Towards Education 4.0: Enhancing Traditional Textbooks with Augmented Reality and Quick Response codes

Marian-Vlăduț TOMA, Cristina Elena TURCU
Faculty of Electrical Engineering and Computer Science
Ștefan cel Mare University of Suceava
Suceava, Romania
vlad.toma@usm.ro, cristina@usm.ro

***Abstract*— By 2025, two billion people will be part of Generation Alpha, which refers to children born between 2010 and 2025. These children, who have had the greatest access to technology up to this point, naturally use smartphones, tablets, computers, and other devices. Students of this generation will be able to benefit from the incorporation of emerging technologies and innovations into classrooms. The present paper aims to investigate the potential of these technologies in education to facilitate the leap towards Education 4.0 as part of the overall picture of Industry 4.0. The first section of the paper deals with a review of the scientific literature on the use of Quick Response (QR) codes and Augmented Reality (AR) in the development of learning materials. Then, the paper proposes a solution that supports and facilitates the integration of such technologies in regular textbooks. Connecting learning materials with the technologies that students use every day can lead to a better understanding and involvement in the classroom. However, traditional textbooks and other learning materials need to be updated to meet the expectations of students who use smartphones and other technologies as extensions of their bodies.**

Keywords— Education 4.0, QR codes, Augmented Reality, Enhanced textbooks.

I. INTRODUCTION

Digital technologies have revolutionized the transition from the industrial to the information age, reshaping every aspect of life, society, business, industry, and so on. Development and progress rely on competent human capital, which can be ensured by educating the younger generation. The development of students' deep thinking abilities, as well as increasing the efficiency of the process of assimilation and application of knowledge, will be possible only through the provision of a valuable and complex education. Teachers should encourage the students to think creatively and innovatively, motivating them to express their ideas, by stimulating, but also raising awareness of cognitive processes to achieve higher levels of learning. Furthermore, in order to prepare future competitive specialists on the labor market, the educational field must align its training process with technological advances. Over time, different stages of education development have been recorded, ranging from Education 1.0 to Education 4.0.

Education 1.0 begins in the second half of the twentieth century, when web tools are used by teachers, only to provide information, communication being one-way [1]. During this period, mostly traditional, teacher-oriented approaches are adopted, while students were considered passive consumers of knowledge. Technology is not permitted in the classroom.

Education 2.0 appears and develops under the influence of Industry 2.0 and 3.0. At the beginning of the new millennium, both students and teachers are increasingly utilizing and integrating various digital technologies, making them an integral part of the learning process. This stage is built on the student-centered approach, with the implementation of interactive teaching strategies such as: project/ problem-based learning, collaborative learning, lifelong learning, etc., bringing substantial and profound changes in the roles of students and teachers. Students acquire knowledge of a subject not only through direct interaction with the teacher in class, but also through direct interaction with online content (through access to virtual libraries, social networks and other online resources) and one another.

Education 3.0 was launched in 2010 due to advances in information and communication technology (ICT) and the widespread use of the Internet. The education process is being digitized, and students already have access to information through e-learning and connections to various worldwide communities. There is a diversity of educational offers with free and unlimited access, the boundaries of the disciplines blur, interdisciplinarity and interculturality become elements that dictate new imperatives in the training process. In this context, the student continues to accumulate knowledge, develop skills and form attitudes under the guidance of the teacher, but at the same time, he also takes advantage of the multitude of available resources and learning opportunities, trying to develop his own connections and networks, with multiple sources of information.

Education 4.0 is developing a new approach that aligns with the Fourth Industrial Revolution **(Industry 4.0)**. This new phase refers to a period in which digital transformation and innovation began to dominate education, as well as many other areas of social life [1]. Combining an impressive number of technologies, Education 4.0 enables students to adapt their

This paper has been financially supported within the project entitled "DECIDE-Development through entrepreneurial education and innovative doctoral and postdoctoral research", project code POCU/380/6/13/125031, project co-financed from the 2014-2020 Operational Program Human Capital.

978-1-6654-8162-5/22/$31.00 ©2022 IEEE

learning to their individual needs through the use of artificial intelligence, cognitive technologies, data analytics, and the Internet of Things (IoT), etc. Traditional classrooms as well as virtual classrooms can be used for training.

As a result, Education 4.0 becomes a more realistic and practical approach to personalized learning. Digital technology-based resources facilitate problem solving, innovation, creativity, and collaboration - the building blocks of the future in education. This type of education encourages critical thinking and employs more dynamic tools and resources that imitate the job experience by fostering an industry-like collaborative environment. Fig 1 shows the main trends for the future of global education, according to [2]:

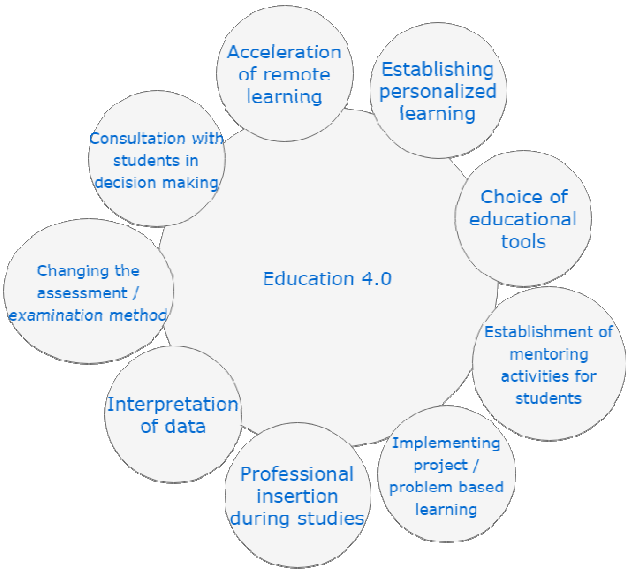

Fig 1. Education 4.0 future perspectives (adapted from [2]).

The Quick Response (QR) code (Fig. 2) is a 2D matrix code that provides "high data storage capacity, fast scanning, omnidirectional readability, and many other advantages including, error-correction (so that damaged code can also be read successfully)"[3]. Very easy to build and use these codes can tag objects to bring them online, making it possible to integrate them into the IoT, a key component in the development of Education 4.0.

Fig. 2. Basic QR code [4]

Augmented reality (AR) is a new technology that comes with a unique and interactive experience. In short, augmented reality combines virtual world with the real world by superimposing virtual, in some cases three-dimensional (3D) objects in real time onto a real environment. This technology provides a unique visual experience that greatly enhances the user's view of reality. Also, with augmented reality, information based on various themes becomes interactive and much easier to handle. So far, most AR technology has had an impact on the entertainment and marketing industry [5]. Today, more than ever, the global education sector aims to reap the full benefits of these technologies. There are several educational institutions that already include courses and laboratories of Virtual Reality and Augmented Reality in the curricula, as is the case of the Ștefan cel Mare University of Suceava, Romania, delivering new learning experiences. While computers have been helping the learning process for many years, new technologies bring novelty and possibilities in addition to existing ones.

II. Related Work

We analyzed the adoption of QR codes and AR in education using Web of Science (WoS) as a well-known citation database. WoS allows users to define search criteria and use various filters to extract relevant and high-quality papers using an advanced search option. All time periods were taken in consideration (WoS holds records from 1975), although QR codes and AR are relatively new technologies, and both articles and proceedings papers are included. In the first stage, "QR codes" and "augmented reality" were the used input search terms, with the possibility to add alternative terms like "quick response codes" and "augmenting reality" using the operator "OR" to combine multiple terms, taking in consideration that some author might use these keywords. Results were roughly refined by research areas: Education and Educational Research, returning a total of 2.105 items. In the second stage, the keyword textbook was included which narrowed down the results to 55, applying the same filters, as can be seen in Fig. 3.

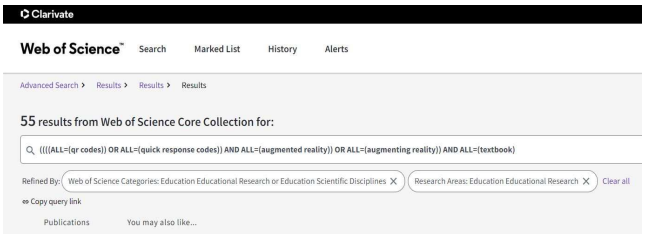

Fig. 3. Results returned in the second stage.

Finally, "higher education" search terms were added, which brough up 19 results. Analyzing both results from stage 2 and final stage of searching, it can be stated that the use of QR codes and augmented reality in the rethinking of traditional textbooks is still in its infancy, despite the fact that out of the educational context, and more than that, taken separately, there is plenty of research, presenting much interest. It can also be said that there is no clear delimitation between the use of these technologies in the K-12 students' classroom or in higher education, despite the fact that it can be used in the understanding of complex concepts from, but not limited to

physics, chemistry, engineering or medical field. In fact, study presented in [6] showed that K-12 students are the preferred learner type, while university students are the second most common learner type.

A. Quick Response (QR) codes in mobile learning

Identification and detection are key features in the development of IoT [8]. Radio-frequency identification (RFID) tags and QR codes are solutions that act as a bridge between the physical world and the virtual one, extending the internet to what is called IoT [7]. These contactless and effective tagging solutions can be scanned by devices such as RFID scanners or mobile devices (smartphones).

QR codes are an easy to build and use solution for object identification, that offers various benefits over RFID tags, such as low cost, simplified scanning, accessibility, unlimited information space, and more. Furthermore, as an increasing number of researchers (e.g., authors from [9]-[14]) have shown, QR codes can be used in conjunction with other technologies such as artificial intelligence, Wi-Fi, Bluetooth, and wireless sensor networks, to facilitate the development of various (smart) systems.

Despite the fact that QR codes were invented way back in 1994 by Denso-Wave – a Japanese company specialized in equipment automation, the technology found its way to the general public with the development of smartphones and increasing their use. Given the widespread use of smartphones among students, as well as the ease of use of QR codes, these have begun to be adopted in the educational field. Author of [15] describes the potential of QR codes in education, and emphasizes the ease of use. Thus, users don't have to buy additional equipment to generate or read the codes. For example, Google Chrome browser has a built-in function to generate QR codes for webpages, just by accessing the contextual menu (Fig. 4).

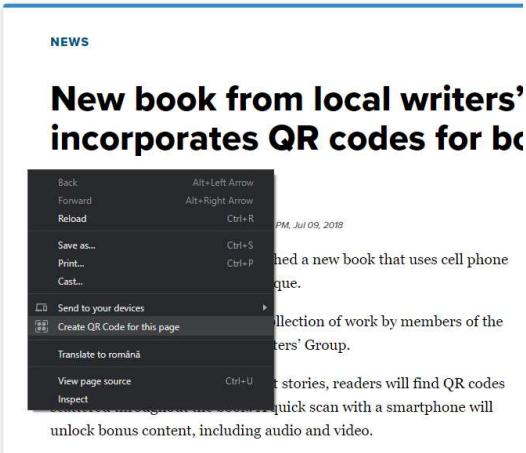

Fig. 4. Option to create QR code

QR codes could be used to help teachers in the process of transferring knowledge to students using smartphones by making a connection between the physical and digital worlds. Thus, as in the case of mobile applications, students would use only a device they already have and a good internet connection. This way, QR codes would act as a portal to the digital world [16] and provides a quick solution for the problem of introducing long web addresses manually in the address bar [17]. Because they allow quick and effortlessly access to digital materials, some researchers suggest using them to enhance printed materials with online content [18]. Different research projects ([19][20][21]) showed that QR codes are motivating and it introduced variety in classroom, arousing students interests probably due to the mystery involved in accessing unknown information incorporated in the code [17].

Typical use cases of these versatile codes include, but are not limited to: enriching printed materials by introducing complementary audio-visual or written information in the supplied materials, filling panels with additional content, hiding answers in a test paper, making class surveys and so on. Moreover, given how easy are to use, QR codes could be generated by students too, not only by teachers. For example, work from [19] used QR codes to define grammatical terms and audio version of a book and asked students to create their own codes for integrating a movie trailer into a poster. In the majority of use cases, regardless of their creator, QR codes are often used to extend or augment given information. An example of enhanced text is shown in Fig. 5.

Fig. 5. Enhanced textbook with QR code. Source: https://www.qrcodechimp.com/qr-codes-for-publishing/

B. Augmented reality for interactive classroom

Augmented reality technology is increasingly used in the educational field, enabling students to learn in an interesting and hands-on way. Moreover, it increases efficiency and helps developing more engaging lessons with the opportunity to explore the subject from more than one point of view. As stated in [22], a considerable advantage is its "unique ability to create immersive hybrid learning environments that combine digital and physical objects, thereby facilitating the development of processing skills such as critical thinking, problem solving, and communicating through interdependent collaborative exercises". Another study conducted in [23] showed that in higher education laboratories, students have built a more positive attitude related to the laboratory work and improved their skills.

While virtual reality (VR) offers a completely new world that has no connection to the real world, augmented reality enriches our world by overlaying various digital elements. When used in education, it provides a way to combine the traditional teaching methods with the new ones, without

completely immersing students in VR. One of the most significant differences between virtual and augmented reality is the required equipment. Thus, virtual reality needs various equipment for the VR experience to take place, such as head mounted devices or special glasses, controllers and more, which are often expensive. AR has a much higher level of accessibility, as it only requires the device's camera and internet connection.

Authors of [24] successfully implemented augmented reality to enhance a textbook for the Cutting Tools bachelor's degree course, as can be seen in Fig. 6.

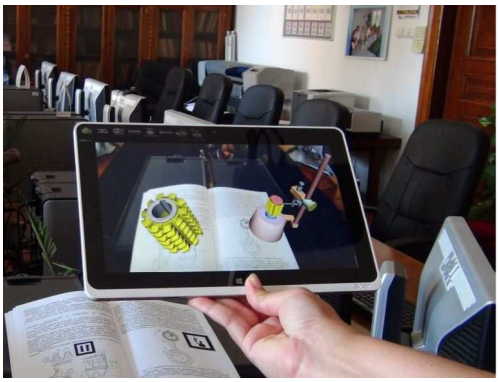

Fig. 6. Enhanced textbook with augmented reality [24].

Once we have established the benefits of these concepts and the reasons why we would try to augment spaces and objects, we need to think about how we can implement them using current technologies. According to [25], smartphones are ideal for AR application, being very popular among younger students that use it as an extension of themselves. It is largely accepted that at least in higher education, the majority of students own such a device. Wireless mobile devices bring technology to the mobile space where applications promise several benefits. Augmented reality has gained popularity through mobile technologies due to its geolocation functions but also due to the widespread use of these devices. Thus, users can benefit from AR without having to purchase additional equipment. Integrated cameras and high-performance screens integrated into mobile devices serve as a means of combining real-world data with virtual data. Using GPS capabilities, image recognition, and a digital compass, AR applications can determine where the camera is pointing in space and overlay relevant content on the screen.

III. CASE STUDY

Considering that most of the studied papers focused on developing a particular aspect of the use of QR codes and augmented reality in enhancing textbooks, very often treated separately, the current paper aims to develop a hybrid and efficient solution that combines the simplicity of the QR codes with the complexity of augmented reality. In most cases the AR is brought to textbooks by complex apps that need to be developed and later installed on devices, causing compatibility problems with the operating system or other problems like hard to use interface or security-privacy related concerns.

Our approach uses a web-based implementation of augmented reality using javascript by Jeromie Etienne [26] – AR.js. This is the only solution available for using AR on the web, being developed in 2017 with version 3 currently available. Some of the most notable advantages are:

- Open-source software – completely free, hosted on Github with a team of contributors constantly improving and documenting the application;
- Cross-platform – mobile app development and cost related concerns are avoided, work on any camera-equipped device with internet access;
- Javascript, HTML and CSS – well-known technologies are re-used to customize the app;
- Instant update – being web-based it means that critical updates or new futures can be deployed instantly;
- Fast and simple – no installation of special software is required, and it doesn't need high processing power.

The first step in enhancing a traditional textbook is made by connecting the analogue, printed text with digital, online content by using QR codes. At this stage, it can lead to any website address, video platform or application store. Nowadays, most smartphones have a build-in app for code scanning, but there are also many free applications available either in Google Play (Android) or App Store (iOS). The application workflow is presented in Fig. 7.

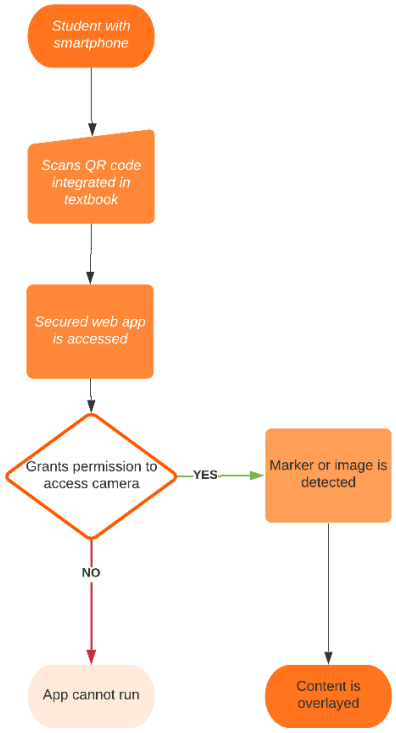

Fig. 7. Application workflow

After scanning the QR code, the student is directly accessing the web application, and for security reasons is asked

for permission to access the smartphone camera or cameras, depending on the devices used. After permission are granted, the marker or image is detected and specific content is overlayed. AR.js v3 currently supports augmented reality based on image tracking, location or marker tracking. These are triggering factors that indicate where to place the virtual content. For example, when a 2D image is detected by the camera, related content (image gallery, video, GIF or 3D model) is overlayed. The same happens when a Hiro Marker is detected, but these types of markers are limited in color and shape design, with the advantage of stability (more accurate detection). AR based on location uses GPS coordinates to place content, for example – additional information over a building when the camera is pointed to it.

Our choice for the presented application is a marker-based AR which can later be integrated into a QR code, thus creating a hybrid solution to save space and time for codes/markers scanning. Using a tool for training markers [27], a pattern was generated and a PNG image as well.

Online tools for QR code generator, such as [28], provide the option to generate personalized QR codes with the desired logo, which in our case is the PNG image trained marker. The combined result can be seen in Fig. 8.

Fig. 8. QR code with AR marker

The AR web application interface is accessed through a HTML page (Fig. 9). Fig. 10 presents the corresponding code, which uses the imported javascript related libraries (ar.js, a-frame, artoolkit, three.js) and the pattern file to display a rotating sphere on top of the above hybrid marker integrated in a printed material.

Fig. 9. Rotating globe displayed above a Hybrid marker.

Because accessing the device's camera may pose security risks, the application needs to be hosted on a secure https server in order to run.

```
<!DOCTYPE html>
<head>
    <meta name="viewport" content="width=device-width, user-scala
    <title>Enhanced textbook example</title>
    <!-- include three.js library -->
    <script src='js/three.js'></script>
    <!-- include jsartookit -->
    <script src="jsartoolkit5/artoolkit.min.js"></script>
    <script src="jsartoolkit5/artoolkit.api.js"></script>
    <!-- include threex.artoolkit -->
    <script src="threex/threex-artoolkitsource.js"></script>
    <script src="threex/threex-artoolkitcontext.js"></script>
    <script src="threex/threex-arbasecontrols.js"></script>
    <script src="threex/threex-armarkercontrols.js"></script>
</head>

// build markerControls
markerRoot1 = new THREE.Group();
scene.add(markerRoot1);
let markerControls1 = new THREEx.ArMarkerControls(arToolkitContext,
    type: 'pattern', patternUrl: "data/usv.patt",
})

let geometry1 = new THREE.SphereGeometry(1, 32,32);

let loader = new THREE.TextureLoader();
let texture = loader.load( 'images/earth-sphere.jpg', render );
let material1 = new THREE.MeshLambertMaterial( { map: texture, opac
```

Fig. 10. Code snippet

IV. DISCUSSION AND CONCLUSIONS

A major concern of introducing such IoT facilitating technologies like QR codes and augmented reality for enhancing textbooks in the educational field is related to the digital delay between the wealthy and the poor. Authors from [29] highlights that these differences “are not going to be an easy or happy discussion when it comes to implementing new technologies” and “the dream of personalized, detailed and interactive teaching will be tightened to financial problems”. Another problem is that in some areas, some institutions do not have access to high-bandwidth internet connection, placing them in the context of Education 1.0, making it difficult to discuss Education 4.0. Moreover, it doesn’t mean much if digital equipment is assured without a teacher willing to use them efficiently in pedagogical purposes. This is stated in [29], which emphasizes that the education needs creative ways to use the internet in learning purposes. Rethinking entire learning materials can be a difficult task for some teachers who use traditional methods. At this stage, the transition to Education 4.0 often involves the purchase of expensive equipment and specialized software for use by trained teachers.

The current paper has fulfilled its purpose by presenting related work on the potential of QR codes and augmented reality in the educational field, analyzing the lack of research in the development of learning materials using these technologies and filling a gap by proposing a free, open-source solution to enhance traditional textbooks with QR codes and augmented reality, thus taking a step further towards Education 4.0.

ACKNOWLEDGMENT

This paper has been financially supported within the project entitled “DECIDE-Development through entrepreneurial

education and innovative doctoral and postdoctoral research", project code POCU/380/6/13/125031, project co-financed from the 2014-2020 Operational Program Human Capital.

REFERENCES

[1] Keser H., Semerci A, "Technology trends, Education 4.0 and beyond", Contemporary Educational Researches Journal, Volume no. 09, Edition 3, p.39-49, 2019.

[2] Das, Shuvra & Kleinke, Darrell & Pistrui, David, "Reimagining Engineering Education: Does Industry 4.0 Need Education 4.0?" doi:10.18260/1-2—35136, 2020.

[3] S. Tiwari, "An Introduction to QR Code Technology," 2016 International Conference on Information Technology (ICIT), 2016, pp. 39-44, doi: 10.1109/ICIT.2016.021.

[4] Online resource retrieved from https://www.nj.com/business/2010/10/qr_codes_bring_quick_response.html

[5] Technavio, "Top 3 Trends in Augmented Reality that are Paving the Way for Digital Transition in the Education Sector", Available online at https://blog.technavio.org/blog/top-3-trends-augmented-reality-digital-education-sector ,accessed on august, 2017.

[6] Murat Akçayır, Gökçe Akçayır, "Advantages and challenges associated with augmented reality for education: A systematic review of the literature", Educational Research Review, Volume 20, pp. 1-11, 2017. ISSN 1747-938X, https://doi.org/10.1016/j.edurev.2016.11.002.

[7] L. Coetzee, and J. Eksteen, "The Internet of Things - promise for the future? An introduction", 2011. Retrieved from https://ieeexploreieee_org.portal.lib.fit.edu/stamp/stamp.jsp?tp=&arnumber=6107386

[8] D. Miorandi, S. Sicari, F. D. Pellegrini, and I. Chlamtac, "Internet of things: Vision, applications and research challenges," Ad Hoc Networks, vol. 10, no. 7, pp. 1497–1516, 2012.

[9] Adorni, G., Coccoli, M., & Torre, I, "Semantic web and Internet of Things supporting enhanced learning", Journal of e-Learning and Knowledge Society, 8(2), pp. 23-32, 2012.

[10] Dlodlo, N., Foko, T. E., Mvelase, P., & Mathaba, S, "The state of affairs in internet of things research", The Electronic Journal Information Systems Evaluation, 15(3), pp. 244-258, 2012.

[11] Jinghua, C., & Jie, W, "Discussion on the development and applications of mobile phone two-dimensional barcode in Internet of Things" Telecommunications Science, 4, 009, 2010.

[12] Madakam, S., Ramaswamy, R., & Tripathi, S, "Internet of things (IoT): A literature review", Journal of Computer and Communications, 3(05), pp. 164-173, 2015.

[13] Ralhan, B. D, "6 ways the Internet of Things is transforming the education sector: Featurephilia", 2017. Retreived from http://indiatoday.intoday.in/education/story/internet-of-things-transforming-education/1/870592.html

[14] Want, R., Schilit, B. N., & Jenson, S, "Enabling the internet of things" Computer, 48(1), pp. 28-35, 2015.

[15] So, S, "Beyond the simple codes: QR in education" In G. Williams, P. Statham, N. Brown & B. Cleland (Eds.), Changing Demands, Changing Directions. Proceedings ascilite Hobart, pp.1157–1161, 2011.

[16] Baik, S, "Rethinking QR code: analog portal to digital world", Multimedia tools and applications, 58(2), pp. 427–434, 2012. Retrieved from https://doi.org/10.1007/s11042-010-0686-9

[17] Thorne, T, "Augmenting classroom practices with QR codes", TESOL Journal, 7(3), pp. 746-754, 2016. Retrieved from https://doi.org/10.1002/tesj.257

[18] Uluyol, C., & Agca, R. K, "Integrating mobile multimedia into textbooks: 2D barcodes" Computers and Education, 59(4), pp. 1192–1198. 2012. Retrieved from https://doi.org/10.1016/j.compedu.2012.05.018

[19] Baruffi, S, "What happens when QR codes are used to increase student engagement, motivation and independence in a fourth grade basic skills classroom? "Theses and Dissertations. 336., 2015. Retrieved from https://rdw.rowan.edu/etd/336

[20] Huah, G. L., & Jarrett, B. W, "Integrating QR codes and mobile technology in developing listening and speaking skills in the teaching of english language", International Journal on E-Learning Practices (IJELP), 1(1), pp. 25–38, 2014.

[21] Rikala, J., & Kankaanranta, M, "*Blending classroom teaching and learning with QR Codes*", 2014. Retrieved from https://files.eric.ed.gov/fulltext/ED557237.pdf

[22] Dunleavy, M., Dede, C. & Mitchell, R, "Affordances and Limitations of Immersive Participatory Augmented Reality Simulations for Teaching and Learning", J Sci Educ Technol 18, pp. 7–22 2009. Retrieved from https://doi.org/10.1007/s10956-008-9119-1

[23] Murat Akçayır, Gökçe Akçayır, Hüseyin Miraç Pektaş, Mehmet Akif Ocak, "Augmented reality in science laboratories: The effects of augmented reality on university students' laboratory skills and attitudes toward science laboratories", Computers in Human Behavior, Volume 57, pp. 334-342, 2016. ISSN 0747-5632, https://doi.org/10.1016/j.chb.2015.12.054.

[24] Ivanova, Galina & Aliev, Yuksel & Ivanov, Aleksandar, "Augmented Reality Textbook for Future Blended Education", 2014.

[25] Henrysson, Anders, Mark Billinghurst, and Mark Ollila, "Face to face collaborative AR on mobile phones." Fourth IEEE and ACM International Symposium on Mixed and Augmented Reality (ISMAR'05). IEEE, p. 80-89, 2005.

[26] Online resource available at https://github.com/AR-js-org/AR.js

[27] Online resource available at https://jeromeetienne.github.io/AR.js/three.js/examples/marker-training/examples/generator.html

[28] Online resource available at https://www.qrcode-monkey.com/

[29] Augur, H, "IoT in education: The Internet of school things", 2015. Retrieved from https://dataconomy.com/2015/12/iot-in-education-the-internet-of-school-things/