and QR code). Using the Vuforia Object Scanner, you can scan and create marker objects. The recognition process can be implemented using a database (local or cloud storage). Unlike other SDKs, Vuforia supports both 2D and 3D markers, including Image Target markerless, three-dimensional Multi-Target, as well as benchmark markers that select objects in the scene for recognition.

In our opinion, in the process of preparing future STEM teachers for the use of AR systems for developing interactive teaching materials it is advisable to use an integrated approach. The design with use of standard objects can be performed in a visual design environment. Providing standard objects with new properties and creating new ones can be performed in an object-oriented programming environment. At the present stage

of ICT development, it is advisable to use the Unity environment [27] for visual design, Visual Studio [28] or a similar programming environment, as well as virtual platforms (Google VR or the like) and AR (Vuforia or the like).

The result of solving the third research problem is the course “Development of software tools for VR and AR”. The substantive basis this course is the open course from the University of San Diego on the EdX platform [29] and the book by Jesse Glover [30].

The course consists of two substantive modules.

Content module 1. Development of VR tools

Topic 1.1. VR and Game Engines

Topic 1.2. Physical interactions and camera

Topic 1.3. 3D interface and positioning

Topic 1.4. 3D user interaction

Topic 1.5. VR navigation and introduction

Content module 2. Development of AR tools

Topic 2.1. Set up AR tools in Unity 3D

Topic 2.2. Development of a project for a photograph

Topic 2.3. Development of training materials with Vuforia

Vuforia

Topic 2.4. Development for promising devices

80 students were involved in the experiment, which lasted from February 20, 2019 to January 20, 2020: POKT-18m and PO-16 groups of Faculty of Information Technology of the Kryvyi Rih National University and MIM-14 and FIM-14 groups of Faculty of Physics and Mathematics of the Kryvyi Rih State Pedagogical University.

Examples of completed tasks are shown in Fig. 3-5.

So, among the participants in the experiment, a survey was conducted on the formation of competence in the design and use of innovative learning tools. Survey results are shown in Fig. 6-7.

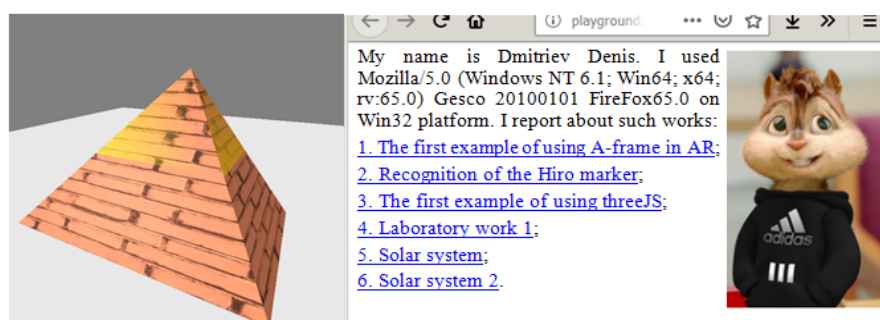


Fig. 3. The sandbox (example 1).

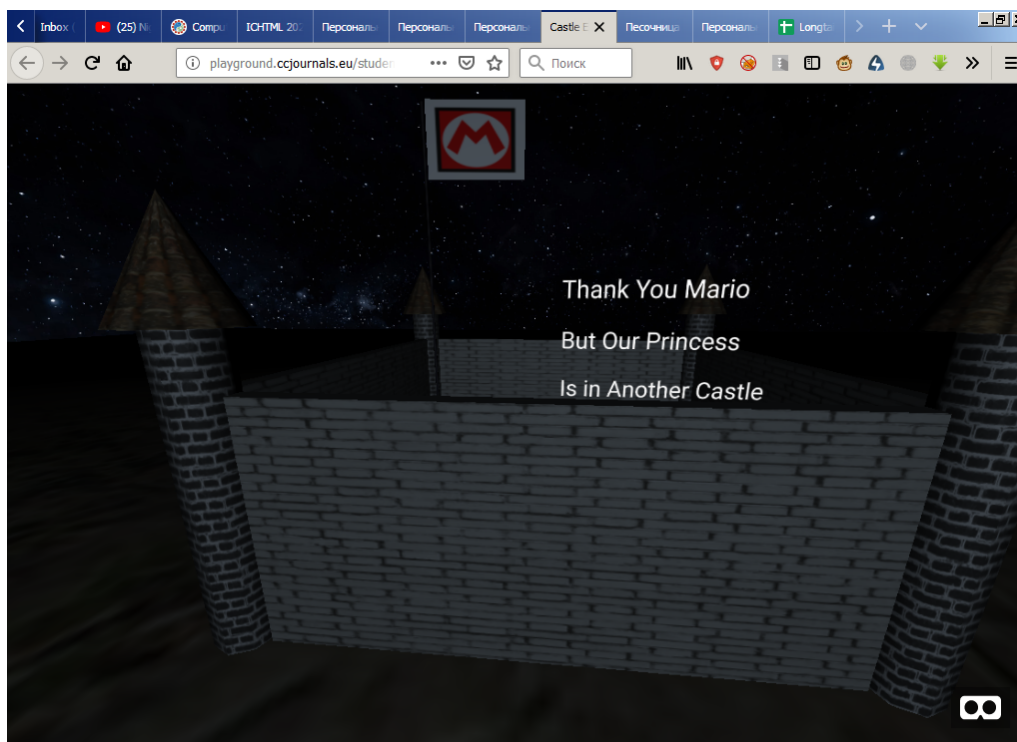


Fig. 4. The castle (example 2).

1. [A-Frame first start](#)
2. [Hiro marker](#)
3. [ThreeJS](#)
4. [Shader](#)
5. [Light](#)
6. [OrbitControls](#)
7. [Object](#)
8. **Awe marker**
 - 8.1. [Awe marker v. 1.0](#)
 - 8.2. [Awe marker v. 2.0](#)
 - 8.3. [Awe marker v. 3.0 modification](#)
9. [Solar system](#)
10. **Castle**
 - 10.1. A-Frame
 - 10.1.1. [Castle A-Frame](#)
 - 10.1.2. [Castle A-Frame Marker](#)
 - 10.1.3. [Castle A-Frame Marker Hiro](#)
 - 10.1.3.1. [Task Marker for A-Frame](#)
 - 10.1.3.2. [Marker Hiro](#)
 - 10.2. ThreeJS
 - 10.2.1. [Castle ThreeJS](#)
 - 10.3. 8th Wall
 - 10.3.1. [Castle 8th Wall by ThreeJS](#)
 - 10.4. Awe.js
 - 10.4.1. [Castle Awe.js](#)
 - 10.4.1.1. [Task marker for Awe.js](#)
11. [Portal](#)
12. ...

Fig. 5. Structure of completed tasks (example 3).

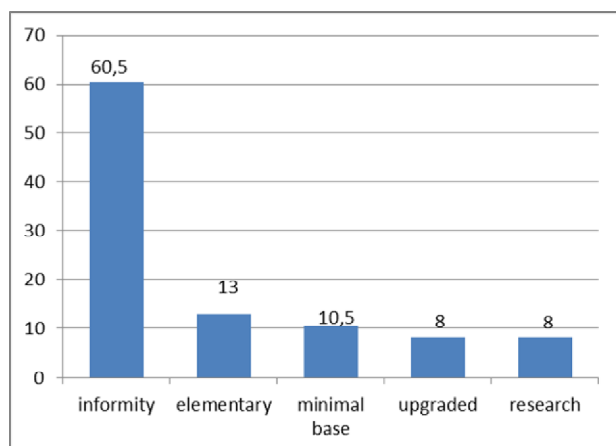


Fig. 6. Pre-course placement.

A survey was conducted after the course to obtain feedback on the impressions of the participants. The research data were collected using interview techniques

in qualitative data collection method. The survey was attended by 23 participants. It should be noted that at the time of the interview all of them were no longer students, but STEM teachers, which allows us to conclude that the responses received are independent. Gender distributions of the interviewees were three men and twenty women.

Interview questions:

1. Have you had any experience with AR before studying the course?
2. What was the most interesting thing to know?
3. Would you like to improve your knowledge of AR?
4. Do you use augmented reality in your professional activities?
5. What would you suggest to change to make the course more effective?

The content analysis method was used to analyze the interview data. Data analysis includes the editing, structuring, and interpretation of collected data.

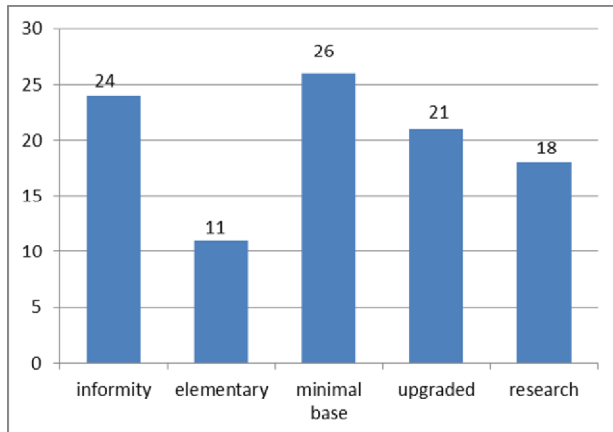


Fig. 7. Post-course placement.

1. Have you had any experience with augmented reality before studying the course?

Initially, the following answers to this question were supposed:

- Yes, I have developed applications myself.
- Yes, I used training applications.
- Yes, I used in everyday life (advertising, entertainment, etc.).
- No, I haven't.

As a result, only 4 of those respondents used AR earlier, and only in everyday life, the remaining 19 before the course had no idea about AR (Fig. 8).

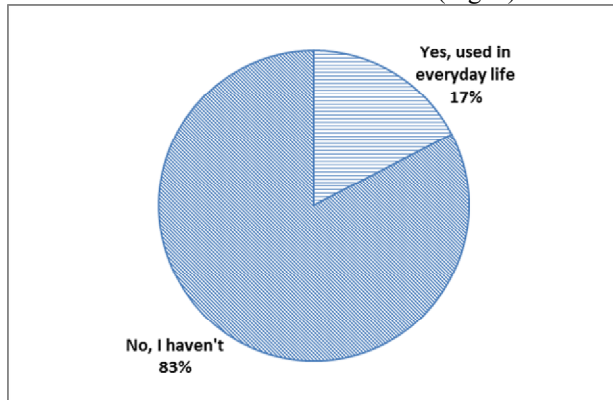


Fig. 8. Answers to the question "Have you had any experience with augmented reality before studying the course?"

2. What was the most interesting thing to know?

The meaning of 100% of respondents' answers was either to the process of development or the result of application development or the practical application of these applications.

All received answers were the application development; process of reviving pictures; convert 2D images to 3D; 3D modeling; practical application; visualization.

The most impressive answer was: "Results exceed all expectations".

3. Would you like to improve your knowledge of AR?

To this question 2 respondents gave a negative answer, 1 was difficult to answer, 15 answered in the

affirmative, and 5 said that they have already improved their knowledge. Fig. 9 shows the distribution of responses as a percentage.

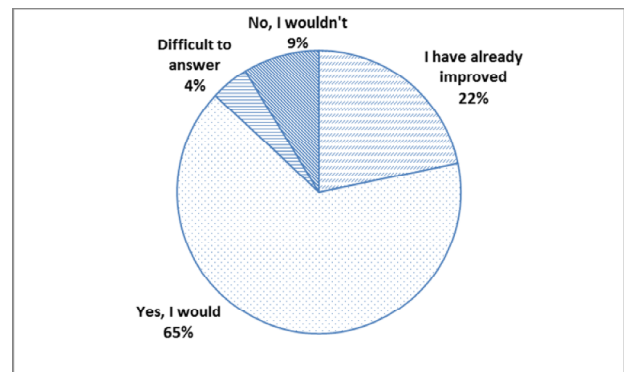


Fig. 9. Answers to the question "Would you like to improve your knowledge?"

4. Do you use AR in your professional activities?

All the received answers are:

- I'm already using it.
- I'm going to use.
- I think I will use it.
- No, I don't.

Respondents identified areas for using AR, such as a master class on the use of augmented reality for school teachers, when learning to program with high school students, when learning mathematics in specialized classes.

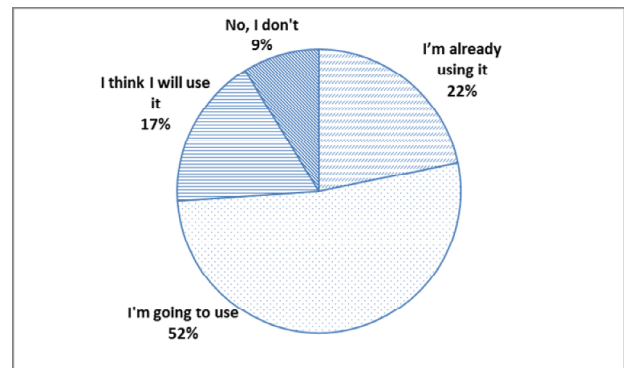


Fig. 10. Answers to the question "Do you use AR in your professional activities?"

One respondent immediately after the course during preparation for the state exam. One of the questions on the exam was "Demonstration of a fragment of a non-standard lesson". The theme of the lesson was "Creating logos. Brandguide. Brand book". The student used self-developed markers in the BlippAR environment to link the logo of the Google search (Fig. 11) with a URL-link to the Google form.



Fig. 11. The logo is an AR marker [31].

Further pupils should have united in groups, having chosen from the offered logos. Group named Historians, Lawyers, Designers, and Psychologists. Access codes for AR markers were 1150544, 1150549, 1150567 and 1150546 respectively (Fig. 12-13).



Fig. 12. Historians' and Lawyers' AR markers [32, 33].



Fig. 13. Designers' and Psychologists' AR markers [34, 35].

5. *What would you suggest to change to make the course more effective?*

The answers we've received:

- Reduce independent work.
- Increase classroom activities (lectures, labs, consultations).
- Extend the course for 2 semesters.
- Detail the methodological guidelines.
- Increase the number of practical tasks connected with STEM courses.
- The idea of conducting a survey using AR markers was interesting.

Conclusion

To get a complete picture of students' impressions of the course, it is necessary to reproduce exactly the answers of some students.

"Before the course, I had no idea what AR was. We enjoyed both the process and the result. And the result exceeded all expectations. The organization of the course was excellent. The presentation of the material in the lectures was available and dosed, the tasks in the laboratory classes were clear and had practical meaning."

"I use and plan to use received knowledge in the future because the AR is not only popular, but it also increases the level of understanding of the material, and what the most important is it helps to interest the student!"

Thus, the course "Development of VR and AR software" promotes the development of competence in the design and using innovative learning tools. The research is not completed, the implementation of the developed course and experimental verification of its effectiveness has been continuing.

References

1. Highlights From Gartner Hype Cycle for Customer Service and Support Technologies (2019), <https://www.gartner.com/smarterwithgartner/highlights-from-gartner-hype-cycle-for-customer-service-and-support-technologies-2019/>. Accessed 27 Jan 2020
2. Gartner Top 10 Strategic Technology Trends for 2020 (2019), <https://www.gartner.com/smarterwithgartner/gartner-top-10-strategic-technology-trends-for-2020>. Accessed 27 Jan 2020
3. 5 Trends Emerge in the Gartner Hype Cycle for Emerging Technologies (2018), <https://www.gartner.com/smarterwithgartner/5-trends-emerge-in-gartner-hype-cycle-for-emerging-technologies-2018/>. Accessed 4 Feb 2020
4. P.P. Nechypurenko, V.N. Soloviev, Using ICT as the Tools of Forming the Senior Pupils' Research Competencies in the Profile Chemistry Learning of Elective Course "Basics of Quantitative Chemical Analysis". CEUR Workshop Proceedings **2257**, 1–14 (2018)
5. P.P. Nechypurenko, T.V. Starova, T.V. Selivanova, A.O. Tomilina, A.D. Uchitel, Use of Augmented Reality in Chemistry Education. CEUR Workshop Proceedings **2257**, 15–23 (2018)
6. O.V. Komarova, A.A. Azaryan, Computer Simulation of Biological Processes at the High School. CEUR Workshop Proceedings **2257**, 24–32 (2018)
7. T.V. Hruntova, Yu.V. Yechkalo, A.M. Striuk, A.V. Pikilnyak, Augmented Reality Tools in Physics Training at Higher Technical Educational Institutions. CEUR Workshop Proceedings **2257**, 33–40 (2018)
8. O.V. Merzlykin, I.Yu. Topolova, V.V. Tron, Developing of Key Competencies by Means of Augmented Reality at CLIL Lessons. CEUR Workshop Proceedings **2257**, 41–52 (2018)
9. V.L. Buzko, A.V. Bonk, V.V. Tron, Implementation of Gamification and Elements of Augmented Reality During the Binary Lessons in a Secondary School. CEUR Workshop Proceedings **2257**, 53–60 (2018)
10. V.B. Shapovalov, A.I. Atamas, Zh.I. Bilyk, Ye.B. Shapovalov, A.D. Uchitel, Structuring Augmented Reality Information on the stemua.science. CEUR Workshop Proceedings **2257**, 75–86 (2018)
11. N.V. Rashevskaya, V.N. Soloviev, Augmented Reality and the Prospects for Applying Its in the Training of Future Engineers. CEUR Workshop Proceedings **2257**, 192–197 (2018)
12. V.S. Morkun, S.O. Semerikov, N.V. Morkun, S.M. Hryshchenko, A.E. Kiv, Defining the Structure of Environmental Competence of Future Mining Engineers: ICT Approach. CEUR Workshop Proceedings **2257**, 198–203 (2018)

13. S.O. Zelinska, A.A. Azaryan, V.A. Azaryan, 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 (2018)
14. I.S. Mintii, V.N. Soloviev, Augmented Reality: Ukrainian Present Business and Future Education. *CEUR Workshop Proceedings* **2257**, 227–231 (2018)
15. M.V. Popel, M.P. Shyshkina, The Cloud Technologies and Augmented Reality: the Prospects of Use. *CEUR Workshop Proceedings* **2257**, 232–236 (2018)
16. N.O. Zinonos, E.V. Vihrova, A.V. Pikilnyak, Prospects of Using the Augmented Reality for Training Foreign Students at the Preparatory Departments of Universities in Ukraine. *CEUR Workshop Proceedings* **2257**, 87–92 (2018)
17. T.H. Kolomoiets, D.A. Kassim, Using the Augmented Reality to Teach of Global Reading of Preschoolers with Autism Spectrum Disorders. *CEUR Workshop Proceedings* **2257**, 237–246 (2018)
18. A.E. Kiv, V.N. Soloviev (ed.), *CEUR Workshop Proceedings* **2257** (2018)
19. A.E. Kiv, M.P. Shyshkina (ed.), *CEUR Workshop Proceedings* **2547** (2019)
20. Ye.O. Modlo, Yu.V. Yechkalo, S.O. Semerikov, V.V. Tkachuk, *Vykorystannia tekhnolohii dopovnenoj realnosti u mobilno oriietovanomu seredovyshchi navchannia VNZ* (Using technology of AR in a mobile-based learning environment of the higher educational institution), *Naukovi zapysky, Serii: Problemy metodyky fizyko-matematychnoi i tekhnolohichnoi osvity* **11**, 93–100 (2017)
21. Wikitude Cross-Platform Augmented Reality SDK – Boost your app (2020), <https://www.wikitude.com/products/wikitude-sdk/>. Accessed 27 Jan 2020
22. ARKit 3 – Augmented Reality | Apple Developer (2020), <https://developer.apple.com/augmented-reality/arkit/>. Accessed 27 Jan 2020
23. ARCore – Google Developers | Google Developers (2020), <https://developers.google.com/ar>. Accessed 27 Jan 2020
24. ARToolKit Home Page (2020), <http://www.hitl.washington.edu/artoolkit/>. Accessed 27 Jan 2020
25. MAXST | Technology company specialized in AR (2020), <http://maxst.com/#/>. Accessed 27 Jan 2020
26. Vuforia: Market-Leading Enterprise AR | PTC (2020), <https://www.ptc.com/en/products/augmented-reality/vuforia>. Accessed 27 Jan 2020
27. Unity Real-Time Development Platform | 3D, 2D VR & AR Visualizations (2020), <https://unity.com/>. Accessed 27 Jan 2020
28. Visual Studio 2019 | Visual Studio (2020), <https://visualstudio.microsoft.com>. Accessed 27 Jan 2020
29. Virtual Reality (VR) App Development (UC San Diego, 2019), <https://www.edx.org/professional-certificate/ucsandiegox-virtual-reality-app-development>. Accessed 27 Jan 2020
30. J. Glover, *Unity 2018 AR Projects: Build four immersive and fun AR applications using ARKit, ARCore, and Vuforia* (Packt Publishing, Birmingham, 2018)
31. Google (2020), <https://www.google.com/>. Accessed 27 Jan 2020
32. BMW.com | The international BMW Website (2020), <https://www.bmw.com/>. Accessed 27 Jan 2020
33. Alfa Romeo – Wikipedia (2020), https://en.wikipedia.org/wiki/Alfa_Romeo. Accessed 27 Jan 2020
34. Fanta – Wikipedia (2020), <https://en.wikipedia.org/wiki/Fanta>. Accessed 27 Jan 2020
35. Sprite (drink) – Wikipedia (2020), [https://en.wikipedia.org/wiki/Sprite_\(drink\)](https://en.wikipedia.org/wiki/Sprite_(drink)). Accessed 27 Jan 2020