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AN OVERVIEW OF VIRTUAL REALITY-BASED EDUCATIONAL ANIMATION DESIGN OPTIMISATION

Liew Nyet Fong
Faculty of Applied and Creative Arts,
Universiti Malaysia Sarawak,
94300 Kota Samarahan, Sarawak, Malaysia

Terry Lucas
Faculty of Applied and Creative Arts,
Universiti Malaysia Sarawak,
94300 Kota Samarahan, Sarawak, Malaysia

Corresponding Author
22020162@siswa.unimas.my
lterry@unimas.my

Abstract: Designing virtual reality (VR) experiences for tertiary education appropriately remains an active research topic. VR-based educational animation is seen as a low-cost VR option. It has been mentioned that more effort should be put into designing educational content and the role of design elements for VR. This thematic paper aims to explain the current research in VR-based educational animation. There have been efforts to propose strategies for collaboration with animators, improving the video quality, testing the effects of informational elements, and deriving design guidelines to enhance the video design. The overview identified loopholes and gaps, i.e., a lack of information about learners' preferences for design elements and how to utilise the design elements better. The paper that investigates animators' VR-based educational animation design experience is scarce. Hence, future research could investigate and fill in the gaps mentioned, which includes providing a clear description of the VR-based video design. It is hoped that this thematic paper can support and provide insights into future instructional design and development of VR-based educational animation, thus aiding its wider educational adoption.

Keywords: 360° Video, Educational Animation, Educational Technology, Instructional Design, Virtual Reality

1. INTRODUCTION

Video in the form of animation offers greater imagination in educational material presentation, which has been enriched by virtual reality (VR) and augmented reality (AR) since 2010. Animation, VR, AR, and mixed media are emerging technologies gaining prominence in education (Stadlinger et al., 2021). 360-degree (360°) animation media, also referred to as VR animation, can facilitate a better message and story delivery and can aid in enhancing the effectiveness of the learning process of educational content (Sutrisno et al., 2023). Since we are transitioning from Industrial Revolution (IR) 3.0 to IR 4.0, it is best to keep up with current technology trends and utilise them to benefit learners. One such technology is VR, which uses 360° video. 360° video, or mobile or desktop-based VR, offers the most popular, easiest, and cheapest way to access VR applications (Le et al., 2022). With 360° videos, learners can observe scene(s) from any preferred perspective (Rosendahl et al., 2024). Content creators acknowledge the learning potential of 360° video, where there are attempts to tailor 360° materials to serve instructional purposes (Beege et al., 2024). VR-based learning that provides immersive experiences could be the future of education in Malaysian universities and tertiary colleges (Adnan, 2020). According to Kalkofen et al. (2020), designing VR experiences for tertiary education appropriately remains an active research topic.

The barriers that cause 360° video not to be widely adopted and implemented in education are the insufficiency of suitable video materials on online platforms, e.g. YouTube, as well as the shortage of specialised video materials on specific procedures or for specific areas (for instance, in the medical surgical field) (Ranieri et al., 2022). The creators of multimedia instructional resources are facing a shortage of principled guidance regarding how to design certain elements of animations to promote a better understanding of the content presented (Mustafa, 2023). Huang et al. (2024a) pointed out that 360° videos do not always lead to positive learning effects because the 360° environment may cause learners to focus more on the immersive experience rather than the learning content itself, thus obstructing the learning process. There are times when novel instructional resources, e.g. 360° videos, enhance learners' perceived understanding because of their engaging nature. However, in actual learning, there is no corresponding improvement (Sun & Ch'ng, 2024). When designing instructional immersive technologies, the challenge is to develop a product that can facilitate deep cognitive processing, not just for grabbing the learner's initial attention.

According to Evens et al. (2023), developing a research foundation on 360° video in education has just begun. Researchers are encouraged to consider every aspect of 360° video and the implementation of design to ensure their system can be utilised efficiently, and it has been mentioned that learner experience design is an emerging field (Schroeder et al., 2023). The upcoming research should concentrate more on the instructional design of 360◦ video and the role of design elements for VR (Radianti et al., 2020; Evens et al., 2023). Sun and Ch'ng (2024) mentioned the need for instructional designs that transcend novelty to promote engagement while also helping to align actual academic performance with perceived understanding closely.

360° videos can lead to learning success, as demonstrated by some studies. Nevertheless, the results cannot be applied or generalised to other contexts (Rosendahl et al., 2024). Future studies should attempt to fully exploit animation technology in VR to create unique, instructive and immersive user experiences (Hashim et al., 2024). This thematic paper seeks to provide an overview with regards to the efforts done on optimising the design of educational 360° animation media or VR-based educational animation so that we can have a better understanding of the issues, views, or even gaps present to support and provide insights to future instructional design and development of VR-based educational animation, thus aiding with broader adoption of VR-based educational animation in higher education and other education levels.

2. EDUCATIONAL ANIMATION

Animation has been explained as a pictorial display that alters its structure or other features over time, which gives rise to a continuous change in perception (Weitz, 2015). Educational animations are developed to facilitate learning (Atabhotor & Kofoworola, 2020). It is shown that animation has five characteristics that contribute to learning: (1) providing explanation, (2) presenting information, (3) motivating students, (4) attracting attention, and (5) making teaching appealing (Cevahir et al., 2022).

3. 360° VR

As stated by Elmqaddem (2019), VR refers to a technology that enables us to immerse ourselves in a synthetic world, while this world can be an entirely fictional universe or a replication of the real environment. Omnidirectional video or 360° video is a panoramic spherical (or immersive) video that enables the user to look around during playback, and the viewing of video can be performed through different devices ranging from mobile phones and desktop computers to Head Mounted Displays

(HMD) (Shahid Anwar et al., 2020). 360° video is a new type of video based on VR technology, which has great application potential in the field of education (Liu et al., 2022). 360° video may vary depending on the setup, equipment, and digital content utilised (Queiroz et al., 2022). The 360° content has two main categories: Natural Images (NI) and Computer-generated Graphics (CG) (Shafi et al., 2020; Queiroz et al., 2022). Based on different methods of viewing, 360° video can be classified into immersive 360° video (also known as 360° VR video) and non-immersive 360° video (Liu et al., 2022).

4. VR-BASED EDUCATIONAL ANIMATION DESIGN OPTIMISATION

In terms of development process or steps, 360° videos having three-dimensional (3D) content (e.g., animation) are slightly different from 360° videos that only have real-world content (e.g., actual footage of real scene) due to specific steps like 3D modelling (Hussian, 2020). The paper by Liao et al. (2021) discusses optimising the production of 360° animation video, but the guidelines and considerations primarily focus on entertainment artistry presentation. Instructional video design theory, like the Cognitive Theory of Multimedia Learning (CTML), might need to be considered to assist learners in processing the concept delivered (Fyfield et al., 2019). Besides, since the content is presented using animation, some animation design principles or animating techniques like kinematics may be involved (Schulz et al., 2019). Animation should be utilised in moderation because multi-animation tends to produce unnecessary visual effects (Jeetha & Krishna, 2021). In 360° animation video, informational elements such as directions, labelling and additional text can be incorporated easily to augment such content (Allman et al., 2022). Regarding VR-based educational animation design optimisation, there have been efforts to propose strategies for collaboration with animators, improve video quality, test the effects of informational elements, and derive design guidelines to enhance video design.

Regarding “proposing strategies to collaborate with animators”, it has been stated that educators are required to take up new roles as the creators of 360° videos (Ranieri et al., 2022). Nevertheless, some people have less time to self-educate and create their own educational materials, e.g., 360° animation media or VR animation (Kayler et al., 2020; Sutrisno et al., 2023). In cases like this, collaboration with animators is needed (Ala et al., 2022; Kayler et al., 2020). There have been efforts to report the challenges encountered and respective strategies (short-term and long-term) for three aspects when collaborating with animators to facilitate the production of educational animation. The three aspects are timely design refinement, users’ and

stakeholders' input, and communication with the animator (Kayler et al., 2020). Besides, it has been mentioned that if a sound framework, like a list of design elements, is available, a common understanding can be achieved, reducing confusion when communicating about design choices or decisions (Radianti et al. 2020). An example of terminology usage in the literature that may cause confusion in communication and make impact comparison difficult is that Liu et al. (2022) treated the term 'visual cue' as one type of cueing element appearance (e.g. visual cueing element and textual cueing element). In contrast, in the study by Huang et al. (2024a), 'visual cue' is considered as cues that act on particular sensory channels (e.g. visual channel and auditory channel), of which textual cueing element is part of the 'visual cue'. Moreover, among the available literature, the information on animators' perspectives on the design process (e.g., how they rationalise their design decisions and apply design choices) for VR-based educational animation is still limited.

Concerning "improving the video quality", some 360° video-related studies focus on investigating several aspects of video quality in a VR environment, for instance, cybersickness and presence (Tran et al., 2018). The sensory output of a VR system can contribute to the sense of presence, i.e., the subjective experience of being in a specific environment. Nevertheless, cybersickness can be caused by the addition of sensory information (Narciso et al., 2020). It is worth noting that quality optimisation for the delivery of 360° video is also considered in several studies (Tran et al., 2018). Virtual environments modelled in 3D possess limited capabilities to provide high degrees of realism, which may restrict the effectiveness of virtual training applications. Much effort in terms of time and a high computational cost for rendering all the elements in the scene are needed for modelling photorealistic environments in 3D (Ritter III & Chambers, 2021). Inspired by Wuebben et al. (2023) paper, combining a few recorded real-world elements with virtual animated elements might be a potential option. As stated by Choi et al. (2018), there are research works regarding the creation of 360° content that concentrate on resolution improvement, image-based lighting effects, accurate stitching, and distortion correction of images from wide-angle cameras. Some researchers investigated how to enhance the interactivity of image-based VR content by changing scenes with button clicks and adding uniform resource locators (URLs) to 360° images (Choi et al., 2018). According to Dogan and Sahin (2024), the learning of procedural knowledge seems can be facilitated by realistic experiences simulated using design elements (i.e., interactivity and realism).

As for “testing the effects of informational elements”, the effects of cues that act on two sensory channels (i.e., visual and auditory), macro- and micro-level signalling, narrative style and subtitle presentation were explored (Huang et al., 2024a; Beege et al., 2024; Huang et al., 2024b). Visual and audiovisual cues can reduce cognitive load, improve learning retention performance, effectively direct visual attention, and increase implicit attention. In comparison, auditory cues were found to distract implicit attention. All the cues show no significant effect on emotion, knowledge transfer and long-term memory (Huang et al., 2024a). It has been found that both macro- and micro-level signalling show no effect on disorientation, which could be due to sufficient orientation within the 360° environment. Macro-level signalling improved learning performance, whereas micro-level signalling did not affect learning performance. The result suggests that including macro-signalling in a 360° environment may be necessary. In cases where learners struggle with orientation, micro-signalling could be viewed as a factor that overwhelms the learners (Beege et al., 2024). The human voice could assist humans in learning better than the computer voice. The lack of emotion in computer voice may reduce learning emotion and sense of experience. Besides, for 3D videos, having no captions is better than a presentation with captions because using subtitles in videos could lead to distraction and increase the cognitive load (Huang et al., 2024b). It has been noted that future research should investigate the effects of other elements in 360-degree virtual environments like animation and colour, the cueing elements that act on other sensory channels like olfactory and tactile, as well as learners’ subjective preferences on design elements of 360° video, e.g. narrative style (Huang et al., 2024a; Huang et al., 2024b). Beege et al. (2024) also mentioned the need to establish adaptive signalling techniques for creating 360° content and further investigate signalling techniques at both macro- and micro-levels.

Regarding “deriving design guidelines to enhance the video design”, some researchers put effort into deriving design guidelines based on the video production process or using article review. However, the design guidelines created are either for the creation of specific content, i.e. research communication (Wuebben et al.,2023) or for the makeup of general features that created impact only, as the description on the video designs was not made clear enough in the majority of the paper reviewed by researchers (Evens et al., 2023). Due to unclear design description, Evens et al. (2023) were unable to dive deep into identifying the design feature(s), element(s) or choice(s) that could further make the virtual environment more conducive and engaging for learning, as well as can be personalised or customised depending on the learning content, goal, and context. The guideline by Evens et al. (2023) revealed that the adaptation of 360° video complexity should act according to the learner’s

level. This is because there are times when novices have difficulty concentrating when placed in overwhelming environments, and primarily, they receive benefits from 360° video that is less complex (Evens et al., 2023). Both guidelines suggest using add-ons and complementary elements like animation and virtual actors to help guide learners' attention or aid with content explanation (Evens et al., 2023; Wuebben et al., 2023). Moreover, it has been stated that upcoming studies could concentrate on questions related to the utilisation of add-ons (i.e. text, image, voice-over, chapter idea, switch location, question, 2D-video, object, and virtual actor), for example, how long, for whom, how many, when to utilise add-ons that lead to optimal learning experiences (Evens et al., 2023). Wuebben et al. (2023) mentioned the need for continuous attempts to create 360° videos for knowledge dissemination and the need to identify features of successful science videos on YouTube.

5. DISCUSSION AND CONCLUSION

From the overview of the previous section, several literature gaps or loopholes can be observed among the efforts explored. It has been noted that future research should look into the effects of other elements in 360° virtual environments, such as animation and colour, as well as the cueing elements that act on sensory channels other than visual and auditory (Huang et al., 2024a; Huang et al., 2024b). The creation of adaptive signalling techniques and further investigation of signalling techniques at both macro- and micro-levels are also needed (Beege et al., 2024). Besides, papers that reported on animators' experience of designing VR-based educational animation are scarce, as the literature reviewed either mentions the collaboration with animators to create animated media (Ala et al., 2022; Kayler et al., 2020) or reports on the challenges encountered and respective strategies during the collaboration (Kayler et al., 2020). Since it has been mentioned by Evens et al. (2023) that upcoming studies could focus on exploring the way to utilise add-ons like text, images, and virtual actors to promote an optimal learning experience, thus exploring animators' design experience of practical VR-based educational resources (i.e. finding out the way to utilise the add-ons or design choices using design expert or animator's perspective) could be a solution to fill in the above-mentioned gaps. This is because the multimedia tools creators have their expectations regarding the way the tools will be utilised, perhaps educational (entailing the instructional designs, processes, and impact) or functional (concentrated on the interface) (Abdulrahaman et al.,2020).

Despite learner experience design being an emerging field (Schroeder et al., 2023) and the recommendation for 360° video complexity adaptation should be based on the level of the learner (Evens et al., 2023), the overview revealed that the subjective

preferences of learners (learning motivation and learning style) on-screen elements (narration and subtitle) of 360° video has yet to be explored and discussed (Huang et al., 2024b). As stated by Alamäki et al. (2021), learner experiences related to VR are significant as they support learner's inner motivation and active participation. According to Lange and Costley (2020), obtaining learners' perceptions can help the researchers understand why such media delivery negatively impacts learning, investigate instructional intervention recommendations to tackle these problems, and present new recommendations to solve existing pedagogical concerns. Huang et al. (2024b) noted that the creation of 360° video images should consider learners' experiences and contribute to the development of accurate visual impressions in learners, i.e. the content delivered must be accurate. The essential state of things should be reflected objectively and truthfully. Including many late "virtual" elements that could lead to learner's discomfort and visual loads should be prevented. Therefore, another loophole in the literature regarding design elements is limited information on learner's subjective preferences, which is worth exploring.

The overview also revealed that the description of the 360° video designs was not made clear enough in the majority of the papers reviewed by Evens et al. (2023), where attention is scarce on explaining the embedding of 360° videos in actual context or even the 360° videos design principles (Even et al., 2023). This has made it difficult for Evens et al. (2023) to investigate what video design has created an impact among the 360° videos investigated. The authors emphasise that future research should consider including the following information when describing 360° videos: (1) video content category (i.e. demonstration, situation, environment), (2) the utilisation of (interactive or non-interactive) add-ons, as well as (3) video length and context (Evens et al., 2023). Hence, in any future research that involves the creation of educational 360° videos, the researchers could adopt a direction in providing a clear description of the 360◦ video design to make it easier for readers and researchers to explore the video design and the impacts created. Having more research papers providing a clear description of the 360◦ video design may further assist any future study that seeks to explore and identify design elements or choices that could further make the virtual environment more conducive and engaging for learning, as well as can be personalised or customised depending on the learning content, goal, and context. This also may further lead to the establishment of another new design framework that can serve as a guide for animators when designing and developing VR-based educational animation, thus may assist in tackling the issue mentioned by Mustafa (2023), i.e. the lack of principled guidance in terms of how to design certain elements of animations to promote a better understanding of the content presented. Hence, a clear definition and unified term for each design element

within the new framework may also make communication between educators and animators on selecting suitable design choices that fit the instructional goals that can be done more efficiently. Radianti et al. (2020) stated that the generalisation of design elements facilitates the creation of new VR-based educational resources and aids with a better acceptance of VR in higher education.

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REFERENCES

Abdulrahaman, M. D., Faruk, N., Oloyede, A. A., Surajudeen-Bakinde, N. T., Olawoyin, L. A., Mejabi, O. V., Imam-Fulani, Y.O., Fahm, A. O., & Azeez, A. L. (2020). Multimedia tools in the teaching and learning processes: A systematic review. *Heliyon*, *6*(11), Article e05312. https://doi.org/10.1016/j.heliyon.2020.e05312

Adnan, A. H. M. (2020). From interactive teaching to immersive learning: Higher Education 4.0 via 360-degree videos and virtual reality in Malaysia. In S. Z. S. I. Al Saggoff, W.A. Wan Mustafa, & M. A. Jamlos (Eds.), *IOP Conference Series: Materials Science and Engineering* (p. 012023). IOP Publishing Ltd. https://doi.org/10.1088/1757-899X/917/1/012023

Alamäki, A., Dirin, A., Suomala, J., & Rhee, C. (2021). Students' experiences of 2D and 360° videos with or without a low-cost VR headset: An experimental study in higher education. *Journal of Information Technology Education: Research*, *20*, 309-329. https://doi.org/10.28945/4816

Ala, N. A., Ishyaku, A. M., Adamu, S. B., & Onojah, A. O. (2022). Computer-animation on NCE students' academic performance in vertebrate anatomy and physiology in colleges of education. *Indonesian Journal of Educational Research and Review*, *5*(3), 449-459. https://doi.org/10.23887/ijerr.v5i3.52872

Allman, S.A., Cordy, J., Hall, J. P., Kleanthous, V., & Lander, E.R. (2022). Exploring the perception of additional information content in 360° 3D VR video for teaching and learning. *Virtual Worlds*, *1*(1), 1–17. https://doi.org/10.3390/virtualworlds1010001

Atabhotor, I. S., & Kofoworola, O. M. (2020). Science teaching and learning using animation and simulation strategies in Nigeria. *Iconic Research and Engineering Journals*, *4*(2), 73-82. https://www.irejournals.com/paper-details/1702458

Beege, M., Nebel, S., Schneider, S., & Rey, G. D. (2024). The effect of micro-level and macro-level signalling on learning with 360° videos. *Applied Cognitive Psychology*, *38*(2), Article e4192. https://doi.org/10.1002/acp.4192

Cevahir, H., Özdemir, M., & Baturay, M. H. (2022). The effect of animation-based worked examples supported with augmented reality on the academic achievement, attitude, and motivation of students towards learning programming. *Participatory Educational Research*, *9*(3), 226-247.http://dx.doi.org/10.17275/per.22.63.9.3

Choi, K., Yoon, Y. J., Song, O. Y., & Choi, S. M. (2018). Interactive and immersive learning using 360° virtual reality contents on mobile platforms. *Mobile Information Systems*, *2018*(1), Article 2306031. https://doi.org/10.1155/2018/2306031

Dogan, E., & Sahin, F. (2024). Mapping the research agenda in virtual reality studies within education. *Turkish Online Journal of Distance Education*, *25*(3), 265-293. https://doi.org/10.17718/tojde.1427725

Elmqaddem, N. (2019). Augmented reality and virtual reality in education. Myth or reality? *International Journal of Emerging Technologies in Learning*, *14*(3), 234-242. https://doi.org/10.3991/ijet.v14i03.9289

Evens, M., Empsen, M., & Hustinx, W. (2023). A literature review on 360-degree video as an educational tool: Towards design guidelines. *Journal of Computers in Education*, *10*(2), 325-375. https://doi.org/10.1007/s40692-022-00233-z

Fyfield, M., Henderson, M., Heinrich, E., & Redmond, P. (2019). Videos in higher education: Making the most of a good thing. *Australasian Journal of Educational Technology*, *35*(5), 1-7. https://doi.org/10.14742/ajet.5930

Hashim, M. E. A., Albakry, N. S., Mustafa, W. A., Grahita, B., Md Ghani, M., Hanafi, H. F., Md Nasir, S., & ana Ugap, C. (2024). Understanding the impact of animation technology in virtual reality: A systematic literature review. *International Journal of Computational Thinking and Data Science*, *1*(1), 53–65. https://doi.org/10.37934/CTDS.1.1.5365

Huang, G., Chen, C., Tang, Y., Zhang, H., Liu, R., & Zhou, L. (2024a). A study on the effect of different channel cues on learning in immersive 360° videos. *Frontiers in Psychology*, *15*, Article 1335022. https://doi.org/10.3389/fpsyg.2024.1335022

Huang, G., Zhou, L., Chen, D., Chen, W., & Liu, R. (2024b). Research on the design of panoramic virtual learning environment screen elements. *Frontiers in Psychology*, *14*, Article 1314076. https://doi.org/10.3389/fpsyg.2023.1314076

Hussain, A. (2020). Interactive 360-degree virtual reality into e-learning content design. *International Journal of Innovative Technology and Exploring Engineering*, *10*(2), 1-4. http://dx.doi.org/10.35940/ijitee.B8219.1210220

Jeetha, J. & Krishna, P. K. (2021). Animation for learning: Enhancement of learning through animation - a review of literature. *International Research Journal of Modernization in Engineering Technology and Science*, *3*(1), 1053 -1071.

Kalkofen, D., Mori, S., Ladinig, T., Daling, L., Abdelrazeq, A., Ebner, M., Ortega, M., Feiel, S., Gabl, S., Shepel, T., Tibbett, J., Laine, T. H., Hitch, M., Drebenstedt, C., & Moser, P. (2020). Tools for teaching mining students in virtual reality based on 360° video experiences. In L. O'Conner (Ed.), *2020 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW)* (pp. 455-459). IEEE. https://doi.org/10.1109/VRW50115.2020.00096

Kayler, L. K., Dolph, B. A., Ranahan, M. E., Keller, M. M., Cadzow, R. B., & Feeley, T. H. (2020). The KidneyTIME educational health animation development process: Lessons learned. *Trends in Transplantation*, *13*(3). https://doi.org/10.15761/TiT.1000283

Lange, C., & Costley, J. (2020). Improving online video lectures: learning challenges created by media. *International Journal of Educational Technology in Higher Education*, *17*, Article 16, 1-18. https://doi.org/10.1186/s41239-020-00190-6

Le, T. T. Y., Chen, J. S., & Nguyen, N. B. (2022). The effects of attributes of non-immersive virtual reality on customers' experience of video tours under social distancing for COVID-19. *International Journal of Human-Computer Interaction*, *40*(3), 885-902. https://doi.org/10.1080/10447318.2022.2131251

Liao, W. C., Wu, C. T., & Chung, S. M. (2021). Optimisations of VR360 animation production process. In A. L. Brooks, E. I., Brooks & D. Jonathan (Eds.), *Interactivity and Game Creation* (pp. 320-330). Springer International Publishing. http://dx.doi.org/10.1007/978-3-030-73426-8_19

Liu, R., Xu, X., Yang, H., Li, Z., & Huang, G. (2022). Impacts of cues on learning and attention in immersive 360-degree video: An eye-tracking study. *Frontiers in Psychology*, *12*, Article 6672. https://doi.org/10.3389/fpsyg.2021.792069

Mustafa, B. (2023). Impact effect of using computer graphics animation in education. *IDA: International Design and Art Journal*, *5*(1), 1-12. https://www.idajournal.com/index.php/ida/article/view/180

Narciso, D., Melo, M., Vasconcelos-Raposo, J., & Bessa, M. (2020). The impact of olfactory and wind stimuli on 360 videos using head-mounted displays. *ACM Transactions on Applied Perception*, *17*(1), 1-13. https://dl.acm.org/doi/abs/10.1145/3380903

Queiroz, A. C. M., Fauville, G., Herrera, F., Leme, M. I. S., & Bailenson, J. N. (2022). Do students learn better with immersive virtual reality videos than conventional videos? A comparison of media effects with middle school girls*. Technology, Mind and Behavior*, *3*(3), 1-15. https://doi.org/10.1037/tmb0000082

Radianti, J., Majchrzak, T. A., Fromm, J., & Wohlgenannt, I. (2020). A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. *Computers & Education*, *147*, Article 103778. https://doi.org/10.1016/j.compedu.2019.103778

Ranieri, M., Luzzi, D., Cuomo, S., & Bruni, I. (2022). If and how do 360 videos fit into education settings? Results from a scoping review of empirical research. *Journal of Computer Assisted Learning*, *38*(5), 1199-1219. http://dx.doi.org/10.1111/jcal.12683

Ritter III, K. A., & Chambers, T. L. (2022). Three-dimensional modeled environments versus 360-degree panoramas for mobile virtual reality training. *Virtual Reality*, *26*, 571-581. https://doi.org/10.1007/s10055-021-00502-9

Rosendahl, P., & Wagner, I. (2024). 360 videos in education: A systematic literature review on application areas and future potentials. *Education and Information Technologies*, *29*(2), 1319-1355. https://doi.org/10.1007/s10639-022-11549-9

Schroeder, N. L., Siegle, R. F., & Craig, S. D. (2023). A meta-analysis on learning from 360° video. *Computers & Education*, *206*, Article 104901. https://doi.org/10.1016/j.compedu.2023.104901

Schulz, T., Torresen, J., & Herstad, J. (2019). Animation techniques in human-robot interaction user studies: A systematic literature review. *ACM Transactions on Human-Robot Interaction (THRI)*, *8*(2), 1-22. https://doi.org/10.1145/3317325

Shafi, R., Shuai, W., & Younus, M. U. (2020). 360-degree video streaming: A survey of the state of the art. *Symmetry*, *12*(9), Article 1491. https://doi.org/10.3390/sym12091491

Shahid Anwar, M., Wang, J., Ahmad, S., Ullah, A., Khan, W., & Fei, Z. (2020). Evaluating the factors affecting QoE of 360-degree videos and cybersickness levels predictions in virtual reality. *Electronics*, *9*(9), Article 1530. https://doi.org/10.3390/electronics9091530

Stadlinger, B., Jepsen, S., Chapple, I., Sanz, M., & Terheyden, H. (2021). Technology-enhanced learning: A role for video animation. *British Dental Journal*, *230*(2), 93-96. https://doi.org/10.1038/s41415-020-2588-1

Sun, X., & Ch'ng, E. (2024). Exploring Miao culture: The differential effect of traditional 2D and immersive 360° documentary formats on viewer learning. *Social Sciences & Humanities Open*, *10*, Article 101061. https://doi.org/10.1016/j.ssaho.2024.101061

Sutrisno, A., Pramono, A., Wardhana M. I., & Samodra, J. (2023). 360 degree animation videos for learning basic animation principles. *AIP Conference Proceedings*, *2706*(1), Article 020085. https://doi.org/10.1063/5.0120747

Tran, H. T., Pham, C. T., Ngoc, N. P., Pham, A. T., & Thang, T. C. (2018). A study on quality metrics for 360 video communications. *IEICE Transactions on Information and Systems*, *101*(1), 28-36. https://doi.org/10.1587/transinf.2017MUP0011

Weitz, D. A. (2015). Effectiveness of animation as a learning strategy in a classical control theory introductory course. *World Journal Control Science and Engineering*, *3*(1), 8-12. https://www.sciepub.com/abstract/abstract.aspx?id=WJCSE&num=3809

Wuebben, D., Rubio-Tamayo, J. L., Barrio, M. G., & Romero-Luis, J. (2023). 360° video for research communication and dissemination: A case study and guidelines. *IEEE Transactions on Professional Communication*, *66*(1), 59-77. https://doi.org/10.1109/TPC.2022.3228022