Journal of Engineering Education Transformations ,
Volume 36 , No. 2 , October 2022 , ISSN 2349-2473, eISSN 2394-1707

10.16920/jeet/2022/v36i2/22156

The Role of Interactive and Immersive Technologies in Higher Education: A Survey

Deepti Prit Kaur[1], **Amit Kumar**[2], **Rubina Dutta**[3], **Shivani Malhotra**[4]
Chitkara University Institute of Engineering and Technology
Chitkara University, Punjab, India, 140401

Abstract : The developments in the Engineering domain have risen at an unprecedented rate in the past three decades. New technologies emerge every year and find their use case in multiple industries, also impacting the higher education as a whole. The present ecosystem demands industry-ready graduates from higher education institutes. To meet this, inculcation of newly developed technologies in the engineering education domain is a must. The retention span of Millennials in the traditional classroom settings has lowered down, posing the biggest challenge in student learning outcome at the higher education level. To solve this problem, interactive and immersive technologies has played a significant role through the use of Augmented Reality (AR), Virtual Reality (VR), and Gamification in a modern classroom setting. These technologies are capable of being used online as well as offline, and promise to deliver an enhanced user experience. The use of such tools also improves the student engagement by virtue of interactive content during the classroom session. This results in improved student learning and motivation in various domains of higher education. This paper focuses on the engineering education domain and discusses the role of these technologies in improving student understanding of intricate concepts of various engineering disciplines. A study of research papers presenting different digital learning platforms developed using these technologies from 2017 to 2021 was done, and it was concluded that the trends and technologies discussed in this paper have been tested and proven to be beneficial in engineering education. Further, developing a low-cost learning system using immersive and interactive technologies, and upgrading the present classroom set-up and skill set of instructors to make them significantly capable of utilizing the benefits offered by these technologies is yet to be achieved.

Keywords : Higher Education, Education Technology, Augmented and Virtual Reality, Immersive Technology, Interactive Teaching-Learning, Game-Based Learning, Online Teaching-Learning

Deepti Prit Kaur
Chitkara University Institute of Engineering and Technology
Chitkara University, Punjab, India, 140401

1. Introduction

Educators in the engineering domain are striving hard to imbibe the use of technologies such as multimedia learning, immersive tools, simulation-based solutions, and game-based education in addition to traditional teaching, to enhance the acquired knowledge and skill amongst their students.

Recently, the outbreak of COVID-19 resulted in a pandemic situation globally, pushing the transference of education from regular mode to online. The use of digital platforms for e-learning and educational technologies for imparting professional education has been rising since then. The Massive Open Online Courses (MOOC) is the most widely used and only available digital learning platform in the early days. Nevertheless, with an escalation in technology, several other forms of digital platforms have evolved recently. It includes game-based learning, live e-class, cloud-based learning, immersive and interactive technology-based learning platforms such as AR/VR based applications for education through mobile and desktop versions of apps as depicted in Figure 1.

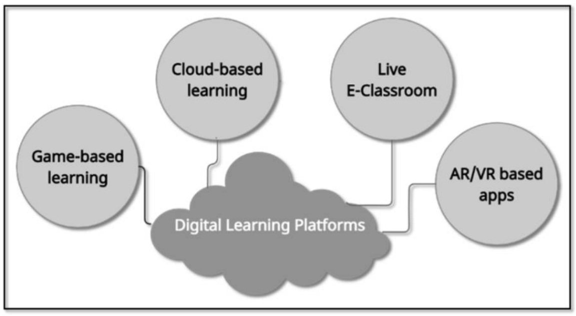

Fig. 1:Different digital learning platforms of 21st century

Augmented reality (AR) is an amalgamation of the natural world with the graphically generated virtual environment (Drascic & Milgram, n.d.). To be specific, using AR, human perception in real-time is modified by computer-generated sensory inputs such as sound, video, or graphics. According to (Azuma, 1997) AR possesses three unique properties: it combines real and virtual worlds simultaneously, interactive in real-time, and can be registered in 3D. An AR system facilitates the visualization of the hidden phenomenon of engineering processes. For example, in an embedded systems course, students may find it challenging to understand the mechanisms inside the devices without seeing their interactions and functioning (Benito, González, & L, 2015). An AR System requires that the real-world objects be appropriately aligned with the objects of the virtual world, or the illusion of co-existence of the two worlds will be compromised.

Virtual reality (VR) is achieved using computational techniques to create and simulate a virtual environment and place the user inside that experience (Dinis, Guimaraes, Carvalho, & Martins, 2017). VR system can bring that experience inside the classroom in specific applications in Civil Engineering, requiring students to study architecture structures. Virtual environments provide complete immersion in the synthetic environment. They can be helpful in many different areas of education, for school-going children, engineering and medical undergraduates, and even the people undergoing specialized training such as plumbing, fire safety, electricians, and other courses.

Gamification in education has also acquired a boost in serious games for the specific purpose of learning. It provides motivation and a more versatile environment for domain-specific knowledge (Backlund & Hendrix, 2013). Gamification of MOOCs (Massive Open Online Courses) and game-based Augmented/Virtual Reality set-ups have also been evolved during the past few years (Borras-gene & Martinez-nun, 2016; Oh, So, & Gaydos, 2017). Through gamification in education, there can be an enhancement in student's learning experience while teaching complex subjects.

According to (Rekimoto & Nago 1995, Rubio-Tamayo, Barrio, & García, 2017) , three types of interactions are feasible in these digital learning platforms. These interactions are human-computer, human-real world, and between computer and real-world. Based on these interactions, the classification and behavior of various digital learning platforms used in this study have been shown in Figure 2.

By reviewing the related literature, this paper aims to study the effects of these techniques on the student's learning capability in engineering education with an

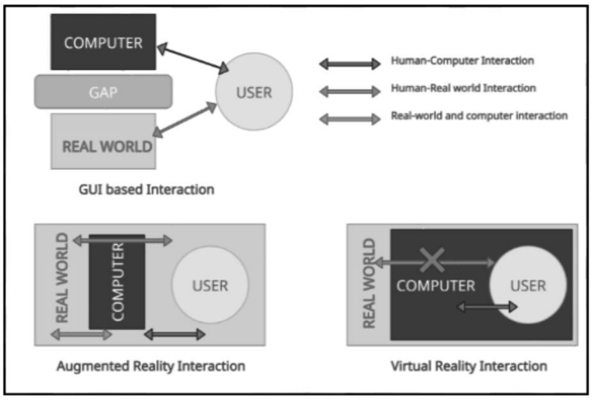

Fig. 2: Types of interactions in digital learning platforms

entire future scope in teaching through techniques other than the conventional classroom teaching methods. This paper discusses the role of technologies like Augmented Reality, Virtual Reality, and gamification in the teaching-learning process for higher education; explicitly engineering education. Further section II outlines the literature covered; section III portrays the survey of implementation and outcome of these technologies in higher education during the last five years. Section IV presents the conclusion and future scope of using these technologies in higher education.

2. Related Work

The field of education technology has always remained an area for researchers to explore different actions taken by teachers to improve the motivation and learning of their students in a classroom. During the past few years, the use of blended learning techniques in addition to traditional instructions in educational set-ups has enabled the utilization of immersive technology such as mixed reality (virtual or augmented, that can provide complete or partial immersion to its users), serious games for learning and MOOCs in order to provide a better learning experience to the learners (Earle & Earle, 2002; Rosen, 2000). A vast literature is available mentioning the role of educational technology as an aid for engineering courses, and precisely, Augmented Reality, Virtual Reality, and Game-based education have been selected from peer-reviewed journals and conference proceedings for review in the present study. Pertinent literature was found using online research databases related to education and engineering (Scopus). Students usually face problems with visualization of the unseen phenomenon while working with electronics equipment. An AR environment with a camera, a tracking system, and a visualization system can help solve this type of problem. Tracking system analyses the data from the camera, where the augmented information (software-based or hardware-based) will appear. The main advantages of such a method include simultaneous presentation of physical, electronic equipment and relevant concepts mentioning the names of electronics parts, etc. As the additional information. This method can facilitate the comprehension of technical concepts and retention of course-related contents for a longer duration. The only drawback to this technology comes from the fact that test participants often misunderstand prototypes during real settings for traditional evaluation sessions (Benito et al., 2015).

Virtual and augmented reality in various fields for learning has been in use for since long. A game-based AR/VR application provides numerous interfaces involving gaming environments in Engineering Education. It is capable of helping disseminate civil engineering and other fields to motivate students during their learning process (Dinis et al., 2017). Educational games can also be used in MOOCs, influencing the student motivation, collaborative capabilities, and learning. Through this method, access to traditional course materials, such as filmed lectures, readings, and problem sets, is also available (Borras-gene & Martinez-nun, 2016). Generally, the term "serious games" is used for a specific purpose of learning, which is different from entertainment games and aid to learning in students through the development of their domain-specific knowledge. The approach "Edutainment – education through entertainment" is followed in game-based learning. Table 1 provides a comparison of serious games with entertainment games.

Table 1 : Comparison of Serious and Entertainment Games

Sr No	Serious Games	Entertainment Games
1	The focus is on enhancing the learning of students.	The focus is on having fun.
2	It involves tasks for problem solving and understanding.	It prefers a rich user experience.
3	The motivation for use is intrinsic for the learner.	The motivation for use is extrinsic for the learner.

These digital learning platforms exhibit immersion between real-world and virtual-world objects, which is highly significant to engage the learners throughout the sessions. Figure 3 depicts the amount of immersion involved in AR-based, VR-based, and Serious games. AR takes the elements that we see; and

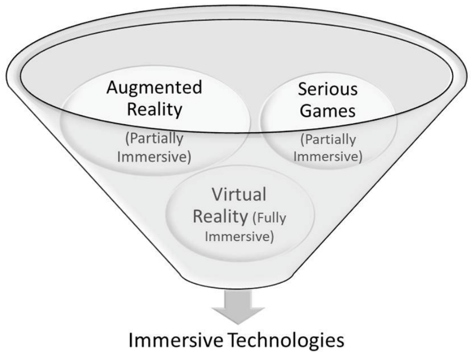

Fig. 3:Amount of immersion in AR & VR Technologies

modifies them by adding relevant information, and is different from virtual reality (VR), which replaces a person's view with a simulated one. Thus, AR and serious games reflect partial immersion of user in the synthetic/virtual environment whereas virtual reality-based solutions offer complete immersion and engages the learner throughout the learning process.

The three technologies, viz. AR, VR and Games in education, chosen for the survey have been summarized on the basis of advantages and disadvantages in Table 2.

Table 2 : Advantages and Disadvantages of Technologies For Engineering Education

Technology	Advantages	Disadvantages
Augmented Reality	• Enhances the comprehension and retention of technical concepts. • Facilitates memorization and recall. • Real-time representation of instruments and machines can be presented.	• Expensive to develop and maintain. • Mishandling of costly AR equipment by students. • Low-performance levels of AR devices can occur during testing.
Virtual Reality	• Visualizations of complex structures are possible without having to visit the actual site. • Increases student engagement.	• Expensive to develop and maintain. • Lack of standardization. • It may induce medical side effects in some participants.
Serious Games	• Increased participant learning. • Learning opportunity for everyone. • Self-paced learning. • Building virtual communities to promote group learning effort. • Improving the access, quality, and scaling of education	• Evaluation and assessment are computer-graded. • Course completion rates are low. • Lack of direct teacher-student interaction.

In many cases, graduates with sound theoretical knowledge lack practical knowledge. The main reason behind it is the lack of resources like labs, instruments, etc. The remote labs presented with graphical visualization to assist the students in developing their skills offer a solution to this problem. However, even they are not very efficient since these systems lack reality. It is easier to understand the practical concepts when the experiments are performed in real. In order to overcome this problem, augmented reality (AR) can be used in a demonstration of experiment-related interfaces in distant labs. Students can perform experiments with real and virtual elements for better understanding (Mackay, 1998). There are many fields in education utilizing these technologies, such as augmented reality, virtual reality, and games by incorporating the algorithms from computer vision, and are also helpful for online teaching-learning for educational engineering labs with distributed system architecture. The real-time video of instruments and equipment of an experiment can be presented. Students can transfer smoothly from augmented video demonstrations of equipment in a remote lab to actual equipment in a real lab.

3. An Exploration Of Different Interactive And Immersive Technologies For Higher Education

In order to comprehend the role of interactive and immersive technologies, research papers from SCI and Scopus indexed journals are considered in this study. The focus areas in these papers are higher education and especially engineering education. Table III presents the summary of the study conducted and highlights the significant outcome, the approach followed, and the evaluation technique applied to different tools developed for digital learning.

Table 3 presents the vast areas of applications where interactive and immersive technologies find their place, to benefit the outcome of students learning in one form or the other. It shows that, during last 5-years, a significant amount of research has been

Table 3 : Survey Of 5-years of Using Immersive and Interactive Technologies In Higher Education

Engineering Discipline	Topic	Approach	Findings	Evaluation Technique	Year of Publication
Civil Engineering	Infrastructure Management	VR	The students got immensely benefited from AR technology in understanding structural design and 3D drawings for better implementation. Overall, student's learning experience increased using VR-based teaching tools.	Rubric based Activity assessment	2021 (Arif,2021)
Chemistry Education	Chemistry	Flipped and gamified learning with AR	The outcome noticed from the paper had shown a positive impact on both attitude and perception	Student's attitude and perception	2021 (Lu, Wong, Cheung, & Im, 2021)
Educational Science	Science	Gamification in the flipped classroom	The outcome of the research work showed a positive impact on motivation and social relatedness. However, no change noticed incompetence level.	Intrinsic motivation, competence, and social relatedness	2021 (Sailer & Sailer, 2021)
Electronics Engineering	Laboratory equipment (CRO and function generator)	VR	The results of the experimental research indicated that VR based teaching approach had put a positive impact on the knowledge, motivation, and cognition of the students	Knowledge development, learning motivation, and cognition	2021 (Singh, Mantri, Sharma, & Kaur, 2021)
Electronics Engineering	Embedded system design	ARITE	System usability evaluated using SUS.	System usability measurement	2020 (Kumar, Mantri, & Dutta, 2020)
Electronics Engineering	Robotics	AR	The AR technology used to explore the task related to the assembly of Robotic Kits designed using Buzz Boards. AR makes this assembly activity more joyful and helpful in achieving the learning outcomes of the activity.	Learning Gain	2020 (AlNajdi, Alrashidi, & Almohamadi, 2020)
Electronics Engineering	Embedded System	ARITE (Table-top)	The technology acceptance model employed to assess the behavior and intention of educators to use ARITE system in their regular classroom for teaching Embedded System course and positive result observed	TAM	2020 (Kumar, Mantri, 2021)
Electronics Engineering	Digital Electronics	Flipped learning approach	The results had shown a positive impact on the motivation and academic performance of the students after adopting flipped learning approach.	Academic performance and learning motivation	2020 (Dutta, Mantri, Singh, Malhotra, & Kumar, 2020)
Mechanical Engineering	Carpentry	AR	The students introduced to different types of Joints used in the Carpentry workshop using AR technology, and it was found that Student's retention and carpentry skills improved a lot using AR technology	Carpentry Skills testing	2019 (Lee & Lee, 2019)
Electronics Engineering	Electronic circuit simulation using AR	AR-based mobile application	Increase learning efficiency by simulating and moving intangible concepts like current, voltage, and so on into the physical world.	Learning & quality of teaching was analyzed	2019 (özüağ, Cantürk, & özyilmaz, 2019)
Electronics Engineering	Control system	ARLE (Mobile and Tabletop)	ARLE acts as an instructional tool that helps the students to learn their concepts.	Efficacy and usability in terms of manipulability and comprehensibility was evaluated	2019 (Prit Kaur, Mantri, & Horan, 2019)
Electronics Engineering	Laboratory equipment (CRO and function generator)	ARLE	The outcome of the research had shown a positive impact on student's laboratory skills and learning motivation. Moreover, the ARLE system helps to reduce the cognitive load of students	Laboratory skills, cognitive load, and learning motivation	2019 (Singh, Mantri, Sharma, Dutta, & Kaur, 2019)
Automobile Engineering	Training to auto mechanics engineer	VR	Training outcome was evaluated between the experimental and control group. After taking training through VR, the experimental group outperforms as compared to the control group.	Training outcome was evaluated	2019 (Makarova, Boyko, Shubenkova, Pashkevich, & Giniyatullin, 2019)
Mechanical Engineering	Electromechanical mechanism	AR	Performance of students was analyzed after teaching through AR and CAD tools. The research outcome indicated that students who learned through AR scored high grades compared to others.	Students' assessment, motivation and engagement	2019 (Scaravetti & Doroszewski, 2019)

Civil Engineering	Virtual field trip for engineers	VR	The proposed system helped the students to correlate the classroom theories with real-time applications. Also, students got familiarized through the whole construction process.	Constructive feedback of students was taken for a new pedagogical approach	2019 (Alexander, Cruz, & Torrence, 2019)
Project development course	Coding	Gamification supported flipped classroom	The research work was carried on faculty, and they gave positive feedback on the teaching methodology in terms of motivation and competence level	Motivation and in-class competition	2018 (Özer, Kanbul, & Ozdamli, 2018)
Undergraduate Course	Online teaching	MOOC teaching with VR	This blended learning approach resulted in a new platform for online teaching education	Student's interest	2018 (Zhang, 2018)
Undergraduate Course	Framework discussed	Mobile virtual reality	Mobile virtual reality could be proved as teaching pedagogy. It could help to enhance the learning skills of the learners	To enhance the learning skills of the learners	2017 (Cochrane et al., 2017)
Language course	Learn languages	Digital game-based learning	The outcome of the experimental work showed the positive attitude of students towards the acceptance of M-learning	Students' acceptance for M-learning	2017 (Chiu, 2017)

carried out in the higher education domain to improve the student learning, reduce the cognition, achieve enhanced user experience, student engagement, technological acceptance, and usability of the developed systems. The interactive and immersive technologies, as listed above, have shown positive results and offer a further scope of improvement for implementation in other fields of education as well.

4. Conclusion

The trends and technologies discussed in this paper have been tested and proven to be beneficial in the engineering education domain. The use of different technologies such as games in education, virtual reality, and augmented reality has been advancing day by day and making a vast ocean of opportunities for the student's bright future. These technologies can remove the blind spots that otherwise are left unchecked by traditional chalk and board learning methods. Incorporating these techniques into the teaching pedagogy proves an effective tool to bring out the change in imparting engineering education even during the COVID-19 pandemic. It is easy for teachers/instructors to inculcate interactive techniques such as serious games and immersive techniques such as augmented reality in their regular classroom. The use of AR enables long-term memory retention in students and improves physical task performance. Games have the potential to create a more versatile environment for learning in a classroom. However, the initial costs of setting up these technologies can be high. Nevertheless, in the long run, it will substantiate a better learning environment for the students and, in turn, craft better engineers for the industry. Better understanding and practical learning provided by these technologies can hold a bright future and valuable growth.

References

[1] Alexander, J. A., Cruz, L. E., & Torrence, M. L. (2019). Gold Star: Enhancing Student Engagement Through Gameful Teaching and Learning. (February). Retrieved from https://www.ideaedu.org/Portals/0/Uploads/Documents/IDEA Papers/IDEA Papers/Gold_Star_Enhancing_Student_Engagement_IDEA_Paper_75.pdf

[2] AlNajdi, S. M., Alrashidi, M. Q., & Almohamadi, K. S. (2020). The effectiveness of using augmented reality (AR) on assembling and exploring educational mobile robot in pedagogical virtual machine (PVM). Interactive Learning Environments, 28(8), 964–990. https://doi.org/10.1080/10494820.2018.1552873

[3] Azuma, R. T. (1997). A survey of augmented reality. Presence: Teleoperators and Virtual Environments, 6(4), 355–385. https://doi.org/10.1162/pres.1997.6.4.355

[4] Backlund, P., & Hendrix, M. (2013). Educational games - Are they worth the Effort?: A literature survey of the effectiveness of serious games. 2013 5th International Conference on Games and Virtual Worlds for Serious Applications, VS-GAMES 2013. https://doi.org/10.1109/VS-GAMES.2013.6624226

[5] Benito, J. R. L., González, E. A., & L, C. I. S. (2015). Augmented Reality Software for Laboratory Exercises. Engaging Computer Engineering Students with an Augmented Reality

Software for Laboratory Exercises, (317882), 2012–2015.

[6] Borras-gene, O., & Martinez-nun, M. (2016). New Challenges for the Motivation and Learning in Engineering Education Using Gamification in MOOC *. 32(1), 501–512.

[7] Chiu, F. Y. (2017). Virtual reality for learning languages based on mobile devices. 2017 16th International Conference on Information Technology Based Higher Education and Training, ITHET 2017, 5–7. https://doi.org/10.1109/ITHET.2017.8067813

[8] Cochrane, T., Cook, S., Aiello, S., Christie, D., Sinfield, D., Steagall, M., & Aguayo, C. (2017). A DBR framework for designing mobile virtual reality learning environments. Australasian Journal of Educational Technology, 33(6), 54–68. https://doi.org/10.14742/ajet.3613

[9] Dinis, F. M., Guimaraes, A. S., Carvalho, B. R., & Martins, J. P. P. (2017). Virtual and augmented reality game-based applications to civil engineering education. IEEE Global Engineering Education Conference, EDUCON, (April), 1683–1688. https://doi.org/10.1109/EDUCON.2017.7943075

[10] Drascic, D., & Milgram, P. (n.d.). I ’. 2653, 123–134.

[11] Dutta, R., Mantri, A., Singh, G., Malhotra, S., & Kumar, A. (2020). Impact of Flipped Learning Approach on Students Motivation for Learning Digital Electronics Course. Integration of Education, 24(3), 453–464. https://doi.org/10.15507/1991-9468.100.024.202003.453-464

[12] Earle, R. S., & Earle, R. S. (2002). The Integration of Instructional Public Education : Promises and Challenges. 42(1), 5–13.

[13] Kumar, A., Mantri, A., & Dutta, R. (2020). Development of an augmented reality-based scaffold to improve the learning experience of engineering students in embedded system course. Computer Applications in Engineering Education, (October 2019), cae.22245. https://doi.org/10.1002/cae.22245

[14] Lee, I., & Lee, I. (2019). Using augmented reality to train students to visualize three-dimensional drawings of mortise – tenon joints in furniture carpentry carpentry. Interactive Learning Environments, 0(0), 1–15. https://doi.org/10.1080/10494820.2019.1572629

[15] Lu, A., Wong, C. S. K., Cheung, R. Y. H., & Im, T. S. W. (2021). Supporting Flipped and Gamified Learning With Augmented Reality in Higher Education. Frontiers in Education, 6(April), 1–11. https://doi.org/10.3389/feduc.2021.623745

[16] Mackay, W. E. (1998). Augmented reality: Linking real and virtual worlds. Proceedings of the Working Conference on Advanced Visual Interfaces - AVI ’98, 13. https://doi.org/10.1145/948496.948498

[17] Makarova, I., Boyko, A., Shubenkova, K., Pashkevich, A., & Giniyatullin, I. (2019). Virtual laboratories: Engineers’ training for automotive industry. ICETA 2019 - 17th IEEE International Conference on Emerging ELearning Technologies and Applications, Proceedings, 505–511. https://doi.org/10.1109/ICETA48886.2019.9040074

[18] Oh, S., So, H., & Gaydos, M. (2017). Hybrid Augmented Reality for Participatory Learning : The Hidden Efficacy of the Multi- User Game-based Simulation. 1382(c), 1–15. https://doi.org/10.1109/TLT.2017.2750673

[19] Özer, H. H., Kanbul, S., & Ozdamli, F. (2018). Effects of the gamification supported flipped classroom model on the attitudes and opinions regarding game-coding education. International Journal of Emerging Technologies in Learning, 13(1), 109–123. https://doi.org/10.3991/ijet.v13i01.7634

[20] özüağ, M., Cantürk, I., & özyilmaz, L. (2019). A new perspective to electrical circuit simulation with augmented reality. International Journal of Electrical and Electronic Engineering and Telecommunications, 8(1), 9–13. https://doi.org/10.18178/ijeetc.8.1.9-13

[21] Prit Kaur, D., Mantri, A., & Horan, B. (2019). Design implications for adaptive augmented reality based interactive learning environment for improved concept comprehension in engineering paradigms. Interactive Learning Environments, 0(0), 1–19. https://doi.org/10.1080/10494820.2019.1674885

[22] Rosen, M. A. (2000). Engineering Education : Future Trends and Advances. 44–52.

[23] Rubio-Tamayo, J. L., Barrio, M. G., & García, F. G. (2017). Immersive environments and virtual reality: Systematic review and advances in communication, interaction and simulation. Multimodal Technologies and Interaction, 1(4), 1–20. https://doi.org/10.3390/mti1040021

[24] Sailer, M., & Sailer, M. (2021). Gamification of in-class activities in flipped classroom lectures. British Journal of Educational Technology, 52(1), 75–90. https://doi.org/10.1111/bjet.12948

[25] Scaravetti, D., & Doroszewski, D. (2019). Augmented reality experiment in higher education, for complex system appropriation in mechanical design. Procedia CIRP, 84, 197–202. https://doi.org/10.1016/j.procir.2019.04.284

[26] Singh, G., Mantri, A., Sharma, O., Dutta, R., & Kaur, R. (2019). Evaluating the impact of the augmented reality learning environment on electronics laboratory skills of engineering students. Computer Applications in Engineering Education, 27(6), 1361–1375. https://doi.org/10.1002/cae.22156

[27] Singh, G., Mantri, A., Sharma, O., & Kaur, R. (2021). Virtual reality learning environment for enhancing electronics engineering laboratory experience. Computer Applications in Engineering Education, 29(1), 229–243. https://doi.org/10.1002/cae.22333

[28] Zhang, X. (2018). Design and analysis of music teaching system based on virtual reality technology. IPPTA: Quarterly Journal of Indian Pulp and Paper Technical Association, 30(5), 196–202.

(Leave this section as is for the double-blind review process. Start this section on a new column. This section does not have a title. In the first paragraph, list the author's educational background. The degrees should be listed with type of degree in what field, which institution, city, state, and country, and year the degree was earned. The author's major field of study should be lower-cased. The second paragraph uses the pronoun of the person (he or she) and lists work experience. Job titles are capitalized. The current job must have a location. State current and previous research interests end the paragraph. The third paragraph begins with the author's title and last name (e.g., Dr. Smith, Prof. Jones, Mr. Kajor, Ms. Hunter). List any memberships in professional societies and awards. If a photograph is provided, it should be of good quality and professional-looking. The following are two examples of an author's biography.)