The Potential of 360° Virtual Reality Videos and Real VR for Education—A Literature Review

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Virtual reality (VR) has a wide variety of potentials for education. Especially 360° videos can provide immersive educational experiences of otherwise not accessible real-world environments. But what potential do 360° videos in VR and real VR settings have for teaching? Research into the use of real VR, providing live-learning experience in the classroom is still scarce, which is why this article investigates this issue in the context of a systematic review. We discuss use cases, advantages, and limitations as well as interaction characteristics of the potential of 360° videos, and also the promises of real VR scenarios. By analyzing 64 articles in-depth, our results suggest that 360° videos can be used for a wide variety of topics. While only a few articles report technological benefits, there are indicators that 360° videos can benefit learning processes in terms of performance, motivation, and knowledge retention. Most papers report positive effects on other human factors such as presence, perception, engagement, emotions, and empathy. Furthermore, an open research gap has been identified in use cases for real VR.

The potential of immersive environments to enhance learning has been known for many years. Especially characteristics of virtual reality (VR) like immersion and additional motivation are often emphasized, as this allows learning in environments that are frequently either difficult or even impossible to reach. This includes, for example, scenarios like a school trip to distant historical sites, to another century, or to the moon. Besides, realistic setups can be offered in VR to perform, for example, chemistry experiments, medical operations, or physics experiments safely and cost-effectively, and can repeat it as often as desired or necessary. With the recent advances in technologies and the release of cost-effective consumer head-mounted displays (HMDs) such as Oculus Rift, HTC Vive, and also the possibility to use smartphones as a device for VR experiences, VR has again received more attention.

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Experiences for the HMDs can be implemented as fully simulated environments to represent interactive and fictional experiences. Doing this often requires high development and design efforts and high corresponding costs. On the other hand, HMDs also offer the possibility to present 360° videos as immersive experiences. In times of lockout and pandemic in particular, when the issues of distance and online education have become more central than ever before, the need for motivating and realistic learning environments, which are both easy for potential learners to use and allow fast content creation by educators, has become apparent once more.

360° videos, also known as immersive or spherical videos, offer users the opportunity to experience videos in a fully immersive format. The recording of videos is usually also more comfortable and more cost-effective than the development of simulated environments. Many experiences allow interactions with the content and support choices by users. Additionally, it allows experiencing live content such as sports broadcasts or music concerts (real VR settings).

While the potential of virtual environments for education has been explored in many studies, there are only a few summaries that describe the potential of 360° videos in education. Additionally, during the pandemic, new arguments for the necessity to also deliver courses online in an engaging live format have been brought to the attention of many. To move beyond common "hit and miss approaches"[1] and investigations of isolated factors relevant for learning in VR,[2] a review of prevalent uses including the technological characteristics as well as reported effects and challenges is necessary to draw a holistic picture of 360° videos and real VR in education.

In this article, we analyze the potential of 360° videos for the education sector including all age groups and levels of education. We focus on possible use cases, advantages, disadvantages, frequently used technologies, and especially the potential for live applications. As a foundation, we ask the following research questions.

- *RQ1.* What are the use cases and educational subjects of 360° videos and real VR in educational settings?
- *RQ2.* What are the advantages, limitations, purposes, and effectiveness of 360° videos and real VR in educational settings?
- *RQ3.* What are interaction methods used or required for 360° videos and real VR in educational scenarios?
- *RQ4.* What is the current use of real VR in education?

BACKGROUND

Virtual Reality for Education

Even before the rise of consumer VR through the Oculus Rift in 2012, researchers estimated the benefits of 3-D virtual learning environments (VLEs). Dalgarno and Lee[1] summarize five learning benefits.

- *Spatial knowledge representation.* Contents that require spatial understanding can benefit from 3-D visualizations in VLEs.
- *Experiential learning.* Learning through experimenting in and experiencing of 3-D-VLEs provides a better understanding of the subject matter.
- *Engagement.* Learning tasks in 3-D VLEs can foster intrinsic motivation for and engagement with the learning content.
- *Contextual learning.* Following a constructivist view, learning is always situated within a broader context. Thee-dimensional learning environments can resemble real-life situations in which the learning contents can be applied.
- *Collaborative learning.* Three-dimensional VLEs can provide environments where learning can happen through collaboration and social interaction.

Despite these promising affordances of 3-D VLEs, research regarding the cognitive, motivational, and emotional effects of immersive experiences is scarce[2] and approaches for designing and developing such experiences for educational purposes are "largely hit-and-miss, driven by intuition and 'common-sense' extrapolations rather than being solidly underpinned by research-informed models and frameworks."[1]

Freina and Ott[3] have presented a comprehensive literature review on immersive VR applications in education and described great advantages for learning such as the direct feeling of situations that are physically out of reach, training in a safe environment, added engagement and involvement, and the support of different learning styles. They also found that most VR learning experiences were evaluated with higher education or adult training students. A more recent systematic review has been presented by Kavanagh *et al.*[4] This analysis also takes into account the reported motivations provided by educators for developing VR educational systems, such as increasing the intrinsic motivation of students. They also focused their attention on the limitations of VR systems. The identified problems include high cost, training, as well as hardware and software usability issues. Many students also found the implementation insufficiently realistic. The authors point out that future work should include investigating experiences supporting increased realism, such as spherical immersions 360° videos. A very recent study by Hamilton *et al.*[5] also discussed the potential immersive VR and showed that many papers use science fields as the primary use case I-VR and often conferred a learning benefit when complex problems require spatial understanding or visualizations.

360° Videos as Educational Experiences

While we found many systematic literature reviews for the potential of virtual for education, only a few studies of this kind have been found for 360° videos. Pirker *et al.*[6] give a broad overview of the literature and describe different scenarios found in the literature supporting learning activities. This includes virtual tours, recorded processes and procedures (medical training, laboratory courses, sports training, craftsman training, enjoyment training), recorded situations (nurse education, safety training), recorded experiences, and recorded processes for learning through reply (teacher education, sports training).

Another study, even though not specifically focused on education, is presented by Bevan *et al.*[7] The authors analyze 150 VR nonfiction experiences. They investigated viewer roles and found that most experiences are designed so that the viewer takes the role of a passive observant without an active role in the story. Some support passive participants, where the viewer is visible (and noticed by) to actors in the world. Active experiences through interaction methods (e.g., gaze-based point-and-click mechanics or possibilities to change the storyline) were rare.

A first scoping review by Snelson and Hsu[8] shows a variety of topics for educational experiences provided through 360° videos. Reported overall content-areas include business, marine biology, psychology, religious studies, sports, surgical education, teacher education, and writing. This range of nine areas promoting immersive learning spread across multiple study designs, including user studies, pretests/posttests, longitudinal experiments, evaluation of implementations, randomized cross-over studies, feasibility studies, qualitative case studies, and mixed-method studies. In summary, the studies show that learners indicated that they greatly enjoyed the immersive experiences within 360° videos, but the learning performance results were inconsistent. Regarding the advantages of 360° videos for education, participants of the summarized studies reported high levels of interest, engagement, enjoyment, or increased learning perceptions. The immersive learning experience was valued in most of the studies. Presence could contribute to the feeling as if the participants were there in the virtual scene. The disadvantages of 360° video experiences included inconsistent results regarding the learning outcomes. Although some studies reported positive results, various studies showed no reliable evidence that 360° VR videos were superior to 2-D videos. Minor problems were associated with distraction or low concentration, motion sickness or physical discomfort, inadequate video quality, and poor usability.

Snelson and Hsu[8] note that research activity is emerging in this area of immersive learning; they suggest expanding literature reviews for educational 360° videos to more databases, and a broader search term. Building upon Snelson and Hsu's literature review, we strive to expand their work by conducting a systematic literature review on the educational use of real VR and 360° videos for education.

METHOD

We used a systematic review as a rigorous approach to collect data from existing use cases and studies.

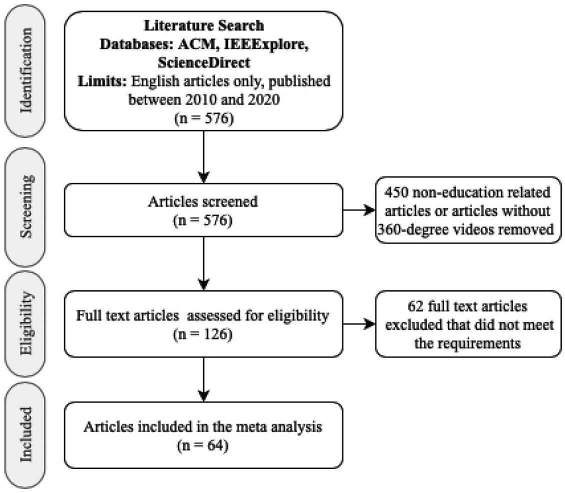

FIGURE 1. PRISMA guidelines.[9]

The process of article selection followed the Preferred Reporting of Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement[9] (see Figure 1). Moher *et al.* suggest four phases for collating relevant articles for systematic reviews: *Identification*, *Screening*, *Eligibility*, and *Included*. In the *Identification* phase, 576 articles were gathered from ACM, IEEE Xplore, and ScienceDirect by using the search terms described in Table 1. The search time was November 2020.

During the *Screening* phase, studies that are not relevant for this systematic review should be removed according to general inclusion and exclusion criteria.[9] All articles were subject to first- and second-round screening. Papers not meeting the eligibility criteria were screened out depending on the time, language, type of article, and type of method. For the inclusion criteria as well as for the search terms described in Table 1, we followed the suggestion of Snelson and Hsu,[8] who argued for expanding the literature review to more data sources. After all articles were aggregated, the authors discussed any possible disagreements within the study selection. The *a posteriori* inclusion criteria are described in Table 2. A review of the abstracts revealed various articles that were irrelevant, particularly those

TABLE 1. Search term.

Search Terms
("360○ video*" OR "360 video*" OR "'immersive video*" OR "spherical video*" OR "360 VR" OR "360 virtual reality") AND (Education)

TABLE 2. Criteria of inclusion and exclusion criteria.

Criterion	*Inclusion*	*Exclusion*
Time	2010 to 2020	Studies before 2010
Language	English	other languages
Type of Article	Peer-reviewed research in conference proceedings or journals	Other types of documents
Type of Method	Studies with described applications	Theoretical articles

without reported 360° video experiences (such as theoretical papers and literature reviews). After the *Screening* phase, 126 articles remained. During the *Eligibility* phase, in which the full text articles were assessed according to the inclusion and exclusion criteria, another 62 articles were excluded as they did not meet the requirements. A total of 64 articles were included in the meta-analysis.

RESULTS

Our final corpus contains 64 publications (for the used references in this analysis, see Table 3 in the Appendix). Following on from this, we describe the use cases, advantages and problems, used hardware, and also the interaction methods. Another interesting corner case that was identified during the analysis is processes for content creation and this will be described in the last section.

Use Cases

The results show that 360° videos are used for a wide range of subjects. An otherview is given in Figure 2. Of the 64 analyzed articles, over a quarter (28.1%) focused on topics from medicine or healthcare. Another fifth (20.3%) focused on STEM subjects such as the natural sciences (physics, chemistry, biology with 7.8% in total), engineering and industry (7.8%), and computer science (4.7%). Geography and the environment (6.3%) together with history and social studies (12.5%) add up to about another fifth (18.8%). Social skills in teacher education (3.1%) and finance and career trainings (3.1%) add up to 6.2% in total. Language learning accounts for 7.8% of the use cases. Other use cases add up to 18.8%.

Regarding the samples of the studies, the majority of the participants was recruited from universities (54.69%, minimum N = 9, maximum N = 981, Mdn = 52). A total of 6.25% of the studies investigated professionals (minimum N = 17, maximum N = 96, Mdn = 43). Another 6.25% of the studies had primary school students as their main focus group (minimum N = 10, maximum N = 45, Mdn = 27.5). Secondary school students accounted for 7.81% of the study samples (minimum N = 53, maximum N = 117, Mdn = 89). Some of the studies investigated mixed groups (9.37%,

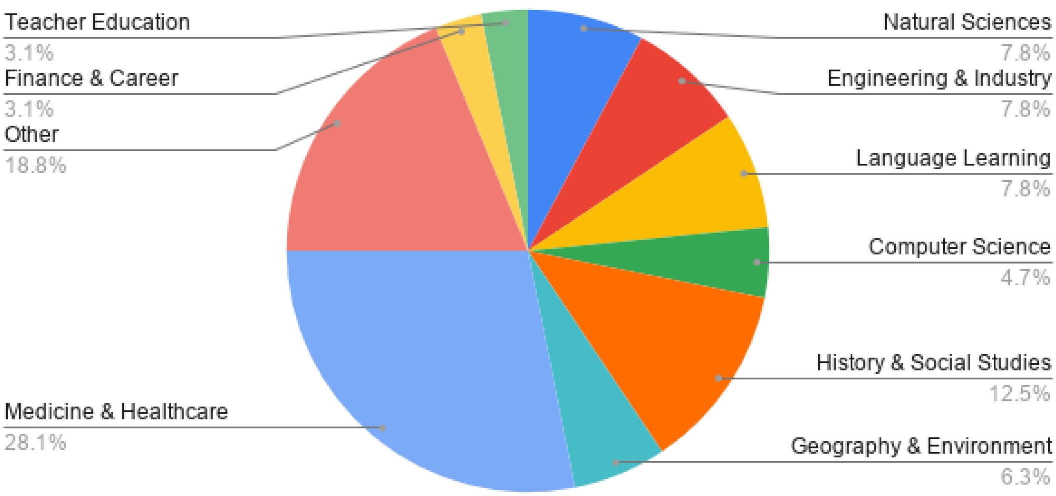

FIGURE 2. Subjects of educational 360° videos.

minimum N = 18, maximum = N = 274, Mdn = 62). A total of 15.63% of the assessed papers did not report the educational level of their participants (minimum N = 7, maximum N = 360, Mdn = 18). Some papers did not report sample sizes. These results show that there are extensive research efforts regarding higher education, but other educational levels, especially those of K-12 education still need further investigations. Another issue that becomes apparent when taking a closer look at the sample size median values is the very low power occurring in the majority of the applied statistical tests, resulting from the low sample sizes.

Medicine and Healthcare

Different scenarios are shown for medicine and healthcare. A total of 360° videos are used, for instance, to show nursing students real-life scenarios of schizophrenic patients. In simulation-based education, the high potential of 360° videos is underlined, because of the high standard of realism that can be provided in a safe environment. Furthermore, the potential of 360° videos for medical training is explored, in particular for surgery. Many advantages are discussed, such as the possibility of repeating surgical operations as frequently as wished, and the fact that shocking experiences can be cushioned when they are experienced in a safe setting. Sankaran *et al.* developed a sepsis prevention education scenario with an integrated 360° video recording of a clinical encounter from a first-person perspective. In a similar context, Harrington *et al.* compared 360° videos of elective laparoscopic cholecystectomy with equivalent 2-D formats. The use of 360° videos in kidney transplant education also was investigated. A project incorporated the view of a transplantation surgeon's headcam for a detailed view of the surgical procedures. To engage learners, activating questions about the transplant procedure and the related immunological concepts are integrated into the videos. Another study utilized a 360° video to generate a virtual operating theatre orientation. Similarly, Francis *et al.* investigated the impact on self-efficacy for preclinical physician assistant students through an immersive VR operating room simulation. A first-person perspective was used to improve engagement and to foster experiential learning. To avoid the manikins and standardized patients of traditional nursing simulation modalities, Hauze *et al.* used 3-D mixed reality simulations and 2-D videos to simulate low-frequency, high-risk patient scenarios for nursing students. By utilizing a game-based learning approach, Yang *et al.* have attempted to improve traditional training of cardiopulmonary resuscitation through a VR-CPRs learning support system. The system includes video health education, assisted real-time interactive operation tools, learning tests, and other self-learning functions. Buchman and Henderson used 360° videos to develop interprofessional empathy, and communication competency. Schiza *et al.* investigated teaching a clinical skills course utilizing 360° videos with medical content for an undergraduate-level course. In another example, a VR training system for gynecology learning is presented. In this learning experience, trainees watch simulated videos and interact with the system to accomplish tasks. Harrison *et al.* provided a tool for teaching surgical hand preparation to healthcare students to prevent postsurgical infection. In the paper by Vankipuram *et al.*, the design of a VR simulator for advanced cardiac life support training is presented as a time-critical, team-based medical scenario. Johnson *et al.* instead focused on the patients as a target group: they provided a prototype VR video to simulate the delivery of image-guided external beam radiation therapy to the pelvis. In a study from Paalimäki-Paakki *et al.*, patients, radiographers, and radiography students reported experiences of a 360° virtual counseling environment for the coronary computed tomography angiography. Ros *et al.* recorded 3-D videos via a main surgeon's perspective using a system combining two side-by-side cameras placed on a helmet. In one particular scenario, external ventricular drainage was selected as a neurosurgical technique to be delivered using a technical note describing this procedure, and a corresponding immersive tutorial as a teaching supplement.

History and Social Studies

Using 360° videos for history and social studies has shown merit in various topics.

Lanzieri *et al.* presented a 360° VR simulation that prepares social work students to interact with people in their respective community environments. Students wore a HMD and presented a given topic to a virtual audience for fostering communication skills. The audience expressed three different attitudes in a given order (neutral, bored, interested). Fang *et al.* investigated the use of Singapore History Alive with 3-D! as a comprehensive multimedia teaching and learning package, where students can interact with key historical figures and learn through presentation slides, animation videos, mini-games, and quizzes. In another example, authors describe the use of 360° videos to help students in rural Indian schools to learn about history. In an AB-split study, they showed that students learning with the videos enhanced their spatial awareness, including the perception of colors, direction, and size. For the purpose of learning factual data, however, the regular learning method showed better results. Wong *et al.* presented a smartphone-based solution incorporating an immersive learning package for students to experience certain field trips to the Fung Yuen Butterfly Reserve and Fung Yuen Village. The embedding of the 360° experiences in a flipped-classroom approach should facilitate preclass learning. In one paper, a MOOC entitled Virtual Hong Kong the immersive learning content is delivered for distant learners. Using these immersive experiences, students can appreciate and experience the impact of the traditional culture and folklore of Hong Kong on the lives of its inhabitants in the 21st Century. Calvert *et al.* used Kokoda VR, a VR to transport high school students into the mountains of Papua New Guinea during World War Two to evoke empathy for the hardships faced by Australian and Japanese soldiers using photogrammetry of real locations and artifacts. In another context, Calvert and Abadia also reported the use of linear educational narratives using the same experience to increase cognitive and affective outcomes in student learning. In one experience, students participated in a virtual field trip to the Stockton State Hospital, a mental institution that was active from 1851 to 1995 in Stockton, California, to elicit more empathy for complex socio-historical experiences.

Science Education

In one example, the users can observe a camera-guided animation of X-ray diffraction and scattering experiment station in a radiation laboratory. Other authors present a special case: spherical AR/VR panoramas, which allow combining real environments with artificial artifacts. The interactive, immersive VR learning application "Polymerase Chain Reaction Virtual Lab simulation" by Labster was used for teaching scientific procedural knowledge and was compared to a video setting. As embodiment is expected to play a vital role for immersive learning, another study compared the two factors of embodiment (low versus high) and platform (2-D PC versus 3-D VR) in STEM learning for physics, biology, and chemistry. Alvarez *et al.* presented didactic sequences incorporating multiple 360° videos for the topics wind turbines (physics) and molecular links (chemistry).

Engineering and Industry

Alvarez *et al.* also provided an immersive experience for logical controllers (logical automatism). Muller *et al.* presented the use of immersive learning games for the topic of mechanical engineering. The setting was a virtual workshop where students can learn how to use machines through natural interactions. Other authors explore the potential for system modeling and combine watching a 360° video presenting a virtual case study representing a library booking system with 3-D-printed physical representations of UML symbols. Kalkofen *et al.* presented the design of a VR Framework for teaching mining students with 360° videos. The immersive experiences were evaluated in three lectures and extended according to students' feedback. Also, an application of VR panoramic technology focusing on aspects of urban rail transit vehicle engineering systems is presented. The immersive experience can be used to change the traditional ideas and methods employed in urban rail transit disaster prevention and mitigation to improve the safety management efficiency of urban rail transit construction. Similarly, Yang *et al.* proposed a VR panoramic learning experience for learning about urban rail transit vehicle engineering with a focus on its main technology and real-time interaction for vehicle maintenance.

Computer Science

A 360° video case study is presented to enhance experiential learning in an ICT systems analysis class. Visual case studies, combined with virtual instructions, can increase learning motivation and improve learner engagement. In a class for VR programming, a tele-immersive distance learning system was used, which integrated a video avatar, a database interface, and several interaction techniques in the shared virtual environment.

Finance and Career

A VR-based professional training solution for bank counselors is introduced to foster soft skills, communication skills, attention, and awareness. An associated study compared a VR-based training solution with face-to-face presence training. Assilmia *et al.* presented IN360, an exploration of alternative media to deliver career education to elementary students in Indonesia utilizing a digital platform and 360° videos.

Geography and the Environment

Tsai *et al.* developed interactive contents with a 360° panorama VR for soil and water conservation. Other authors describe the potential of 360° videos for geography education and discuss implications from the teacher perspective. Another approach asked students to design a VR project after gaining specific geological knowledge. The environmental awareness and earth science knowledge was intended to be increased by their destining of projects in these fields. In another paper, students were provided with a VR device equipped with a control rod that played the video clips of planet Earth 2 by BBC TASTER VR application to enhance environmental knowledge and connectedness.

Language Learning

Berns *et al.* provided foreign language learners with an immersive learning environment incorporating interaction with the environment and its content while practicing different language skills to foster the students' language competencies by simulating real-world-like situations. Another example is CityCompass, a collaborative language learning experience. One user takes the role of a tourist, one as a guide. They see different added elements in the environments. Ji *et al.* investigated the use of 360° videos for learning English as a second language. The authors report authentic material presentation modes (traditional presentation modes versus 360° VR modes) on the English listening comprehension and cognitive load of the learners. Spherical video-based VR technology was also used to build a linguistic environment, combined with a collaborative learning strategy promoting the English communication skills of students. Other projects utilize a spherical video-based VR (SVVR) environment to situate students in authentic English-speaking contexts integrating a peer assessment strategy for guiding students to provide comments on peers' speaking performance as well as reflecting on their performance.

Teacher Education

The potential of 360° videos for training teachers is also investigated. In one study, the authors showed preservice teachers classroom videos in a regular format (19:6) or in a 360° format. Another study shows that 360° video self-reflection is reported as an effective self-development tool for developing reflections of microteaching, providing embodied cognitive experience, supporting student self-efficacy through teaching, and facilitating an active, student-centered approach to teacher education.

Corner Cases and Further Potentials

The potential and also the challenges of learning with immersive video experiences has been shown for teaching disabilities everyday living skills to people with intellectual. These scenarios include a laundry setup, a campus walk, a dog park, and a cafe. Yu *et al.* studied the use of visualizations on topics that do and do not require spatial understanding in astronomy classes using full-dome video digital theaters to create large-scale, group immersive experiences. To increase interest and motivation in learners for learning martial arts, Hsu *et al.* designed a mobile VR learning system in which learners could watch immersive VR and 360° clips. The effects of learning in a 360° multiple-screen video streaming environment were investigated by enabling users to compare the various sources in a situation learning environment and possibilities to present multiple illustrations to develop interrelated concept and knowledge. ImmerTai, a system for teaching Chinese Taichi motion, captures Taichi experts' motions and delivers to students the captured motion in multimodal forms in an immersive CAVE, via HMD and via ordinary PC environments. Yoganathan *et al.* compared the acquisition of knot tying skills taught with a 360° VR video compared to 2-D video teaching. Using 360° panorama images of a milk powder process plant, Rahim *et al.* conducted a virtual field trip to expose students to processing plant environments. Another potential use is integrating 360° videos in school-based bullying prevention programs representing the experience of bullying victims from a first-person perspective. In another example, an immersive experience is introduced as a measure to improve the safety of the most vulnerable traffic participants at level crossings by changing risky attitudes and behavioral intentions of learner drivers. Herbert *et al.* compared a 9-min immersive video for opioid overdose prevention programs with in-person training. Hallberg *et al.* introduced a first-person-view 360° VLE for enhancing basic skill observation and visualization to support traditional hands-on learning in the context of craft learning.

Advantages

Only few papers reported effect sizes or provided the necessary data to do so manually. Therefore, we gathered the advantages of using 360° videos for educational purposes from the body of literature using Mayring's method of qualitative content analysis.[10] Advantage categories were formulated using an deductive approach by summarizing the reported positive aspects of the 360° experiences according to Abadia *et al.*'s categorization of salient features of VR learning environments.[11] The positive aspects reported in the results, discussion, and implications sections of the 64 papers were coded together by 2 raters (divergencies were discussed and clarified) according to the 3 main categories and 12 subcategories.

1) *Technical factors*
   - Usability
   - Immersion
   - Embodiment
2) *Learning factors*
   - Knowledge Retention
   - Mastery Learning

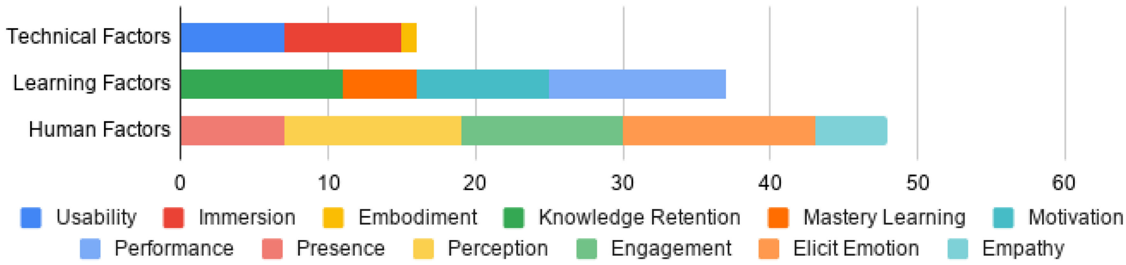

FIGURE 3. Advantages of educational 360° videos.

- Motivation
- Performance

3) *Human factors*
- Presence
- Perception
- Engagement
- Elicit Emotion
- Empathy

An overview of the identified advantages is given in Figure 3.

Technical Factors
Some studies (24.61%) reported advantages of 360° videos mentioning their technical features. Positive aspects of the usability are reported in seven articles. Immersion characteristics are reported by eight articles. Only one article reported embodiment as an advantage of 360° video experiences.

Learning Factors
Half of the studies (50.77%) reported some sort of positive effect on learning with 360° videos. A total of 11 studies could show improved knowledge retention after presenting 360° videos to the participants. Experiences fostering understanding could be empirically proven in five studies. Nine studies reported increased motivation. Increased performance was reported in 12 studies.

Human Factors
Human factors other than learning were the most reported advantages of 360° video experiences (55.38%). An increased sense of presence was reported in seven studies. Perceptual aspects were assessed and positively reported by 12 articles. Engagement (11 studies) was reported as another major advantage within the human factors. Emotions (13 articles) and empathy (5 studies) were also important variables integrated in the human factors.

Disadvantages
Only few articles reported major disadvantages and challenges during their studies. Ji *et al.* noted that participants experienced increased cognitive load in 360° video journalism while not demonstrating higher performance than participants of the traditional presentation mode. Higher cognitive load was also reported. Ip *et al.* mentioned that immersive learning experiences might not directly impact the knowledge gain. In Cho and Chun's study, teachers argue that they see problems in integrating immersive media in the everyday classroom and teaching sequence. In one study, learning tasks on a low cognitive level, such as memorizing factual knowledge, could be carried out more effectively using traditional instruction methods. Furthermore, it has been noted that face-to-face instruction cannot be replaced by computer-assisted learning systems. Also, generating content for VR experiences involves complex tasks, making it very time-consuming. Another study could show that low embodiment, as it is common in 360° videos, affects learning negatively. Torres *et al.* noted that increased interactivity might lead to higher negative affect and lower positive affect than noninteractive videos.

In summary, the disadvantages reported in the studies focus mainly on cognitive factors such as cognitive load or active learning processes and on the question of how immersive experiences can be designed for and integrated in the classroom.

Technology
As shown in Figure 4, a wide range of technologies was used for VR experiences. Almost a third of the studies did not report the technologies that were used. Of the 45 articles that reported the type of device, almost half of the experiences were presented on some kind of mobile VR (48.89%), especially Google Cardboard or Samsung Gear VR. 37.78% of the studies used various professional HMDs such as the Oculus Go/Rift and the HTC Vive/Vive Focus. Another 6.67%

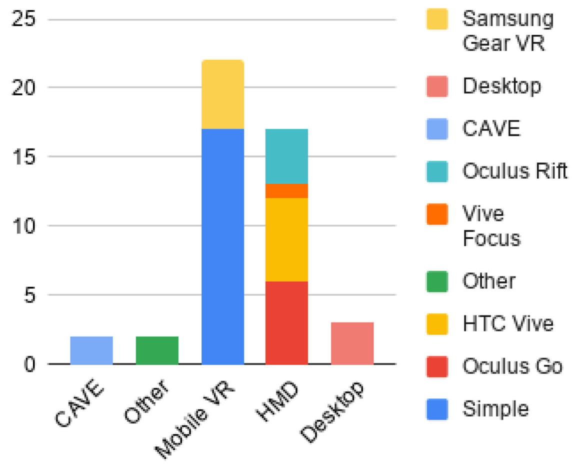

FIGURE 4. Used devices for educational 360° videos.

of the 360° videos were presented using a desktop setting with a regular screen. CAVE settings and other devices account for only 4.44% of the use cases.

Interaction

The interaction within 360° videos is often minimal. The experiences are often designed to be experienced as a video experience, where the viewer's only interaction is the possibility to move the head. A number of examples are listed in the following of a few alternative interaction methods explained in the literature.

Voice commands. In one example, a chatbot system was connected with short voice commands to interact with the 360° videos.

Camera setup. In one paper, the authors describe experiences with different camera setups (switching between two stationary setups and FP-camera) for designing experiences for people with intellectual disabilities.

Visual guidance. Another study presents a visual guidance system. When users interact with the video, the video stops and users can freely view the panoramic image. Otherwise, the camera is guided so that the user's attention is drawn to the main narrative.

Collaborative interaction. A different system incorporates a collaborative learning experience. One user sees information the other user does not see.

Content Creation

One article describes how the production of 360-videos conducting interviews about different careers was used to build empathy from interviewing and also understand better the potential of 360° experiences as well as video production. The authors also describe a codesign workshop to enable users to participate also in a workshop to create content. In this article, a codesign workshop was run as a means of depicting how learning goals can be translated into virtual environment content.

Workshops of this kind are often described as a great medium for comprehending the benefits of the technology.

In one example, a case study is described of how to create 360° videos for education with the Ricoh Theta S 360 Camera and describe issues such as finding the right point of view, the giant hands effect, the prize of the whole setup, the low quality of the video, how to direct the attention, and the high efforts when editing the videos.

DISCUSSION

RQ1. What are the use cases and educational subjects of 360° videos and real VR in educational settings? Our results align with Snelson and Hsu's preliminary work indications: The subject areas show a wide variety in general, with medicine and healthcare education, which is the most prominent area. Further to this, there has been increasing research interest in the STEM area. As also noted by Pirker *et al.*,[6] typical use cases include *virtual tours*, which allow the exploration of historical, dangerous, inaccessible, or distant places. This is an interesting use case, especially for the subjects of geography, history, and industry. The use case of *recorded processes and procedures* is often used in subjects such as medicine, STEM education (e.g., physics or chemistry), and industrial applications. *Recorded situations* are often used in safety-relevant setups. This includes, for instance, extreme scenarios in the field of nurse education or safety training. *Recorded experiences* can be useful in the field of empathy learning and to experience the situation from a different personal perspective. *Recording processes for learning through replay (self-reflection)* was mostly used in teacher education but can also be used in fields such as experiment conduction or situational training scenarios.

The reported sample sizes showed that investigations need more extensive and carefully planned studies in order to establish a certain level of quality, including the report of effect sizes to compare different studies. Thorough reports are also necessary regarding the level of education of the participants. The analysis could also show that educational scenarios in Higher Education are the main source of data and that more research in other areas, especially in K-12 Education is needed.

RQ2, *What are advantages, limitations, purposes, and effectiveness of 360° videos and real VR in* *educational settings?* we can conclude that research shows indicators for a positive effect of using 360° videos in educational settings. But, as only half of the studies report positive effects of 360° videos, more factors than merely using immersive technology would appear to influence this potential. While other human factors are not always the main research interest of performance studies, it is a relatively impressive fact that more than half of the studies emphasize those positive side effects. This might imply that educational 360° experiences affect person-specific factors such as presence, perception, engagement, emotions, and empathy in an implicit way rather than having a direct effect on learning performance. This goes along with the findings of Dengel and Mägdefrau,[2] who emphasize the moderating role of individual factors for learning activities in immersive educational virtual environments and also with Dalgarno and Lee's[1] proposed learning affordances, including social and motivational aspects. Only few disadvantages were reported throughout the whole body of literature. There are reports of increased cognitive load, problems regarding the integration of immersive media in the everyday classroom and teaching sequence, and negative affect. The fact that there are few reports of disadvantages does not mean that there are no limitations and challenges to the educational use and value, but only that research on such issues is rather scarce, or at least not published.

RQ3. What are interaction methods used or required for 360° videos and real VR in educational scenarios? The analysis shows that most of the experiences were presented using some sort of mobile VR. This result is not surprising, as a setup supporting mobile devices for 360° videos can add to the flexibility of the experience and make it more accessible to different user groups. On the other hand, professional HMDs can induce higher levels of presence than Mobile VR headsets, which might be why their use is also popular for 360° immersive VR educational experiences.

RQ4. What is the current use of real VR in Education? The potential of live content for teaching is definitely an underrepresented topic. In our review, we were not able to identify any studies that discuss 360° video live content for teaching. But in times such as the corona pandemic in particular, it was possible to show how important live-streamed content can be for teaching. Many teachers used tools such as Twitch or YouTube to make their teaching accessible to students live, because compared to recorded videos, it is easier to answer questions from the working group. But, especially for subjects like chemistry or physics, a simple camera view is often not sufficient to show the experiment in its entirety and especially to give students the feeling of a laboratory experience. Traditional videos, which are watched by students at home, can be distracting and can be counteracted by immersive experiences. The positive effects of live-streaming efforts of instructions and lectures on different platforms (e.g., Twitch or YouTube) have been shown for traditional video formats. Furthermore, these platforms bring additional benefits such as direct interactions with lecturers and peers through different communication channels. Future research avenue will certainly not only include how to present educational content in live 360° videos streams but also how to integrate social features and interactions between students and teachers.

It should be noted that this literature review did not assess all available sources, since it focused on ACM, IEEE Xplore, and ScienceDirect databases. Also, theoretical articles were excluded as this literature review has the aim of pointing out the evidence-based potentials of 360° immersive experiences, even though theoretical approaches can add a major part to understanding the learning process.

CONCLUSION

This literature review investigated the potential of 360° VR videos and real VR for educational purposes. We identified major advantages regarding student performance, motivation, and knowledge retention. Even more positive effects were reported for the person-specific factors presence, perception, engagement, emotions, and empathy. This gives first indicators that the use of immersive experiences for education has potential in all scenarios that require not just factual learning, but also a change of attitudes, emotional value, increasing interest, and engagement. It was noted above that only a few studies report the limitations and challenges encountered during their experimental works. Fostering research on those disadvantages and challenging issues could well be a help for going the last mile from the evidence-based success of immersive educational virtual environments in laboratory settings to active use of 360° video experiences in the everyday classroom. Indeed, using immersive experiences in the classroom not only requires thinking about the special affordances of the technology: The content of the environment, the developmental stage of the learners (especially in K-12 education), and various modes of social interaction within the environment are crucial factors that can determine the success or failure of immersive learning in the classroom. A major gap was found in the investigation of live-streamed 360° videos and real VR for educational scenarios. Especially in times where distant digital education has become a necessity for all students and learners, we need a rethink on engaging live interactions. Real VR, with a focus on interesting interactions and also on social interactions, could well prove to be a game-changer for the future of distant learning.

APPENDIX

TABLE 3. Bibkey1.

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