Immersive technologies in higher education: Applications, challenges, and good practices

Laura Calvet
IN3-Computer Science Dep., Universitat Oberta de Catalunya
Barcelona, Spain
lcalvetl@uoc.edu
Área de empresa, Universidad Internacional de Valencia
Valencia, Spain
laura.calvet@campusviu.es

Pierre Bourdin
Computer Science Dep., Universitat Oberta de Catalunya
Barcelona, Spain
pbourdin@uoc.edu
Eventlab, Edifici Teatre, Departament de Psicologia Clínica i Psicobiologia, Universitat de Barcelona, Barcelona, Spain
pierre.bourdin@ub.edu

Ferran Prados
Computer Science Dep., Universitat Oberta de Catalunya
Barcelona, Spain
fpradosc@uoc.edu
Medical Physics and Biomedical Engineering Department, University College London
London, United Kingdom
f.carrasco@ucl.ac.uk

ABSTRACT
Immersive technologies are becoming increasingly popular in a wide range of fields from gaming to therapy. While there is a high number of case studies in education with promising results in terms of students' performance and engagement, there has still not been widespread adoption. Indeed, more research focused on large-size samples, assessing and discussing the effects on the medium and large term is required, as well as comparisons among different hardware and software, and guidelines for instructors that want to introduce these technologies in their classrooms. In this paper, we focus on the use of immersive technologies applications in higher education. In particular, we explain the basics of immersive technologies, review the main applications in higher education, discuss benefits and challenges, and describe good practices for instructors.

CCS Concepts
• **Applied computing~Interactive learning environments**

Keywords
Learning & ICT; Virtual reality; Students' engagement.

1. INTRODUCTION
According to the UNESCO [1], the number of students in higher education globally more than doubled to 207 million between 2000 and 2014. This increase has been driven by high and middle income countries. In addition, nowadays there is a high diversity of institutions.

Moreover, during the last decades, the technological development has dramatically changed our lifestyle. This development has led to a greater communication and collaboration resulting in new pedagogical models and tools. For instance, the invention of the Web technologies made online education increasingly accessible, open, flexible [2].

More recently, immersive technologies have started to gain popularity and have a remarkable potential in higher education considering a five-year horizon [3]. These technologies refer to technology that attempts to induce the perception of being physically present in a non-physical world through the means of a digital or simulated world or, on the other way around, seeing and interacting with virtual elements added to the physical reality. The technical goal of immersive technologies is to replace real sense perceptions by the computer-generated ones, creating a sense of immersion [4].

In this context, this paper analyzes the use of virtual reality (the most immersive technology) to enhance both face-to-face learning and e-learning. Although there are some reviews on a subset of immersive technologies in education [5,6,7], to the best of our knowledge, there is no work studying all types of immersive technologies (introduced in the next section) in higher education. Such a review is necessary to compare and evaluate immersive technologies, as well as provide recommendations to instructors so that they can choose the one that best fits each case, based on the educational objectives and budget.

The rest of this paper is organized as follows. Section 2 offers an introduction to immersive technologies. Afterwards, section 3 reviews related work on applications in higher education. A discussion of benefits, challenges, and good practices is provided in section 4. Finally, general conclusions are drawn in section 5.

2. IMMERSIVE TECHNOLOGIES
Immersive technologies bring together virtual reality, augmented reality, mixed reality, and immersive videos, which may be defined as follows.

- Virtual reality (VR): a totally immersive experience relying on head mounted displays (HMDs), which allow users to see a virtual world that totally replaces the real world. Interaction and movement within this alternative world are of great importance.
- Augmented reality (AR): superimposition of virtual elements in a real environment seen through devices such as a Smartphone, tablet, or see-through glasses.
- Mixed reality (MR): devices can be classified according to the role played in the real and virtual environments and can be placed on a continuum that goes from AR to VR. New images may be placed in a real space in such a way that they can interact, to some extent, with what is real in the physical world we know.
- Immersive videos (IV) (or 360 videos): these are spherical videos based on video recordings where a view is recorded in all directions at the same time using a set of cameras or an omnidirectional camera, which allows the viewer, during playback on normal flat display, to control the viewing direction like a panorama. However, there is little freedom to interact or move through the images.

The applications may be for multiple users or just one.

2.1 Evolution

Immersive technologies emerged a long time ago, but there were many factors preventing its massive use [8]. For instance, the relatively high cost of both procurement and maintenance of sophisticated devices. Another relevant disadvantage was the numerous psychological discomforts related, such as: strenuous posture demands, strain injuries, headset weight and fit, simulator sickness, disorientation, etc. [9].

However, this setting has dramatically changed and is still improving due to: a higher financial feasibility (regarding both hardware and software) and a more immersive technology as a result of higher levels of inversion from large companies like Apple, Facebook, and Samsung [10], and a growing mass of empirical evidence supporting the use of these technologies as well as providing guidelines.

2.2 Applications

There is a high number of applications based on immersive technologies. Here we briefly introduce some of them. For a comprehensive review of applications refer to [4].

Today the sector that leads the growth of VR is gaming. According to [11], the global VR gaming market size was estimated at USD 4.29 Billion in 2015. There are big companies investing in these technologies but there is also an increasing use of crowdfunding by start-ups to develop innovative software, accessories, and wearables.

Since its beginnings, the military sector also invests in immersive technologies which are used for flight, vehicle and battlefield simulation, as well as medic training. In addition, these technologies may be used to treat post-traumatic stress disorder, by exposing soldiers to the triggers for their condition which they gradually adjust to [12] and [13]. Indeed, immersive technologies have also been employed since its beginnings for medical uses like exposure therapy for different phobias such as spider phobia [14]. There are also interesting works in the fields of rehabilitation [15] and marketing [16].

2.3 Hardware and software

As stated by [17], current development in immersive technologies is happening at unprecedented speed, with an update of systems and applications in the domain presented at a daily or weekly basis.

Frameworks. A-Frame (https://aframe.io/) is an open-source web framework for building AR/MR/VR experiences based on Web VR using HTML and JavaScript that works on a great variety of hardware such as HTC Vive, Oculus Rift, desktop, or mobile platforms. Vuforia Engine (https://developer.vuforia.com/) offers another possibility for building more complex AR applications, which supports most leading phones, tablets, and eyewear. Vuforia allows developers to easily add advanced computer vision functionality to create AR/MR experiences that realistically interact with objects and the environment.

Game engines. Game engines such as Unity (https://unity.com/) or Unreal (https://www.unrealengine.com/) are good options which integrate the major frameworks allowing building efficiently complex applications targeting a wide range of devices without complications.

Platforms. There is a high variety of devices in terms of cost and quality. Less immersive experiences may be enjoyed using any desktop computer or mobile phone. The simplest HMD is the Google cardboard (Figure 1 – top, https://vr.google.com/cardboard/), which is named for its fold-out cardboard viewer. This device is intended as a low-cost system to encourage interest and development in immersive applications. The success of cardboard convinced Google to develop more advanced hardware and, in 2016, Google announced an enhanced platform called Daydream (https://vr.google.com/daydream/). The company Oculus (https://www.oculus.com/) is one of the major players of virtual reality headsets manufacturer, which was responsible for a revolution in the helmet market in 2012 with its very popular Oculus Rift HMD that started as a Kick starter campaign before being purchased by Facebook in 2014. Although two pre-production versions were sold earlier to the project's backers and a large number of VR enthusiasts, the first commercial model was released in spring 2016. Oculus VR, now a division of Facebook, recently launched the Oculus Go as well as the Oculus Quest and Oculus Rift S, as a replacement of the "old" Oculus Rift. Another popular alternative is the HTC Vive (Figure 1 - bottom, https://www.vive.com/eu/), which was unveiled in 2015. This headset employs "room scale" tracking technology that enables the user to move in 3D space and use motion-tracked handheld controllers to interact with the virtual world. There are several accessories: controllers, base stations, a motion tracker to be attached to physical accessories and controllers, deluxe audio strap, and a wireless adapter. Upgraded models have been launched since then: the HTC Vive Pro, the Vive Focus, the Vive Pro Eye, and the Vive Cosmos.

Figure 1. Google cardboard (top) and HTC Vive (bottom).

3. RELATED WORK

Immersive technologies have plenty of characteristics that make them appealing for higher education. First, they have an inherently interactive nature, which allows a more experiential learning experience in comparison to traditional lessons. In addition, wearing an HMD avoids external visual distractions, immersing users in the virtual environment. Using other hardware for displays might produce this sense of immersion, but less intense.

This section summarizes the findings of related work on immersive technologies in higher education. Due to the very large number of available works, we do not intend to provide a comprehensive review and, therefore, we will focus on reviews and recent works.

3.1 Augmented and mixed reality applications

[18] reviews 28 publications from 2010 to 2017 on the use of AR technology to support STEM learning. 7 of these studies refer to higher education students. Most applications offer similar design features based on digital knowledge discovery mechanisms to

consume information through the interaction with digital elements. The authors state that future applications need to include metacognitive scaffolding and experimental support for inquiry-based learning activities.

[19] reviews 68 articles on AR usage in education from 1980 to 2015 and concludes that: *(i)* the number of publications has been growing since 2007; *(ii)* half of them focus on primary and secondary students while more than a quarter refer to higher education; and *(iii)* mobile devices represent more than half of the AR technologies used, while desktop computers account for a quarter. The top advantages identified are: enhances learning achievement, learning motivation, and enjoyment, helps students to understand, provides positive attitude, raises the level of engagement, enables visualization of invisible concepts, events, and abstract concepts, enhances satisfaction, increases interest, provides interaction opportunities (student-students), and is easy for students to use. The authors also report these challenges: requires more time, errors may cause student frustration, not suitable for large group teaching, causes cognitive overload, distracts students' attention, expensive technology, large file size limits the sharing of content, ergonomic problems, difficult to design, and inadequate instructor ability to use the technology. Similarly, [20] identifies relevant risks: students may be cognitively overloaded by the large amount of information they encounter, the multiple technological devices they are required to use, and the complex tasks they must complete. Thus, it is recommended to find alignment among technology design, instructional approach, and learning experiences.

Given the existing barriers, [21] proposes a methodology to aid adoption of these technologies: *(i)* training instructors; *(ii)* developing conceptual prototypes; *(iii)* teamwork involving the instructor, a technical programmer, and an educational architect; *(iv)* producing the experience; *(v)* training instructors to apply AR solutions within their teaching methodology; and *(vi)* implementing the use of the experience.

[22] presents a meta-analysis of 13 studies based on games, 29 on simulation, and 27 on virtual worlds. They analyze the effect of that technology on students' learning in K-12 or higher education settings. Authors discuss the importance of considering instructional design principles (feedback, student collaboration, etc.) when designing virtual environments.

[23] studies mobile AR. It assesses 10 works (each describing an application), which involves participants of different ages (from elementary school to adults) and various topics ranging from art to recycling. The authors highlight that most of the studies show a positive impact and encouraging results.

An interesting recent work discusses the potential of AR to promote collaborative and autonomous learning in higher education [7]. It describes laboratory practices for an electrical machines course where students interact among them and without an instructor's assistance. The conclusions are that students welcome these technologies while they provide proper methods for developing professional competences.

Finally, [24] highlights that there is growing evidence that simulation improves learners' safety, competence, and skills in health sciences education. However, this approach becomes difficult when students are studying at a distance, making it necessary to develop simulations that suit this pedagogical problem and the logistics. This work describes the development of a MR simulation that uses 3D printed tools to improve skills development in students learning paramedic science at a distance. The experiment with 137 students involved shows improved outcomes.

3.2 Virtual reality applications

[25] reviews 21 experimental studies, from 2013 to 2017, related to VR usage in education and training. The authors identify situations where HMDs are useful for skills acquisition: cognitive skills related to remembering and understanding spatial and visual information and knowledge; psychomotor skills related to head-movement, such as visual scanning or observational skills; and affective skills related to controlling emotional response to stressful or difficult situations. In other situations, the HMDs have no advantage when compared to less immersive technologies or traditional instruction. Indeed, they may even be counterproductive because of cybersickness, technological challenges, or for distracting students from the learning task. A quality assessment based on the Medical Education Research Study Quality Instrument shows that the study quality of the selected works is below average.

[26] reviews 90 works on VR/AR applications in construction safety, which create environments for visualizing complex workplace situations, building up risk-preventive knowledge and undergoing training.

[27] explains emerging VR/AR applications in the field of neurosurgical practice and resident education. The authors discuss benefits, *e.g.*, experiencing surgical procedures becoming increasingly uncommon or identifying individual strengths, weaknesses, and any areas for improvement for neurosurgeons.

[28] reviews 93 works on VR usage in education published in 2013 or 2014. The authors claim that there are four relevant motivations for VR applications: *(i)* time travel; *(ii)* physical inaccessibility (*e.g.*, to explore other planets); *(iii)* avoiding dangerous situations; and *(iv)* ethic issues (*e.g.*, students performing complex surgeries). Half of the works reviewed describe applications to computer science and engineering.

Similarly, [4] explains the potential of immersive technologies in education and the advantages in comparison to traditional methods: *(i)* they can change the abstract into the tangible; *(ii)* they support "doing" rather than just observing; *(iii)* they can substitute methods that are desirable but practically infeasible even if possible in reality (such traveling to many different points of interest); and *(iv)* they can break the bounds of reality as part of exploration (*e.g.*, playing with physics laws).

3.3 Immersive videos applications

[29] analyzes whether a lesson presented in either IV or as a classic video could benefit from the pre-training principle to reduce cognitive load. A sample of 118 students at a large university was analyzed. The results indicate that pre-training had a positive effect on knowledge, transfer, and self-efficacy, but no effect was found when comparing the two types of video.

[30] examines pre-to-post changes in well-being, simulator sickness, and learning outcomes across four devices of varying levels of immersion (Smartphone, Google cardboard, Oculus Rift DK2, and Oculus CV1) using a space-themed 360º educational video. According to the results of the experiment where 136 university students were recruited, more immersive devices induce greater induction of place illusion, greater positive effect, increased interest about the video's subject-matter, and better learning outcomes while demonstrating low prevalence of simulator sickness.

[31] introduces an application into a sewing workshop in which a threading task is carried out. Participants include 46 freshmen. One group of students is provided with a handout, while the other is asked to view an AR video. Authors conclude that the video provides better learning results in terms of learning performance, efficiency, and satisfaction.

4. DISCUSSION

Based on the related literature reviewed, this section compares the different immersive technologies, discusses their benefits and challenges, before describing good practices for instructors.

4.1 Benefits

Immersive technologies may improve learning experiences in terms of engagement, motivation, time required, knowledge and skills, students' satisfaction, creativity, and innovation. Since the traditional limitations of immersive technologies (mentioned in Section 2) are less and less important as technological development goes on and the costs are also reducing, thus it is expected a higher adoption in education in the very next years.

4.2 Challenges

Despite their benefits, immersive technologies have failed to achieve widespread adoption. This is the result of the limitations of these technologies, including usability factors, display quality/lack of realism, motion sickness, and recognition inaccuracies. In addition, there is an important overhead incurred by content developers, instructors, and students.

4.3 Comparison among immersive technologies

VR, AR, MR, and IV have different characteristics and it is important to study and compare the different immersive technologies in order to find the technology that better suits a given learning objective and the limits of its budget.

VR applications tend to have a greater effect of immersion, followed by AR/MR applications and IV. There are significant differences regarding costs. On the one hand, the hardware required to use the applications is typically higher for VR, but the range is large, from low-cost cardboards to extremely sophisticated HMDs and accessories. AR applications may be displayed with cheaper devices such as mobile phones, an option also popular for IV. On the other hand, the range of options and costs regarding software is becoming increasingly wide, from low-cost and friendly platforms to complex platforms enabling the construction of sophisticated environments. In general, enjoying experiences based on immersive technologies is easy, but the configuration of controllers and HMDs requires time. Nowadays, the probability of feeling sick is relatively low. All immersive technologies but IV invite the user to explore the environment by providing different interactivity options, moreover VR and AR/MR applications are self-paced.

4.4 Good practices

It is essential to define detailed pedagogical objectives, design the materials or activities, select the most appropriate immersive technology considering the budget, ensure technological support for instructors and students, design an experiment (which includes choosing performance measures and defining a validation process), and obtain feedback to analyze and improve the whole process.

As commented before, these technologies may not be useful/efficient or even counterproductive in some scenarios. Thus, we need to know when to use immersive technologies. [32] explains reasons to use or not use VR, which may be extended to all immersive technologies. Basically, they should be implemented when it is feasible and convenient in terms of cost, to avoid negative consequences (such as anxiety), to achieve the learning objective, to ease visualization of information, when it is the only option to make perceptible the learning concepts, and/or to help the disabled. In contrast, they should be avoided when the real thing cannot be replaced, using a virtual environment may be damaging, or it is too expensive. The authors also added that it should be avoided when interaction with real humans is needed, can be discussed now that virtual agents have improved so much and that the technology offers possibilities of having a realistic virtual human representation.

5. CONCLUSIONS

Immersive technologies are becoming increasingly popular in plenty of fields other than entertainment, such as therapy and marketing. There are plenty of immersive technology applications in learning. They benefit from the interactive nature and the effect of immersion to improve learning experiences in terms of engagement, motivation, the time required, knowledge and skills, learners' satisfaction, and creativity, among others. There are different software and devices, and it is important to assess and compare them in order to be able to choose the most suitable for a given learning objective and budget.

Although there are many works on immersive technology, most are mainly descriptive and rely on small samples and short periods of times. Thus, works of better quality with a higher focus on validation are required. In addition, technological development (which brings more complex graphics, sophisticated controllers …) will increase the potential of these technologies.

6. ACKNOWLEDGEMENTS

We thank the eLearn Center of the Open University of Catalonia (UOC) for its financial support.

7. REFERENCES

1. UNESCO, 2017. *Six ways to ensure higher education leaves no one behind*. UNESCO Global Education Monitoring Report. UNESCO International. Institute for Education Planning (IIEP).

2. Harasim, L. 2000. Shift happens: Online education as a new paradigm in learning. *The Internet and Higher Education* 3, 41–61. DOI=https://doi.org/10.1016/S1096-7516(00)00032-4.

3. Johnson, L., Becker, S.A., Cummins, M., Estrada, V., Freeman, A., and Hall, C., 2016. *NMC horizon report: 2016 higher education edition*. The New Media Consortium.

4. Slater, M., and Sanchez-Vives, M.V., 2016. Enhancing our lives with immersive virtual reality. *Frontiers in Robotics and AI* 3, 74. DOI=https://doi.org/10.3389/frobt.2016.00074.

5. Jensen, L., and Konradsen, F., 2018. A review of the use of virtual reality head-mounted displays in education and training. *Education and Information Technologies* 23, 1515–1529. DOI=https://doi.org/10.1007/s10639-017-9676-0.

6. Akçayır, M., and Akçayır, G., 2017. Advantages and challenges associated with augmented reality for education: A systematic review of the literature. *Educational Research Review* 20, 1–11. DOI=https://doi.org/10.1016/j.edurev.2016.11.002.

7. Martín-Gutiérrez, J., Fabiani, P., Benesova, W., Meneses, M.D., and Mora, C.E., 2015. Augmented reality to promote collaborative and autonomous learning in higher education. *Computers in human behavior* 51, 752–761. DOI=https://doi. org/10.1016/j.chb.2014.11.093.

8. Psotka, J., 1995. Immersive training systems: Virtual reality and education and training. *Instructional science* 23, 405–431. DOI=https://doi. org/10.1007/BF00896880.

9. Costello, P. 1997. Health and safety issues associated with virtual reality: A review of current literature. *JISC Advisory Group on Computer Graphics Technical Report Series No. 37, Computing Services, Loughborough University*.

10. Martín-Gutiérrez, J., Mora, C.E., Añorbe-Díaz, B., and González-Marrero, A., 2017. Virtual technologies trends in education. *EURASIA Journal of Mathematics Science and Technology Education* 13, 469–486. DOI=https://doi. org/10.12973/879eurasia.2017.00626a.

11. Grand View Research, 2017. *Virtual reality in gaming market analysis by component, by device, by country, and segment forecasts, 2018 - 2025*. Technical Report.

12. Pallavicini, F., Argenton, L., Toniazzi, N., Aceti, L., Mantovani, F., 2016. Virtual reality applications for stress management training in the military. *Aerospace medicine and human performance* 87, 1021–1030. DOI=https://doi.org/10.3367/AMHP.4596.2016.

13. Lele, A., 2013. Virtual reality and its military utility. *Journal of Ambient Intelligence and Humanized Computing* 4, 17–26. DOI=https://doi.org/10.1007/s12652-011-0052-4.

14. Miloff, A., Lindner, P., Dafgard, P., Deak, S., Garke, M., Hamilton, W., Heinsoo, J., Kristoffersson, G., Rafi, J., and Sindemark, K. 2019. Automated virtual reality exposure therapy for spider phobia vs. in-vivo one-session treatment: A randomized non-inferiority trial. *Behaviour research and therapy* 118, 130–140. DOI=https://doi.org/10.1016/j.brat.2019.04.004.

15. Glegg, S.M.N. and Levac, D.E., 2018. Barriers, facilitators and interventions to support virtual reality implementation in rehabilitation: A scoping review. *Physical Medicine & Rehabilitation* 10, 1237–1251. DOI=https://doi.org/10.1016/j.pmrj.2018.07.004.

16. Barnes, S., 2016. Understanding virtual reality in marketing: Nature, implications and potential. Available at SSRN: https://ssrn.com/abstract=2909100.

17. Anthes, C., Garcia-Hernandez, R.J., Wiedemann, M., and Kranzlmuller, D., 2016. State of the art of virtual reality technology. In *IEEE Aerospace Conference*. 1–19. DOI=https://doi.org/10.1109/AERO.2016.7500674.

18. Ibáñez, M.B. and Delgado-Kloos, C., 2018. Augmented reality for STEM learning: A systematic review. *Computers & Education* 123, 109–123. DOI=https://doi.org/10.1016/j.compedu.2018.05.002.

19. Akçayır, M. and Akçayır, G., 2017. Advantages and challenges associated with augmented reality for education: A systematic review of the literature. *Educational Research Review* 20, 1–11. DOI=https://doi.org/10.1016/j.edurev.2016.11.002.

20. Wu, H.K., Lee, S.W.Y., Chang, H.Y., and Liang, J.C., 2013. Current status, opportunities and challenges of augmented reality in education. *Computers & Education* 62, 41–49. DOI=https://doi.org/10.1016/j.compedu.2012.10.024.

21. Fernández, M., 2017. Augmented virtual reality: How to improve education systems. *Higher Learning Research Communications* 7, 1–15. DOI=https://doi.org/10.18870/hlrc.v7i1.373.

22. Merchant, Z., Goetz, E.T., Cifuentes, L., Keeney-Kennicutt, W., and Davis, T.J., 2014. Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis. *Computers & Education* 70, 29–40. DOI=https://doi.org/10.1016/j.compedu.2013.07.033.

23. Nincarean, D., Alia, M.B., Halim, N.D.A., and Rahman, M.H.A., 2013. Mobile augmented reality: The potential for education. *Procedia-social and behavioral sciences* 103, 657–664. DOI=https://doi.org/10.1016/j.sbspro.2013.10.385.

24. Cowling, M. and Birt, J., 2018. Pedagogy before technology: A design-based research approach to enhancing skills development in paramedic science using mixed reality. *Information* 9, 29. DOI=https://doi.org/10.3390/info9020029.

25. Jensen, L. and Konradsen, F., 2018. A review of the use of virtual reality head-mounted displays in education and training. *Education and Information Technologies* 23, 1515–1529. DOI=https://doi.org/10.1007/s10639-017-9676-0.

26. Li, X., Yi, W., Chi, H.L., Wang, X., Chan, A.P., 2018. A critical review of virtual and augmented reality (VR/AR) applications in construction safety. *Automation in Construction* 86, 150–162. DOI=https://doi.org/10.1016/j.autcon.8652017.11.003.

27. Pelargos, P.E., Nagasawa, D.T., Lagman, C., Tenn, S., Demos, J.V., Lee, S.J., Bui, T.T., Barnette, N.E., Bhatt, N.S., Ung, N., et al., 2017. Utilizing virtual and augmented reality for educational and clinical enhancements in neurosurgery. *Journal of Clinical Neuroscience* 35, 1–4. DOI=https://doi.org/10.1016/j.jocn.2016.09.002.

28. Freina, L., Ott, M., 2015. A literature review on immersive virtual reality in education: State of the art and perspectives. In *The International Scientific Conference eLearning and Software for Education*. p. 133.

29. Meyer, O.A., Omdahl, M.K., Makransky, G., 2019. Investigating the effect of pre-training when learning through immersive virtual reality and video: A media and methods experiment. *Computers & Education*, DOI=https://doi.org/10.8901016/j.compedu.2019.10360.

30. Rupp, M.A., Odette, K.L., Kozachuk, J., Michaelis, J.R., Smither, J.A., McConnell, D.S., 2019. Investigating learning outcomes and subjective experiences in 360-degree videos. *Computers & Education* 128, 256–268. DOI=https://doi.org/10.1016/j.compedu.2018.09.015.

31. Yip, J., Wong, S.H., Yick, K.L., Chan, K., and Wong, K.H., 2019. Improving quality of teaching and learning in classes by using augmented reality video. *Computers & Education* 128, 88–101. DOI=https://doi.org/10.1016/j.compedu.2018.09.014.

32. Pantelidis, V.S., 2010. Reasons to use virtual reality in education and training courses and a model to determine when to use virtual reality. *Themes in Science and Technology Education* 2, 59–70.

Columns on Last Page Should Be Made As Close As Possible to Equal Length

Authors' background

Your Name	Title*	Research Field	Personal website
Laura Calvet	Lecturer	Applied statistics & optimization; e-learning	https://lauracalvetl.wordpress.com/
Pierre Bourdin	Senior lecturer	Virtual & augmented technologies	https://www.researchgate.net/profile/Pierre_Bourdin
Ferran Prados	Senior lecturer	e-learning; medical image processing	https://www.researchgate.net/profile/Ferran_Prados

***This form helps us to understand your paper better, the form itself will not be published.**

***Title can be chosen from: master student, Phd candidate, assistant professor, lecture, senior lecture, associate professor, full professor**