Analytical review of augmented reality MOOCs

Liubov F. Panchenko[0000-0002-9979-0625]

National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute",
37, Peremohy Ave., Kyiv, 03056, Ukraine
lubov.felixovna@gmail.com

Ivan O. Muzyka[0000-0002-9202-2973]

Kryvyi Rih National University, 11, Vitaliy Matusevych Str., Kryvyi Rih, 50027, Ukraine
musicvano@gmail.com

Abstract. *The aim* of the article is to provide an analytical review of the content of massive open online courses about augmented reality and its use in education with the further intent to create a special course for the professional development system for the research and teaching personnel in postgraduate education. *The object of research* is massive open online courses. The *subject of the study* is the structure and content of augmented reality MOOCs which are offered by acclaimed providers of the world. *The methods of research* are: the analysis of publications on the problem; the analysis of MOOCs' content, including observation; systematization and generalization of research information in order to design a special course about augmented reality for the system of professional training and retraining for educators in postgraduate education. *The results of the research* are the following: the content and program of specialized course "Augmented Reality as a Storytelling Tool" for the professional development of teachers. *The purpose of the specialized course* is to consider and discuss the possibilities of augmented reality as a new direction in the development of educational resources, to identify its benefits and constraints, as well as its components and the most appropriate tools for educators, to discuss the problems of teacher and student co-creation on the basis of the use of augmented reality, and to provide students with personal experience in designing their own stories and methodical tools in the form of augmented books and supplementary training aids with the help of modern digital services.

Keywords: massive open online courses, augmented reality, augmented books, professional training and retraining.

1 Introduction

Augmented reality is considered a world trend. Tim Cook, executive director of Apple, says he believes more in the success of augmented reality, rather than the virtual reality, since the former allows people to use new technology and stay in the real world; and he considers the augmented reality to be as "a great idea as smartphones" [26].

Augmented reality allows you to combine the real world with virtual objects and possesses vast and diversified didactic learning opportunities. Use of augmented reality in education has been analyzed by numerous Ukrainian researchers, for instance Yevhenii O. Modlo and others presents using technology of augmented reality in a mobile-based learning environment of the higher educational institution [17; 18; 30]; Tamila H. Kolomoiets and others describe the use the augmented reality in teaching global reading to preschoolers with autism spectrum disorders [13], Pavlo P. Nechypurenko and others analyzed augmented reality in chemistry education [19; 20].

Consequently, we consider it very important tasks to train teachers to use it in the classroom.

UNESCO's motto "Lifelong Learning" suit educators better than anybody else, since, despite their long working hours, sometimes lack funds and opportunities for official retraining, but should always remain at the top of education and research work, constantly updating the content of training programs in accordance with innovative educational processes and changes taking place in the world.

While solving the scientific problem of training educators for using the augmented reality in education, the following main results were obtained in past author works: the potential of the massive open online course (MOOC) phenomenon as an alternative form of teacher training (Coursera, Udacity, edX, etc.) was analyzed [23], the facet classification of the MOOCs was offered [22], the fundamentals of the specialized course "Digital Storytelling in Adult Education" were designed [22; 25], the form of co-creation of teacher and students in the educational environment was described [24].

2   Research objective and methods

Therefore, *the aim* of the article is to provide analytical review of the content of massive open online courses about augmented reality and its use in education with the further intent to create a specialized course for the system of professional training and retraining for educators in postgraduate education.

The methods of research are: the analysis of the publications on the problem; the analysis of the content of MOOCs about augmented reality, including observation; systematization and generalization of research information in order to develop a specialized course about augmented reality for the system of professional training and retraining for educators in postgraduate education.

3   Results and discussion

MOOC (massive open online course) is a kind of online course in which a large number of participants (up to 50,000) can participate, with open access to all materials via the Internet. The most well-known providers of massive online open courses are Coursera [4], Udacity [15], edX [6], FutureLearn [8], the Ukrainian projects are: Prometheus [27] and Ed-Era [5]. Ed-Era focuses precisely on secondary education.

Researchers distinguish two kinds of MOOC, conventionally referred to as xMOOC and cMOOC [14].

The prefix "c" in the cMOOC name refers to "connectivism", and such courses include George Siemens, Stephen Downes et al. [2; 28]. In connectivism's courses, knowledge is created and generated as a result of course participants processing large volumes of unstructured information; such courses are a private initiative of individual members of the teaching community, and are usually not funded.

The second category of MOOCS, xMOOC, includes projects such as Coursera, Udacity, edX. Such courses are mostly content-oriented. They contain videos, questionnaires, tests; the educational information is clearly structured, and mandatory student knowledge control and duplication of knowledge is present.

Let us look at the content of some of the most recent MOOCs about the augmented reality (table 1).

Table 1. Augmented Reality MOOC

No	MOOC	Platform	Brief Description	Software of Augmented Reality
1.	Getting Started with Augmented Reality, Institut Mines-Tele-com, 2017-2018 [9]	Coursera	Introduction to augmented reality. Augmented Books. Augmented games.	Third partytools http://mymultimediaworld.com, ARAF browser
2.	21st Century Learning, Self-Paced, University of Bath, University of Naples Federico II, Self-Paced [3]	EMMA	Tools and practice of teaching in the 21st century. Evaluation of personal digital literacy, creation of personal learning environment, finding open educational resources, learning about virtual worlds.	–
3.	Emerging Technologies: From Smartphones to IoT to Big Data Specialization, 2017-2018, Yonsei University [7]	Coursera	Fundamental functions, history of virtual and augmented realities, technologies of augmented reality.	–
4.	Zappar Powered STEM Learning Using Augmented Reality, 2016, Self-Paced [32; 33]	Canvas	The creation of augmented poster for scientists in the framework of STEM education	ZapWorks
5	Introduction to Augmented Reality and ARCore, 2018 [11]	Coursera	Fundamentals of augmented reality, and how to build an AR experience using ARCore.	ARCore
6	Introduction to XR: VR, AR, and MR Foundations, 2018 [12]	Coursera	The first course of the "Unity XR" specialization. An introduction to XR (AR, VR, and MR), brief description of each	Unity

No	MOOC	Platform	Brief Description	Software of Augmented Reality
			technology's, history, limitations and future potential for improvement.	

Let us study these courses in more detail.

The first course "Getting Started with Augmented Reality" includes the following 5 modules:

− Introducing Mixed and Augmented Reality
− Augmented Books
− Augment Your City Map
− Augmented Reality with Geolocation
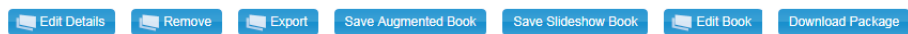− Customizing an Augmented Reality Game

Module 1. Introduction to mixed and augmented reality. The basics of understanding when working with computers and complementing reality, the basic characteristics of AR systems and the basic components of AR architecture.

Module 2. In this module, the user will create augmented reality application − augmented book with authoring tool (Fig. 1).


Fig. 1. The augmented book, attached to the story "Invisible" by Maria Primachenko, made during the course

Module 3. In this module the user will build the application, in which a 3D model is added to a city map.

Module 4. This module is about the creation of augmented reality application − geolocalized quiz (Fig. 2).

Module 5. This module is about understanding the ARAF format for quiz and changing the behavior of this application.

The 5th module of the 21st Century Learning course [3] is dedicated to virtual and augmented realities. Students need to learn how to distinguish between games, serious games, gameplay, virtual worlds, and augmented reality. The module demonstrates using games as learning tools and changing people's behavior, as gaming can inspire students; exploring virtual worlds and virtual reality as learning environments; augmented reality as a learning tool for the future. The course uses interesting videos, such as dinosaurs at the mall (from National Geographic [1]).
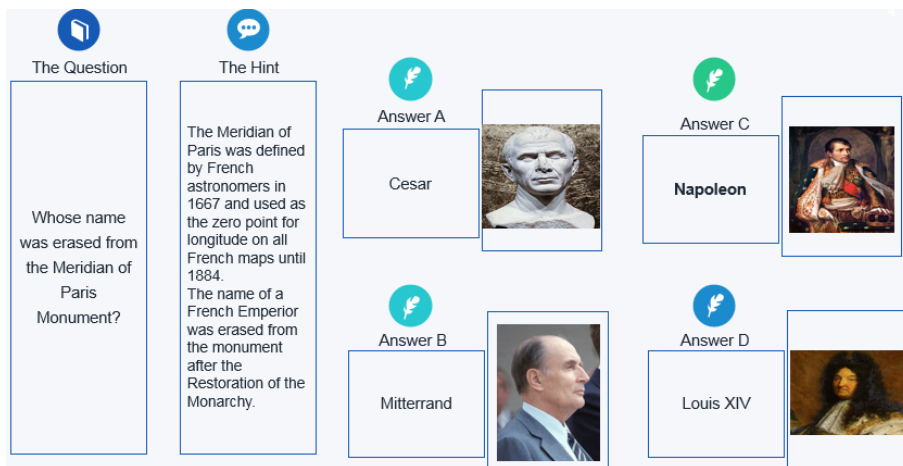
Fig. 2. The augmented reality quiz "Parc Montsouris" [9]

The activity of the students in the course is to participate in the discussion and to describe their personal experience. At the end of each week, one of the developers of the course in the blog summarizes the results of the discussion. In the discussion, students list the applications they worked with, such as Sky Map, as well as zoo burst (http://inform-lider.blogspot.com/2013/10/3d-zooburstcom.html). This course can be categorized as cMOOC.

The second week of the course of the *Internet of Things & Augmented Reality Emerging Technologies* [7] on Coursera platform is dedicated to the augmented reality. Lectures cover the purpose and main functions of the AR. The characteristics and a brief history of virtual and supplemented reality are presented, some definitions of AR; AR technology and directly the process of AR and its stages are given. Tests that check the understanding of the lecture material are offered (Fig. 3).

Thus, the course consists of the following elements: video lectures with built-in questions, tests that help to recall and review the lecture material, a list of further reading, which for the second week of the course consists of only one article, which is indicated as optional [21]. There are no practical tasks in the course.

The Zappar Powered STEM Learning Using Augmented Reality 2016 is based on the use of ZapWorks software. ZapWorks is a complete AR toolkit created by Zappar

[32]. It allows different users to create their own AP experience. ZapWorks includes three tools: widgets, designer and studio. In this online course, a simple "Designer" tool is used (Fig. 4).

The course consists of 9 small simple modules: 1) introduction to the course; 2) what is added to reality; 3) the objectives of the course; 4) introduction to ZapWorks; 5) creation of a ZapWorks account; 6) explanation of the cycle of water circulation (Fig. 5); 7) preparation and planning of the poster; 8) designing a poster; 9) the experience of creating an augmented reality. Each module contains a brief video lecture, its text summary, and tests.

An AR workflow is described below. Find the processes that properly fills the blanks in ⓐ-ⓑ-ⓒ-ⓓ order among the options below.

AR System   **User**

ⓐ

ⓑ   ⓓ   Visual Feedback

ⓒ   **Interaction**   Input
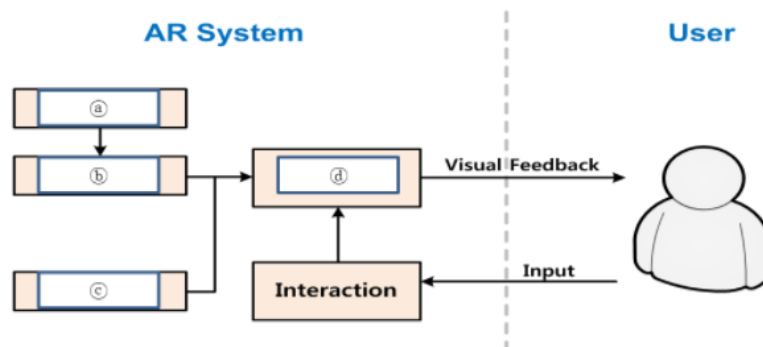
○ Detection – Tracking – Rendering - Contents

○ Detection – Tracking – Contents - Rendering

○ Tracking – Detection – Contents - Rendering

○ Tracking – Detection – Rendering - Contents

Fig. 3. The test question from "Internet of Things & Augmented Reality Emerging Technologies" course [7]
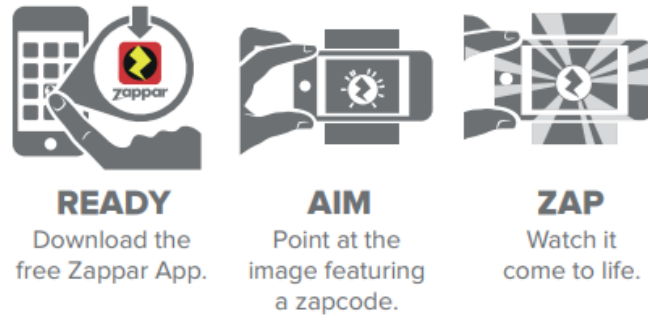
Fig. 4. Augmented reality in the Zappar App [32]

The sequence of creating augmented reality in this course is as follows:

1. choice of own multimedia content and decision on how it will be presented;
2. adding button images, video, links, audio;
3. adding different "scenes" that are similar to slides in PowerPoint;
4. adding conversions so that content is displayed in a variety of ways;
5. adding actions to allow users to interact with the content.

The authors also provided small guidance for 4 lessons on the use of this tool in 5th and 6th grade secondary schools [33].
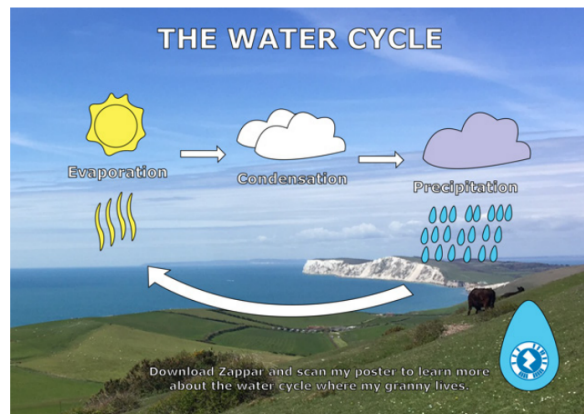
Fig. 5. Module 6 of "Zappar Powered STEM Learning Using Augmented Reality" course [33]

"Introduction to Augmented Reality and ARCore" [11] teach the fundamentals of augmented reality and how to build an AR experience using ARCore. The 4 units of course are: "Introduction to AR", "The basics of AR functionality", "Taking the next steps with ARCore", "Bringing ARCore to life". The course is great for beginners who are just getting started with AR or ARCore. Authors consider advanced 3D design tools like Maya, Zbrush, Blender, and 3ds Max powerful professional tools; and Google's

Poly (repository of 3D assets) can be a good starting resource for building first ARCore experience. In the course next resources proposed: Poly, Tilt Brush, Blocks, Google Development Portal, Unity, Sceneform. The users must fill the spreadsheet and describe the technology they learn about (Fig. 6).

The topics on course discussion forum are: "Looking to the future of augmented reality", "Understanding AR essentials", "Thinking about your users", "Your own AR journey".

"Introduction to XR: VR, AR, and MR Foundations" [12] is the first of the three planned courses in Unity's XR Specialization. This course is an introduction to XR (AR, VR, and MR), and briefly describes each technology, its history, limitations and future potential for improvement. The users will create two simple applications on their own smartphone: a virtual reality museum and a handheld augmented reality application. The user will brainstorm, define, and visualize their own original concept for an XR application and participate in a peer-reviewed activity. There are peer-graded assignments: brainstorm XR application ideas and XR product brief.

Fig. 6. The spreadsheet with technology description [11]

In the Table 2 we present some features of Coursera's MOOCs about augmented reality (as in January, 2019). All of the courses are introduction courses and not oriented towards educators. We think, it's possible to use the fragments of these courses in the framework of blended education of educators.

Table 2. Course rating

Course	Score	Ratings	Reviews	Year
Introduction to Augmented Reality and ARCore	4,4	495	150	2018
Introduction to XR: VR, AR, and MR Foundations	4,8	6	2	2018
Getting started with Augmented Reality	4,3	133	30	2016-2018

Taking into account the purpose of our article, that is the development of the content of the special course for educators on the use of additional reality in the educational process, we offer the augmented books as a practical component. An augmented book represent a physical or digital copy of a traditional book that contains text and illustrations, and which is connected to additional, non-traditional content through the

176

technology of augmented reality. When the reader accesses the book page for which additional content is specified, the smartphone or other device reads it and displays this additional content on the screen. Additional content may represent a simple image, video file or audio recording, and also be complex, representing animation, play, or interactive activity.

Researches place the augmented books between virtual and mixed reality books on the corresponding reality – virtuality continuum, presented in Fig. 7.

The author module "Augmented reality as a tool for storytelling" consist of next blocks:

‒ thematic plan of the module (Table 3);
‒ content of the module by themes;
‒ lecture plans;
‒ plans of practical classes;
‒ independent work of students;
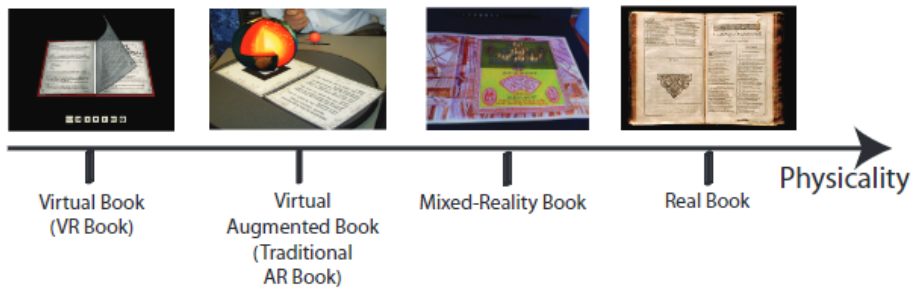‒ practical tasks for self-control;
‒ recommended reading.

Fig. 7. Virtual book typology [10]

Table 3. Thematic module plan

No	Thematic module	Class format, hours			
		Lections	Practices	Independent work	Total
1	Augmented Reality as a Storytelling Tool	2		2	4
2	Software and Internet Services about Augmented Reality. Augmented books. Augmented books tools.		2	2	4
	Total	2	2	4	8

"Augmented Reality as a Storytelling Tool" lecture plan

Determining reality-virtuality continuum. Virtual reality. Augmented reality. Mixed reality. Examples of application of augmented reality in various industries. Augmented reality in education. Massive open online courses on augmented reality. Tools and platforms used in the augmented reality landscape. Digital storytelling in adult education. Augmented reality as a storytelling tool.

"Software and Internet Services about Augmented Reality" practical training plan.

Motion tracking for augmented reality. Accelerometer. Gyroscope. Phone camera. Location-based augmented reality. Magnetometer. GPS.

Augment Education. Sky Map. Human Anatomy Atlas. HP Reveal (Aurasma). Vuforia, ARToolkit. EasyAR. Wikitude.

Google Poly. Tit Brush. Blocks.

Typology of virtual books. Examples of augmented books. Children's books. Digital stories with augmented reality.

Sample practice tasks for educators:

1. participate in discussion of "Introduction to Augmented Reality and ARCore" course discussion forum in the following topics: "Looking to the future of augmented reality", "Understanding AR essentials", "Thinking about your users", "Your own AR journey";
2. create a sample augmented book about Maria Primachenko's artwork (according to the guidelines of course "Getting started with Augmented Reality");
3. analyze the video about an augmented book from Ukrainian company Live Animations & Little Hippo. The company has released 4 world-famous children's books with Little Hippo: "Little Red Riding Hood", "Three Little Pigs", "Velveteen Rabbit", "Masha and the Three Bears" [16];
4. find and analyze some augmented books according to the professional interests of the student;
5. discuss how augmented reality can help the following: 1) allow student to construct their own understanding or experience in a content area; 2) facilitate collaborative activities in which students work together in small groups; 3) promote in-class discussion; 4) help learn problem-solving and critical thinking skills; 5) help understand complex ideas; 6) introduce student to new content [31];
6. design and create a fragment of their own textbook with augmented reality.

We believe that an augmented textbook is a new educational tool, it can contain fragments of video lectures, electronic pads such as Padlet, augmented quizzes, animated tours in the history of the problem being studied, in-depth exercises, and so on.

We also think that the use of additional reality technology will facilitate the co-creation of students and teachers. We understand co-creation [22] as a joint creative activity of a teacher and a student, aimed at developing the educational environment and ourselves in this environment. Because "the environment begins where their meeting occurs and where they jointly develop or build something" [29].

4 Conclusions

Thus, the augmented reality can provide modern education with new didactic measurements and tools at the teacher and student level, contribute to a better understanding of complex topics, visualize hidden processes, which makes it acceptable for adults and people with disabilities. On the basis of the analysis of the content of the

massive open online courses about augmented reality offered by well-known providers of the world, the author's specialized course "Augmented Reality as a Tool for Storytelling in Adult Education" is proposed for the system of professional training and retraining of teachers. The purpose of the special course is to consider and discuss the possibilities of augmented reality as a new direction in the development of educational resources, to identify its benefits and constraints, the components and the most appropriate tools for educators, discuss the problems of teacher and pupil co-creation on the basis of the use of augmented reality, and to provide students with personal experience in designing their own stories and methodical tools in the form of augmented books with the help of modern digital technologies.

The further development of the study is seen in the analysis of the specialty Unity XR on the platform Coursera as well as looking for ways to integrate augmented reality into existing learning management systems.

References

1. AvatarSupiddGuy: Live Augmented Reality-National Geographic. https://www.youtube.com/watch?v=D0ojxzS1fCw (2011). Accessed 21 Mar 2017
2. Baker, T.J.: Connectivism and Connected Knowledge: Participating in a MOOC. Amazon, Toronto (2012)
3. Conole, G.: 21st Century Learning. https://platform.europeanmoocs.eu/course_21st_century_learning (2015).
4. Coursera | Build Skills with Online Courses from Top Institutions. https://www.coursera.org/ (2019). Accessed 28 Nov 2019
5. EdEra – studiia onlain-osvity (EdEra – online education studio). https://www.ed-era.com/ (2019). Accessed 28 Nov 2019
6. edX | Free Online Courses by Harvard, MIT, & more. http://www.edx.org/ (2019). Accessed 28 Nov 2019
7. Emerging Technologies: From Smartphones to IoT to Big Data Specialization. https://www.coursera.org/specializations/emerging-technologies (2019). Accessed 18 Jan 2019
8. FutureLearn: Online Courses and Degrees from Top Universities. http://www.futurelearn.com/ (2019). Accessed 28 Nov 2019
9. Getting started with Augmented Reality | Coursera. https://www.coursera.org/learn/augmented-reality/home (2016). Accessed 18 Jan 2019
10. Grasset, R., Dunser, A., Billinghurst, M.: Design of a Mixed-Reality Book: Is It Still a Real Book? In: Proceeding of the 17th IEEE/ACM International Symposium on Mixed and Augmented Reality, Cambridge, 15–18 September 2008, pp. 99–102. IEEE (2008). doi:10.1109/ISMAR.2008.4637333
11. Introduction to Augmented Reality and ARCore | Coursera. https://www.coursera.org/learn/ar (2019). Accessed 18 Jan 2019
12. Introduction to XR: VR, AR, and MR Foundations | Coursera. https://www.coursera.org/learn/xr-introduction (2018). Accessed 18 Jan 2019
13. Kolomoiets, T.H., Kassim, D.A.: Using the Augmented Reality to Teach of Global Reading of Preschoolers with Autism Spectrum Disorders. In: Kiv, A.E., Soloviev, V.N. (eds.) Proceedings of the 1st International Workshop on Augmented Reality in Education (AREdu

2018), Kryvyi Rih, Ukraine, October 2, 2018. CEUR Workshop Proceedings **2257**, 237–246. http://ceur-ws.org/Vol-2257/paper24.pdf (2018). Accessed 30 Nov 2018

14. Kuharenko, V.N.: Innovatsii v E-learning: massovyiy otkryityiy distantsionnyiy kurs (Innovation in e-learning: a massive open distance course). Vyisshee obrazovanie v Rossii 10, 93–99 (2011)

15. Learn the Latest Tech Skills; Advance Your Career | Udacity. https://www.udacity.com/ (2019). Accessed 28 Nov 2019

16. Live Animations RU: Kniga AR Krasnaja shapochka (Book AR Little Red Riding Hood). https://www.youtube.com/watch?time_continue=33&v=46cbUGAQIq4 (2018). Accessed 25 Oct 2018

17. Modlo, E.O., Echkalo, Yu.V., Semerikov, S.O., Tkachuk, V.V.: Vykorystannia tekhnolohii dopovnenoi realnosti u mobilno oriientovanomu seredovyshchi navchannia VNZ (Using technology of augmented reality in a mobile-based learning environment of the higher educational institution). Naukovi zapysky, Seriia: Problemy metodyky fizyko-matematychnoi i tekhnolohichnoi osvity 11(1), 93–100 (2017)

18. Modlo, Ye.O., Semerikov, S.O., Bondarevskyi, S.L., Tolmachev, S.T., Markova, O.M., Nechypurenko, P.P.: Methods of using mobile Internet devices in the formation of the general scientific component of bachelor in electromechanics competency in modeling of technical objects. In: Kiv, A.E., Shyshkina, M.P. (eds.) Proceedings of the 2nd International Workshop on Augmented Reality in Education (AREdu 2019), Kryvyi Rih, Ukraine, March 22, 2019, CEUR-WS.org, online (2020, in press)

19. Nechypurenko, P.P., Starova, T.V., Selivanova, T.V., Tomilina, A.O., Uchitel, A.D.: Use of Augmented Reality in Chemistry Education. In: Kiv, A.E., Soloviev, V.N. (eds.) Proceedings of the 1st International Workshop on Augmented Reality in Education (AREdu 2018), Kryvyi Rih, Ukraine, October 2, 2018. CEUR Workshop Proceedings **2257**, 15–23. http://ceur-ws.org/Vol-2257/paper02.pdf (2018). Accessed 30 Nov 2018

20. Nechypurenko, P.P., Stoliarenko, V.G., Starova, T.V., Selivanova, T.V., Markova, O.M., Modlo, Ye.O., Shmeltser, E.O.: Development and implementation of educational resources in chemistry with elements of augmented reality. In: Kiv, A.E., Shyshkina, M.P. (eds.) Proceedings of the 2nd International Workshop on Augmented Reality in Education (AREdu 2019), Kryvyi Rih, Ukraine, March 22, 2019, CEUR-WS.org, online (2020, in press)

21. Olsson, T., Salo, M.: Online User Survey on Current Mobile Augmented Reality Applications. In: Proc. IEEE International Symposium on Mixed and Augmented Reality, Basel, 26–29 October 2011, pp. 75–84. IEEE (2011). doi:10.1109/ISMAR.2011.6162874

22. Panchenko, L.F.: Masovi onlain vidkryti kursy dlia rozvytku pedahoha novoi ukrainskoi shkoly (Massive open online courses for the development of a teacher of a new Ukrainian school). Metodyst 2, 59–64 (2018)

23. Panchenko, L.F.: Masovyi vidkrytyi on-lain kurs yak alternatyvna forma pidvyshchennia kvalifikatsii vykladacha vyshchoi shkoly (The massive open online course as an alternative form of training high school teacher). Education and pedagogical sciences 1(156), 19–28 (2013)

24. Panchenko, L.F.: Spivtvorchist vykladacha ta studenta v informatsiino-osvitnomu seredovyshchi universytetu (Creativity of the teacher and student in the university's informational and educational environment). Osvita Donbasu 1, 48–52 (2008)

25. Panchenko, L.F.: Tsyfrovyi storitelinh: spivtvorchist pedahoha y uchnia (Digital storytelling: co-creation of a teacher and a student). Metodyst 6(78), 34–36 (2018)

26. Phelan D.: Apple CEO Tim Cook: As Brexit hangs over UK, 'times are not really awful, there's some great things happening'. The Independent. https://www.independent.co.uk/life-

style/gadgets-and-tech/features/apple-tim-cook-boss-brexit-uk-theresa-may-number-10-interview-ustwo-a7574086.html (2017). Accessed 25 Oct 2019

27. Prometheus – Naikrashchi onlain-kursy Ukrainy ta svitu (Prometheus – The best online courses in Ukraine and the world). https://prometheus.org.ua/ (2019). Accessed 28 Nov 2019

28. Siemens, G.: MOOCs are really a platform. https://web.archive.org/web/20180530225929/ http://www.elearnspace.org/blog/2012/07/25/moocs-are-really-a-platform (2012). Accessed 21 Mar 2017

29. Slobodchikov, V.I.: Obrazovatel'naja sreda: realizacija celej obrazovanija v prostranstve kul'tury (The educational environment: the implementation of educational goals in the cultural space). In: Novye cennosti obrazovanija: Kul'turnye modeli shkoly, pp. 177–184. Innovator, Moscow (1997)

30. Syrovatskyi, O.V., Semerikov, S.O., Modlo, Ye.O., Yechkalo, Yu.V., Zelinska, S.O.: Augmented reality software design for educational purposes. In: Kiv, A.E., Semerikov, S.O., Soloviev, V.N., Striuk, A.M. (eds.) Proceedings of the 1st Student Workshop on Computer Science & Software Engineering (CS&SE@SW 2018), Kryvyi Rih, Ukraine, November 30, 2018. CEUR Workshop Proceedings **2292**, 193–225. http://ceur-ws.org/Vol-2292/paper20.pdf (2018). Accessed 21 Mar 2019

31. The Reasons for Using Digital Storytelling with Students. http://digitalstorytelling.coe.uh.edu/archive/survey/T7_Reasons.pdf (2011). Accessed 21 Mar 2019

32. Zappar Powered STEM Learning Using Augmented Reality. https://www.canvas.net/browse/stem/zappar/courses/zappar-augmented-reality (2019). Accessed 18 Jan 2019

33. Zappar: Zappar for Education: inspiration for schools of how toget the most out of zapworks. https://d1hh40g6daqks4.cloudfront.net/doc/ZapparForEducationLessonPlans.pdf (2017). Accessed 18 Jan 2019