A Systematic Review of Augmented Reality in Multimedia Learning Outcomes in Education

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Abstract. This research involved a systematic and thematic review of literature of studies involving the use of Augmented Reality (AR) in the educational context. Specifically, the review was performed by searching and identifying relevant and recent articles on several leading online databases, which were published from 2014 to 2020. The review yielded 40 articles that discuss various applications of this novel technology. Based on the analysis of their contents, 15 articles are related to multimedia learning involving augmented reality in primary classroom settings. On the other hand, 25 articles discuss studies involving the use of AR in university settings. In terms of content, 18 articles articulate the applications of AR from the explorative perspective, while another 18 articles elaborate the use of AR books in education. By contrast, only 4 articles highlight the use of game-based AR applications in education. The findings of the content analysis carried out suggest that student learning can be improved in AR-enabled learning environments with multimedia elements that provide high interactivity and immersion in which not only students can see and visualize learning objects and contents but also they can readily interact with such three-dimensional visual objects. Arguably, in exploring or navigating and interacting in such environments, students can enhance their cognitive and spatial skills as well. Overall, the above findings provide a greater insight into the understanding of AR characteristics that have a profound impact on the teaching and learning process.

Keywords: Augmented reality · Interactivity · Immersion · Multimedia elements · Learning environments · Thematic review

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1 Introduction

Over recent years, Augmented Reality (AR) has become a popular educational research topic [1–3] that focuses on the potentials of AR in the teaching and learning process. The main factor that contributes to the wide acceptance of AR are its cost-effectiveness in creating highly immersive and enjoyable learning environments in which students can learn more efficaciously [4, 5]. Specifically, teaching and learning can be carried out in real-world environments containing embedded virtual contents to support for formal and informal learning [6, 7]. Several researchers have also pointed out that AR can significantly help improve learning in various contexts, particularly in conceptual understanding, inquiry learning, technology, and engineering [8–10]. Furthermore, the deployment of multimedia contents on internet resources during lessons enables lecturers and teachers to perform their respective tasks more flexibly and conveniently [11] to explain theoretical aspects and increases students' motivation in invigorating settings [12–14]. With the use of mobile devices, AR learning contents can be made more accessible to students transcending temporal and geographical barriers [15, 16]. To date, several researchers have begun conducting studies that focus on learning assisted by AR in many disciplines and fields [17, 18]. In this study, a systematic review of the current literature of the applications of AR in various educational contexts was carried out o highlight its advantages and disadvantages and the challenges in its implementation. The findings of this undertaking helped the researchers to determine the main research objective and formulate appropriate research questions that focused on the instructional design of AR mobile learning with the use of relevant multimedia elements.

2 Related Work

In the current literature, many educational benefits accorded by AR have been highlighted in many educational contexts [19–21] in a number of disciplines and fields [22]. In particular, many researchers have conducted several systematic reviews of the applications of AR in a diverse range of important fields, which have identified a host of educational benefits and potentials [23, 24]. The same reviews have also identified several barriers in the implementation of this technology in educational contexts [25]. In such reviews, the main focus was on the use of AR in multimedia context learning [26] and on the insight into how AR could serve as an assistive tool for students to learn more efficiently and effectively [27]. In this regard, according to Erbas et al. [28], most students perceive the use of AR in learning to be both highly useful and enjoyable, signifying the educational potential of this novel technology [29]. Interestingly, most of the studies in the current literature were carried out based on a qualitative approach that helped highlight the impact of AR on students' performance, motivation, attitudes, and interest in learning [30–32]. Given these revelations, it can be reasonably argued that the implementation of AR technology in educational settings can further enhance the teaching and learning process through interactive and immersive learning environments, benefitting both teachers and students [33, 34]. Table 1 summarizes some of the studies of the applications of AR in multimedia education in classroom settings.

Table 1. The objectives and results of AR studies in multimedia education

Authors	Type of Literature Review	Aim of the study	Result of the study
Zhang et al. [24]	Integrative review	The main objective of this research is to manipulate AR-based objects applied in a class environment	The result suggests that AR is able create innovative learning objects that can enhance students' learning performance and motivation
Radu [35]	Integrative review	This aim of this research is to analyse the positive and negative impacts of educational Augmented Reality on student learning	The overall result of this research indicates that physical tasks performed by students in AR-based collaborative learning environments can help improve their motivation, cognitive skills, and spatial abilities
Arulanand et al. [36]	Semi-systematic review	This main aim of the research is to provide a comprehensive use of Augmented Reality and multimedia application on three-dimensional printing to promote self-learning activities	This research finding signifies that the use of this novel technology can stimulate creative thinking among students as they learn to develop learning objects by themselves
Kara et al. [37]	Semi-systematic review	The main aim of this study is to articulate the values in technology in education, notably on early childhood education by comparing a smart toy and conventional learning using print media	The research finding underscores the importance of smart AR toys to attract young children's attention to learn in enjoyable learning environments in the classroom
Chen [38]	Review papers and systematic reviews	This primary aim of the study is to analyse the advantages of an AR-based scaffolding video in helping students in the learning of English language	This research finding suggests that such a novel AR learning tool is able to enhance students' motivation, satisfaction, and learning achievement, indicating a major advantage of using augmented reality for educational purposes

(*continued*)

Table 1. (*continued*)

Authors	Type of Literature Review	Aim of the study	Result of the study
Maas et al. [39]	Semi-systematic review	This research aims to highlight the positive impacts of appropriate versions of Virtual Reality (VR) and Augmented Reality (AR) on the teaching and learning of general education. Additionally, the study aims to explore the educational benefits of Mixed Reality (MR) in instructional education	This research finding indicates that practitioners should exercise extreme caution in choosing a suitable platform for the deployment of AR, VR, and MR technologies for educational purposes
Chen [40]	Review papers	This research focuses on the use of AR technology on early childhood education of young children in acquiring sound reading skills in comparison to a traditional approach that relies on textbooks	The research finding suggests that the use of AR learning tools can help young children to learn to read more efficaciously than learning based on conventional methods, as the former can make learning more attractive by allowing students to learn using interactive educational games and interactive embedded videos
Buchner et al. [41]	Semi-systematic review	This main aim of this research is implement a multimedia and instructional model using an AR book as an educational medium in learning	The research finding indicates that multimedia elements of AR books can help improve students' motivation and interest to learn
Martin et al. [42]	Integrative review	The primary aim of this study is to examine the effects of a novel game-based AR on the learning of digital circuit in a mobile learning environment	The research finding suggests that engineering students will be able to gain a firm understanding of the principles of digital circuit. The researchers also caution that teachers need to possess sufficient programming experiences to help them teach with greater efficacy

Figure 1 highlights the flow of the steps taken by the researchers in carrying out the systematic review of the current literature of studies of Augmented Reality in multimedia learning in education. This review helped reveal the positive impacts of multimedia Augmented Reality technology in helping students to achieve learning outcomes in a diverse range of educational settings [43–45]. More importantly, the review helped highlight the potential of improving learning efficacy by capitalizing on mobile devices, notably smartphones, to provide mobile learning with the use of interactive multimedia elements [46, 47]. The following section provides a detailed account of the systematic review carried out by the researchers by focussing on collecting appropriate data, which is essential in the early stages of a systematic review process [48, 49].

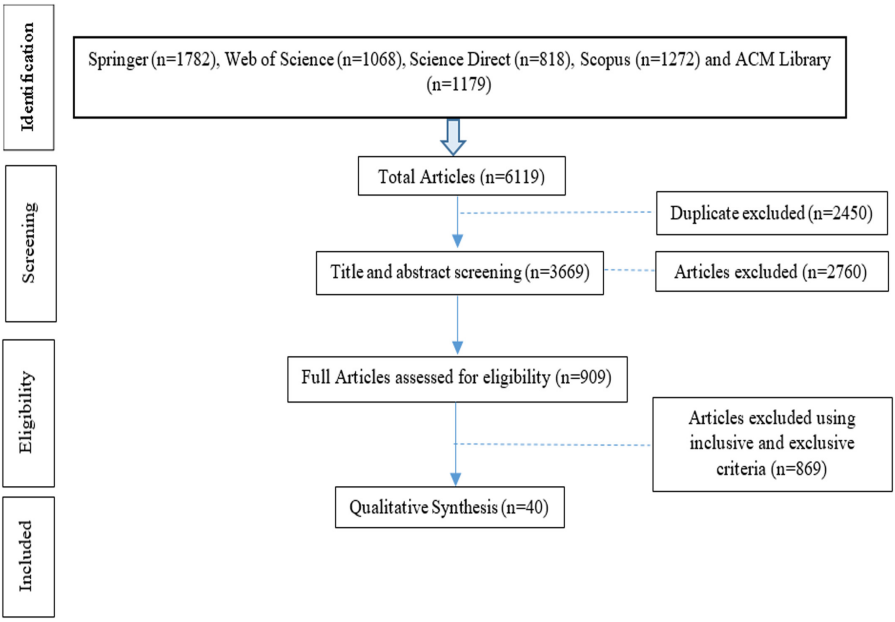

Fig. 1. The flow diagram of the systematic review of literature of studies of Augmented Reality in multimedia contexts

3 Method

3.1 The Manuscripts Selection

The selection of relevant academic articles and was made by searching several online research databases. The researchers conducted such a process on 20 August 2020 by applying appropriate keywords or strings of phrases, such as "Augmented Reality" AND Education AND Learning AND Multimedia. Such a query search helped the researchers to identify and select relevant documents that were both appropriate and current. Specifically, the online databases searched were several leading online publications, namely

Springer, ISI Web of Science, ScienceDirect, Scopus, and ACM Digital library. The selection process of articles was inter-coded through the agreement and disagreement between two different coders that helped determine the veracity of such articles based on several inclusion and exclusion criteria. Ultimately, this filtering process yielded 40 articles that were deemed relevant and current according to such criteria as summarized in Table 2.

Table 2. The inclusion and exclusion criteria in selecting relevant articles relating to Augmented Reality in the Multimedia learning context

Inclusion Criteria	Exclusion Criteria
The articles in respective databases have to be published within a period from January 2014 to January 2020.	The studies only focus on "Augmented Reality" and "Virtual Reality."
The articles have to be peer-reviewed prior to publication.	The contents of the articles do not include teaching and learning in a multimedia context.
The articles must be related to empirical research design, multimedia, and the utilization of augmented reality in education.	The area dealt with in related studies is not related to the application of Augmented Reality.

The following subsection will analyse the manuscripts based on the content analysis to deduce the textual information.

3.2 Analysis of the Manuscripts

In this study, the researchers carried out a thematic analysis of contents and contexts of selected papers or articles. Even though such an analysis is quite simple, the results it yield can be significant for research [50, 51]. In principle, the systematic categorization process [52] of a large amount of data consisting of textual information can help determine patterns [53] and trends of words, as depicted in Fig. 2. The reliability of the selected articles was deemed high based on the calculated value of Cohen's Kappa at 0.94, which is regarded extremely high [54]. In this research, the thematic analysis was implemented based on a qualitative methodology. Figure 2 shows the characteristic of the thematic and content analysis.

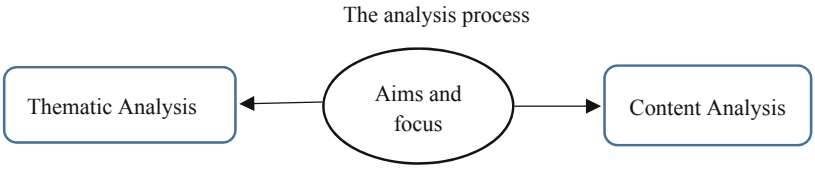

Fig. 2. The characteristic of the thematic and content analysis

The analysis process was performed by the researchers in determining a group based on the categorical analysis of sub-categories. Later, research questions were grouped based on the domains and characteristics of the criteria of the study. This content analysis is also suitable for multi-faceted criteria based on the AR classification process [55, 56]. In the following stage of the systematic review process, emerging classifications were refined to reveal the appropriate sub-categories [57]. Arguably, other researchers can manually code studies depending on the sub-categories that have been defined earlier. For this type of research, iterative discussions among researchers are essential.

4 Result

As highlighted, this study involved a systematic review of the current literature of studies of the applications of AR in education. Specifically, the review was performed by searching and identifying relevant and recent articles on several leading online databases, which were published from 2014 to 2020. The review yielded 40 articles that discuss various application of the novel technology. Based on the analysis of their contents, 15 articles are related to multimedia learning involving augmented reality in primary classroom settings. On the other hand, 25 articles discuss studies involving the use of AR in university settings. In terms of content, 18 articles articulate the applications of AR from the explorative perspective, while another 18 articles elaborate the use of AR books in education. By contrast, only 4 articles highlight the use of game-based AR in education. Interestingly, 81% of the researchers used image-based AR technology. The above findings helped the researchers to address both the first and second research questions of this study. The findings of studies discussed in the selected articles suggest that specific instructional models are needed based on appropriate learning contexts [58, 59]. For instance, Salar et al. [60] discovered that students' focus and attention were influenced by a particular AR-learning approach used in a classroom setting. In addition, Zafar et al. [61] argues that students can learn more efficaciously in a AR-enabled learning environment because they can visualize learning objects that help improve cognition.

5 Discussion

In this study, the researchers used a qualitative research methodology involving a systematic and thematic review of literature. The process helped highlight descriptive accounts of relevant papers or articles that discuss studies of the applications of AR in various learning contexts. In particular, such a review enabled the researchers to examine the characteristics of AR that could help students to learn in learning environments that are engaging, entertaining, and motivating, which ultimately can lead to enhanced learning through which students gain better understanding of learning contents.

References

1. Kesim, M., Ozarslan, Y.: Augmented reality in education: current technologies and the potential for education. Procedia - Soc. Behav. Sci. **47**, 297–302 (2012). https://doi.org/10.1016/j.sbspro.2012.06.654

2. Georgiou, Y., Kyza, E.A.: Bridging narrative and locality in mobile-based augmented reality educational activities: effects of semantic coupling on students' immersion and learning gains. Int. J. Hum. Comput. Stud. **56**, 102546 (2020)
3. Staccini, P.: Serious games, simulations, and virtual patients. In: Digital Innovations in Healthcare Education and Training. pp. 17–27. Elsevier (2020)
4. Gargrish, S., Mantri, A., Kaur, D.P.: Augmented reality-based learning environment to enhance teaching-learning experience in geometry education. Procedia Comput. Sci. **172**, 1039–1046 (2020)
5. Ibáñez, M.B., Portillo, A.U., Cabada, R.Z., Barrón, M.L.: Impact of augmented reality technology on academic achievement and motivation of students from public and private Mexican schools. A case study in a middle-school geometry course. Comput. Educ. **145**, 103734 (2020)
6. Laine, T.H., Nygren, E., Dirin, A., Suk, H.-J.: Science Spots AR: a platform for science learning games with augmented reality. Educ. Technol. Res. Dev. **64**(3), 507–531 (2016). https://doi.org/10.1007/s11423-015-9419-0
7. Zhu, L., Cao, Q., Cai, Y.: Development of augmented reality serious games with a vibrotactile feedback jacket. Virtual Real. Intell. Hardw. **2**, 454–470 (2020)
8. Dunleavy, M., Dede, C., Mitchell, R.: Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning. J. Sci. Educ. Technol. **18**, 7–22 (2009)
9. Bujak, K.R., Radu, I., Catrambone, R., MacIntyre, B., Zheng, R., Golubski, G.: A psychological perspective on augmented reality in the mathematics classroom. Comput. Educ. **68**, 536–544 (2013)
10. Flores-Bascuñana, M., Diago, P.D., Villena-Taranilla, R., Yáñez, D.F.: On augmented reality for the learning of 3D-geometric contents: a preliminary exploratory study with 6-grade primary students. Educ. Sci. **10**, 4 (2020)
11. Sampaio, D., Almeida, P.: Pedagogical strategies for the integration of Augmented Reality in ICT teaching and learning processes. Procedia Comput. Sci. **100**, 894–899 (2016)
12. Midak, L.Y., Kravets, I.V., Kuzyshyn, O.V., Pahomov, J.D., Lutsyshyn, V.M.: Augmented reality technology within studying natural subjects in primary school (2020)
13. Ducasse, J.: Augmented reality for outdoor environmental education. In: Augmented Reality in Education. pp. 329–352. Springer (2020)
14. Rossing, J.P., Miller, W., Cecil, A.K., Stamper, S.E.: iLearning: The future of higher education? Student perceptions on learning with mobile tablets (2012)
15. Kiryakova, G.: The Immersive Power of Augmented Reality. In: Human-Computer Interaction. IntechOpen (2020)
16. Radosavljevic, S., Radosavljevic, V., Grgurovic, B.: The potential of implementing augmented reality into vocational higher education through mobile learning. Interact. Learn. Environ. **28**, 404–418 (2020)
17. Akçayır, M., Akçayır, G., Pektaş, H.M., Ocak, M.A.: Augmented reality in science laboratories: The effects of augmented reality on university students' laboratory skills and attitudes toward science laboratories. Comput. Human Behav. **57**, 334–342 (2016)
18. Sucihati, R., Malyan, A.B.J., Cofriyanti, E.: Augmented reality in the registration flow for enterance eximination at state polytechnic of sriwijaya based on Android. In: Journal of Physics: Conference Series, p. 12128 (2020)
19. Habig, S.: Who can benefit from augmented reality in chemistry? Sex differences in solving stereochemistry problems using augmented reality. Br. J. Educ. Technol. **51**, 629–644 (2020)
20. Fan, M., Antle, A.N., Warren, J.L.: Augmented reality for early language learning: a systematic review of augmented reality application design, instructional strategies, and evaluation outcomes. J. Educ. Comput. Res. 0735633120927489 (2020)
21. Alzahrani, N.M.: Augmented reality: a systematic review of its benefits and challenges in e-learning contexts (2020). https://doi.org/10.3390/app10165660

22. Costa, M.C., Manso, A., Patrício, J.: Design of a Mobile Augmented Reality Platform with game-based learning purposes. Information **11**, 127 (2020)
23. Pigueiras, J., Ruiz-Zafra, A., Maciel, R.: An augmented reality-based mlearning approach to enhance learning and teaching: a case of study in Guadalajara. In: International Conference in Methodologies and intelligent Systems for Techhnology Enhanced Learning. pp. 174–184. Springer (2020)
24. Zhang, Z., Li, Z., Han, M., Su, Z., Li, W., Pan, Z.: An augmented reality-based multimedia environment for experimental education. Multimedia Tools Appl. **3**, 1–16 (2020). https://doi.org/10.1007/s11042-020-09684-x
25. Nechypurenko, P.P., Stoliarenko, V.G., Starova, T.V, Selivanova, T.V, Markova, O.M., Modlo, Y.O., Shmeltser, E.O.: Development and implementation of educational resources in chemistry with elements of augmented reality. (2020)
26. Bektas, K.: Toward a pervasive gaze-contingent assistance system: attention and context-awareness in augmented reality. In: ACM Symposium on Eye Tracking Research and Applications. pp. 1–3 (2020)
27. Priestnall, G.: Augmented reality. Geogr. Educ. Digit. World Link. Theory Pract. **39** (2020)
28. Erbas, C., Demirer, V.: The effects of augmented reality on students' academic achievement and motivation in a biology course. J. Comput. Assist. Learn. **35**, 450–458 (2019)
29. Chang, S.-C., Hwang, G.-J.: Impacts of an augmented reality-based flipped learning guiding approach on students' scientific project performance and perceptions. Comput. Educ. **125**, 226–239 (2018)
30. Hanafi, H.F., Said, C.S., Wahab, M.H., Samsuddin, K.: Improving students' motivation in learning ICT course with the use of a mobile augmented reality learning environment. IOP Conf. Ser. Mater. Sci. Eng. **226**, 012114 (2017). https://doi.org/10.1088/1757-899X/226/1/012114
31. Sahin, D., Yilmaz, R.M.: The effect of Augmented Reality Technology on middle school students' achievements and attitudes towards science education. Comput. Educ. **144**, 103710 (2020)
32. Tuli, N., Mantri, A.: experience fleming's rule in electromagnetism using augmented reality: analyzing impact on students learning. Procedia Comput. Sci. **172**, 660–668 (2020)
33. Muangpoon, T., Osgouei, R.H., Escobar-Castillejos, D., Kontovounisios, C., Bello, F.: Augmented reality system for digital rectal examination training and assessment: system validation. J. Med. Internet Res. **22**, e18637 (2020)
34. Triepels, C.P.R., Smeets, C.F.A., Notten, K.J.B., Kruitwagen, R.F.P.M., Futterer, J.J., Vergeldt, T.F.M., Van Kuijk, S.M.J.: Does three-dimensional anatomy improve student understanding? Clin. Anat. **33**, 25–33 (2020)
35. Radu, I.: Augmented reality in education: a meta-review and cross-media analysis. Pers. Ubiquitous Comput. **18**(6), 1533–1543 (2014). https://doi.org/10.1007/s00779-013-0747-y
36. Arulanand, N., Babu, A.R., Rajesh, P.K.: Enriched learning experience using augmented reality framework in engineering education. Procedia Comput. Sci. **172**, 937–942 (2020)
37. Kara, N., Cagiltay, K.: Smart toys for preschool children: a design and development research. Electron. Commer. Res. Appl. **39**, 100909 (2020)
38. Chen, C.: AR videos as scaffolding to foster students' learning achievements and motivation in EFL learning. Br. J. Educ. Technol. **51**, 657–672 (2020)
39. Maas, M.J., Hughes, J.M.: Virtual, augmented and mixed reality in K–12 education: a review of the literature. Technol. Pedagog. Educ. **29**, 231–249 (2020)
40. Chen, L., Yang, X., Wang, B., Shu, Y., He, H.: Research on augmented reality system for childhood education reading. In: 2018 12th IEEE International Conference on Anti-counterfeiting, Security, and Identification (ASID), pp. 236–239. IEEE (2018)

41. Buchner, J., Jeghiazaryan, A.: Work-in-progress–the ari 2 ve model for augmented reality books. In: 2020 6th International Conference of the Immersive Learning Research Network (iLRN), pp. 287–290. IEEE (2020)
42. Martin, S., Parra, G., Cubillo, J., Quintana, B., Gil, R., Perez, C., Castro, M.: Design of an augmented reality system for immersive learning of digital electronic. In: 2020 XIV Technologies Applied to Electronics Teaching Conference (TAEE). pp. 1–6. IEEE (2020)
43. Syawaludin, A., Gunarhadi, G., Rintayati, P.: Enhancing elementary school students' abstract reasoning in science learning through augmented reality-based interactive multimedia. J. Pendidik. IPA Indones. **8**, 288–297 (2019)
44. Hanafi, H.F. bin, Said, C.S., Ariffin, A.H., Zainuddin, N.A., Samsuddin, K.: Using a collaborative Mobile Augmented Reality learning application (CoMARLA) to improve Improve Student Learning. IOP Conf. Ser. Mater. Sci. Eng. 160, 012111 (2016). https://doi.org/10.1088/1757-899X/160/1/012111
45. İbili, E., Çat, M., Resnyansky, D., Şahin, S., Billinghurst, M.: An assessment of geometry teaching supported with augmented reality teaching materials to enhance students' 3D geometry thinking skills. Int. J. Math. Educ. Sci. Technol. **51**, 224–246 (2020)
46. Morris, N.P., Lambe, J.: Multimedia interactive ebooks in laboratory bioscience education. High. Educ. Pedagog. **2**, 28–42 (2017)
47. Videnovik, M., Trajkovik, V., Kiønig, L.V., Vold, T.: Increasing quality of learning experience using augmented reality educational games. Multimedia Tools and Applications **6**, 23861–23885 (2020). https://doi.org/10.1007/s11042-020-09046-7
48. Meline, T.: Selecting studies for systematic review: Inclusion and exclusion criteria. Contemporary Issues in Communication Science and Disorders. ASHA. 33 (2006)
49. Baragash, R.S., Al-Samarraie, H., Alzahrani, A.I., Alfarraj, O.: Augmented reality in special education: a meta-analysis of single-subject design studies. Eur. J. Spec. Needs Educ. **35**, 382–397 (2020)
50. Sandelowski, M., Leeman, J.: Writing usable qualitative health research findings. Qual. Health Res. **22**, 1404–1413 (2012)
51. Vaismoradi, M., Turunen, H., Bondas, T.: Content analysis and thematic analysis: Implications for conducting a qualitative descriptive study. Nurs. Health Sci. **15**, 398–405 (2013)
52. Mayring, P.: Qualitative content analysis. A companion to Qual. Res. **1**, 159–176 (2004)
53. Morgan, D.L.: Qualitative content analysis: a guide to paths not taken. Qual. Health Res. **3**, 112–121 (1993)
54. Primer, A.P.: Quantitative methods in psychology. Psychol. Bull. **112** (1992)
55. Struck, H.N.: International E-Conference on Advances in Engineering, Technology and Management-ICETM 2020 S
56. Pfeiffer, T.: A Context-Aware Assistance Framework for Implicit Interaction with an Augmented Human
57. Donyavi, Z., Asadi, S.: Diverse training dataset generation based on a multi-objective optimization for semi-Supervised classification. Pattern Recognit. **108**, 107543 (2020)
58. Inglese, T., Korkut, S.: Modeling the instructional design of a language training for professional purposes, using augmented reality. In: Dornberger, R. (ed.) New Trends in Business Information Systems and Technology. SSDC, vol. 294, pp. 205–222. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-48332-6_14
59. Kanivets, O.V, Kanivets, I.M., Kononets, N.V, Gorda, T.M., Shmeltser, E.O.: Development of mobile applications of augmented reality for projects with projection drawings (2020)
60. Salar, R., Arici, F., Caliklar, S., Yilmaz, R.M.: A model for augmented reality immersion experiences of university students studying in science education. J. Sci. Educ. Technol. **29**(2), 257–271 (2020). https://doi.org/10.1007/s10956-019-09810-x
61. Zafar, S., Zachar, J.J.: Evaluation of HoloHuman augmented reality application as a novel educational tool in dentistry. Eur. J. Dent. Educ. **24**, 259–265 (2020)