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360° videos in education – A systematic literature review on application areas and future potentials

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Abstract

As a teaching and learning medium, 360° videos offer new teaching-learning experiences. Through the possibility of immersion, individual 360° panoramic images, multi-perspective viewing options and interaction possibilities, they extend the advantages of conventional video technology. To understand the potential of using 360° video technology for educational processes, a systematic literature review analyzed previous scientific articles ($N=44$) about the interdisciplinary use of 360° videos according to PRISMA guidelines. In the systematic literature selection, particular emphasis was placed on the conceptual distinction between virtual reality and 360° videos. By the authors, 360° videos are understood as a specific video format that has characteristics of virtual reality but is to be distinguished from virtual reality by the necessary real recording situation without programmed virtual environments. The results show a use of 360° videos mainly for three teaching-learning purposes: presentation and observation of teaching–learning content, immersive and interactive theory–practice mediation, and external and self-reflection. Combined with the added value of conventional video technology and other immersive technology such as virtual reality, five added value categories for its use as a teaching–learning medium were identified: To increase learning motivation and interest, to learn in authentic and realistic learning scenarios, for immersive and interactive learning experiences, for multi-perspective observation opportunities and for individual learning. These consisted primarily of positive motivational effects for authentic or immersive learning experiences.

Keywords 360° video · Immersive video · VR video · Spherical video · Omnidirectional video · eLearning · Systematic literature review

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1 Introduction

New teaching and learning experiences become possible with 360° videos. While the use of videos in teacher education is already well-established, the further development of video technology allows immersive and interactive applications in education which have a positive impact on motivation in learning processes (Kavanagh et al., 2017). In the past, financial costs and time-consuming systems limited the implementation of high-quality virtual reality and augmented reality applications in education. These barriers can be overcome nowadays due to increasingly cost-effective technology providers (Jensen & Konradsen, 2018) and new video technologies (Kavanagh et al., 2017). In particular, 360° videos provide a low-cost opportunity for video-based teaching (Kavanagh et al., 2016; Roche et al., 2021), which extends the advantages of traditional videos via immersion and multi-perspective reflection. Immersive experiences can now be sustainably implemented in the classroom using 360° videos in combination with desktop PCs, smartphones or even smartphones with low-cost head-mounted-displays such as cardboard.

The confusion and lack of differentiation between the terms 360° videos and virtual reality is addressed by Snelson and Hsu (2020) in their scoping review. Similarly, Roche et al. (2021) argue for a clear conceptual separation, e.g., due to the design process of both applications. They used a SWOT analysis to identify the strengths of 360° videos in teacher education. Ranieri et al. (2022) conducted a scoping review to investigate the uses and potentials of clearly defined 360° videos in education. In their search term, they exclusively used different spellings of the term 360° video. Therefore, it cannot be ruled out that due to the lack of a conceptual distinction between 360° videos and virtual reality in the literature, thematically relevant contributions were not recorded by the authors. In addition, no reference to conventional video technology could be established. However, we see the link to traditional video technology as necessary, as we understand 360° videos as a specific video format and agree with the argumentation of Roche et al. (2021).

Different video techniques and their use in teaching, for example for explanation or viewing classroom videos in teacher education (Gaudin & Chaliès, 2015) have been analyzed until now. We recognize a systematic linking of the educational potentials of conventional video technology with those of 360° videos as well as a sharp differentiation of 360° videos from virtual reality as an important addition to existing reviews (e.g., Pirker & Dengel, 2021; Ranieri et al., 2022; Dhimolea et al., 2022). To avoid future misunderstandings between 360° videos and virtual reality and to clarify the potentials of 360° video technology, we conducted a systematic review of 360° videos in education, building on the scoping reviews by Snelson and Hsu (2020) and Ranieri et al. (2022), as well as the systematic reviews by Kavanagh et al. (2017) and Pirker and Dengel (2021).

2 Definition of terms

The 360° video technology enables the video recording of the real environment with special video cameras (Ranieri et al., 2022). As with conventional video technology, a video image of the real environment is created. The decisive common criterion is the video recording. A 360° video camera records the

environment around it both statically at a fixed point and from a dynamically moving camera position. With 360° videos the user can freely choose his viewing angle in a 360° angle around the camera (Roche et al., 2021). These individually controllable options are called degrees of freedom (DoF). Three-hundred-and-sixty-degree-videos predominantly allow three DoF of rotation on the X, Y and Z axes around the fixed camera point (Griffin, Langlotz & Zollmann, 2021). Thus, the viewing perspective can be freely selected up or down, left or right, or in tilt. By freely choosing the viewing direction, viewers interact with the medium, but the recorded action cannot be manipulated when compared to programmed virtual reality (VR) scenarios (Roche et al., 2021). However, 360° videos can also be viewed via different playback media with different degrees of immersion, thus picking up on an important characteristic of virtual reality: immersion.

Immersion is the feeling of reality in a non-physical world (Ranieri et al., 2022). Different immersive technologies and their definitions complement each other and cannot be completely distinguished (Kaplan-Rakowski & Gruber, 2019). For example, Pirker and Dengel (2021) distinguish in their systematic literature review between 360° VR-videos and real VR. Pellas et al. (2021) were able to include articles about 360° videos in their systematic review, although they only used the terms "immersive technology" or term variations of VR in their search term.

The definition of VR is not undisputed (Jensen & Konradsen, 2018; Kaplan-Rakowski & Gruber, 2019). Kavanagh et al. (2017) state a minimum consensus definition of VR is a digital representation of a three- dimensional object and/or environment. Unlike 360° videos, programmed VR applications enable action control in a virtual world. The digital environments and actions are programmed, unlike 360° videos, while 360° videos record real environments and actions. In VR, other control options are offered in addition to action control. Thus, translational movements forward or backward, to the side or up and down are possible (Griffin et al., 2021). Accordingly, six DoF are characteristic for VR applications. The necessary requirements for the creation process of VR applications is thus higher than for 360° videos (Kavanagh et al., 2017).

360° videos and VR can be systematized according to the kinds of media used and their degree of immersion (Kaplan-Rakowski & Gruber, 2019, Kucher Dhimolea et al., 2022). Low-immersive VR is defined as applications controlled with keyboard or mouse on the desktop, while high-immersive VR is defined as applications controlled with a head-mounted display (HMD), among others.

In general, 360° videos can be viewed or controlled in a low immersive manner on the desktop or in a highly immersive way with head-mounted-displays (HMD) and are also categorized under the term VR (Kucher Dhimolea et al., 2022; Pellas et al., 2020, 2021; Rupp et al., 2016, 2019). On one hand, 360° videos are associated with the medium of video in general due to the recording and sequencing of moving images. On the other hand, it is associated with VR because of its immersive possibilities. We agree with the necessary terminological separation of both technologies proposed by Roche et al. (2021) and define 360° video as a specific video format that combines features of VR with conventional video technology.

3 State of research

In general, digital media present new ways of teaching and learning. Traditional videos already offer extensive possibilities for visualization and reflection in education. Immersive technology offers the opportunity for more authentic learning processes. Due to the classification of 360° videos as a specific video format, conventional videos as a teaching-learning medium will be first analyzed and potentials identified (3.1) followed by an overview of research on immersive technologies such as VR (3.2). For a condensed presentation, primarily reviews were considered. Since 360° videos are considered to be video technology but also exhibit properties of immersive technologies, the potentials that need to be examined in this review are finally derived (3.3).

3.1 Traditional videos in education

Yousef et al. (2014) were able to identify video benefits in process learning in their systematic literature review of video-based learning ($n=76$); in particular to present and visualize content in an attractive and realistic way. However, they were also able to determine no difference in learning success between teaching with videos as compared to other methods. In contrast, Gaudin and Chaliès (2015) identified high motivational potential and authentic presentation possibilities through videos and the advantages they provide in enhancing the perception of teaching situations with reflexive learning processes. Based on their analysis of 255 articles, in a systematic literature review on the use of video in teacher education, videos have advantages in problem-oriented presentations, provide multi-perspectivity to illustrate theoretical and practical content in contrast to text. Noetel et al. (2021) confirmed the potential video has for a more authentic and realistic way of learning. They analyzed the effects of video on learning in higher education with a systematic literature review ($n=105$). As a result, they found strong benefits in the learning process were exhibited through a combination of video learning and traditional learning methods.

3.2 Immersive technology in education

Immersive technology such as VR applications are already used as a teaching–learning medium in higher education contexts, depending on the discipline (Kavanagh et al., 2017). In a systematic literature review, Kavanagh et al. examined 379 papers for their use of VR applications in higher education and their influence on learning motivation. They conclude that VR applications positively influence motivation in the learning process because of their immersive and interactive possibilities. In their systematic literature review ($n=18$), Radianti et al. (2020) also mention the high realistic display capabilities of immersive technologies. VR applications enable interactive and realistic learning experiences based on discovery learning or learning by doing in an authentic and realistic virtual environment (ibid). Pellas et al. (2020) reached similar conclusions in their scoping review ($n=41$). VR allows students to access realistic, high-quality educational resources with authentic simulations

generated by computing devices. Due to the higher sense of authenticity in a realistic virtual environment combined with the interactivity they provide, students favor higher immersive virtual reality applications (Kaplan-Rakowski & Gruber, 2019). It is assumed the novelty effect cannot be ruled out, because VR applications offer a new way of learning (ibid.). In another systematic review on the use of highly immersive VR in language learning ($n=32$), Dhimolea et al. (2022) found positive effects on motivation and learning engagement as well as on the reduction of speaking anxiety through VR. However, the authors also mentioned the effect sizes were related to both students' experiential use of the technology and technology acceptance. Longer experiences with VR and especially higher levels of immersion have more positive effects on learning outcomes (ibid). Besides the motivational impact of learning process and realistic learning experiences, Jensen and Konradsen (2018) summarized in their review ($n=21$) that VR applications provide protected learning spaces for timeless learning experiences without spatial constraints.

However, the widespread implementation of VR applications as a learning medium is difficult because it requires knowledge in programming and computer science (Kavanagh et al., 2017). The increased resource requirements for VR applications as a learning medium are confirmed by the findings of Jensen and Konradsen (2018). High resource requirements combined with unclear positive impact on learning outcomes lead to low usage of it as a teaching–learning medium (ibid). Radianti et al. (2020) arrive at a similar conclusion. Due to the high technical component of highly immersive VR, mobile VR can be used as a cost-effective alternative for educational processes, as it also provides experiences which are independent of spatial and temporal constraints (Pellas et al., 2020). Similar to Kavanagh et al. (2017), Jensen and Konradsen (2018) suggest the resource-efficient use of 360° videos.

3.3 360° videos in education

Three potentials of 360° videos as a teaching–learning medium were identified in a scoping review by Snelson and Hsu (2020) ($n=12$). They are multi-perspective reflection, increased engagement and motivation. Mohd Adnan et al. (2020) also found a high positive evaluation of 360° videos and VR as a teaching–learning medium in their study ($n=560$) especially for students' learning enjoyment. Independent, repeatable practice time is also mentioned alongside the immersive and interactive possibilities of 360° videos and VR (ibid.). Although VR has great potential for education due to the immersion and interaction it allows, Kavanagh et al. (2016) stated that its implementation is difficult due to its high cost and large quantity of resources it requries. In their case study, they proposed 360° videos as a cost-effective alternative to VR technology. However, the effectiveness of 360° videos as a learning medium still needs to be investigated. Snelson and Hsu (2020) confirm the call for studies on the effectiveness of 360° videos. They note most studies are rather exploratory and make few statements about learning effects, which are seen to greatly differ especially in terms of effectiveness. In their systematic review ($n=64$), Pirker and Dengel (2021) examined the potential of both 360° videos and VR for educational processes. So far, the authors have found increased use in the medical field (28.1%), followed by history

and social studies (12.5%). In general, 360° videos generate interest, especially in STEM subjects, enable discovery learning in different disciplines, and can be viewed with different output media, especially mobile devices (ibid.) The playback media have an influence on the perceived immersion content and thus on the perceived reality and authenticity. Ranieri et al. (2022) confirmed in their scoping review ($n=29$) the positive effects of 360° videos on motivation, attention, information intake, and knowledge transfer. In particular, 360° videos can be used to link theory with practice, illustrate learning content, and develop learning scenarios. However, no clear evidence of a positive effect of 360° videos could be found for pure theory transfer, e.g. in the form of lectures (ibid). In addition to the medical field ($n=8$), 360° videos are also used in teacher education ($n=4$) (ibid). For example, in an exploratory study, Cross et al. (2022) used 360° videos in teacher education to perceive classroom situations. In contrast to conventional videos, the complexity of the classroom can be presented from multiple perspectives in a 360° video. In their SWOT analysis on the use of 360° videos in teacher education, Roche et al. (2021) recognize a high potential for observational learning processes to improve teaching skills, explore teaching situation and reduce anxiety in classroom (ibid). Due to the low resource requirements of 360° videos, 360° videos can be used as a teaching-learning medium. However, despite a clear distinction from VR, the authors also note a that high level of immersion is also possible with HMD (ibid) and that further research is needed on immersive playback media in 360° video.

By using the VR term for 360° videos and systematically categorizing applications according to their immersive content, the potentials of VR and 360° videos are blended. However, it results in the need to specifically investigate the previous uses of 360° videos in order to analyze their potential. Only through comprehensive findings on their potentials can their effectiveness be verified. This systematic literature review is therefore intended to help. The findings of Snelson and Hsu (2020), Pirker and Dengel (2021), Roche et al. (2021), and Ranieri et al. (2022) are combined using a clear conceptual definition of 360° videos and VR and linked to the potential of traditional videos as a teaching-learning medium.

4 Methods

The aim of the review is to analyze areas of application of 360° videos in education and to present and discuss their potential for teaching and learning processes. Because of limited research about 360° videos as an educational medium, we focus on three broad research questions (RQ):

1. Which disciplines can be categorized using 360° videos as a teaching–learning medium?
2. What purposes can be categorized using 360° videos as a teaching–learning medium?
3. What potentials of 360° videos as a teaching–learning medium can be identified or derived from the categorized results?

A systematic literature review will be carried out to examine the areas of application, purposes and potential of using 360° videos as an educational medium. The approaches are based on the PRISMA statement and the recommended protocol (Moher et al., 2015) (Fig. 1).

4.1 Search strategy

The previous reviews of 360° videos in education, which show the state of research, are supplemented by the search with a clear distinction from VR in order to show the potential of 360° videos more clearly. In particular, 360° videos became popular with the technical possibility of 360° videos on social media platforms and video portals between 2015 and 2017 (Ranieri et al., 2022). Roche et al. (2021) noted that 360° videos in teacher education have become more prominent in research, especially from 2018. Therefore, the period of selection in the search is limited to publications from the last 5 years: 2017– May 2022.

In order to obtain many studies of 360° videos as an educational learning medium and ensure quality, only peer reviewed papers in the English language will be included using the Education Resources Information Center (ERIC) and the Academic Search Premier EBSCOhost.

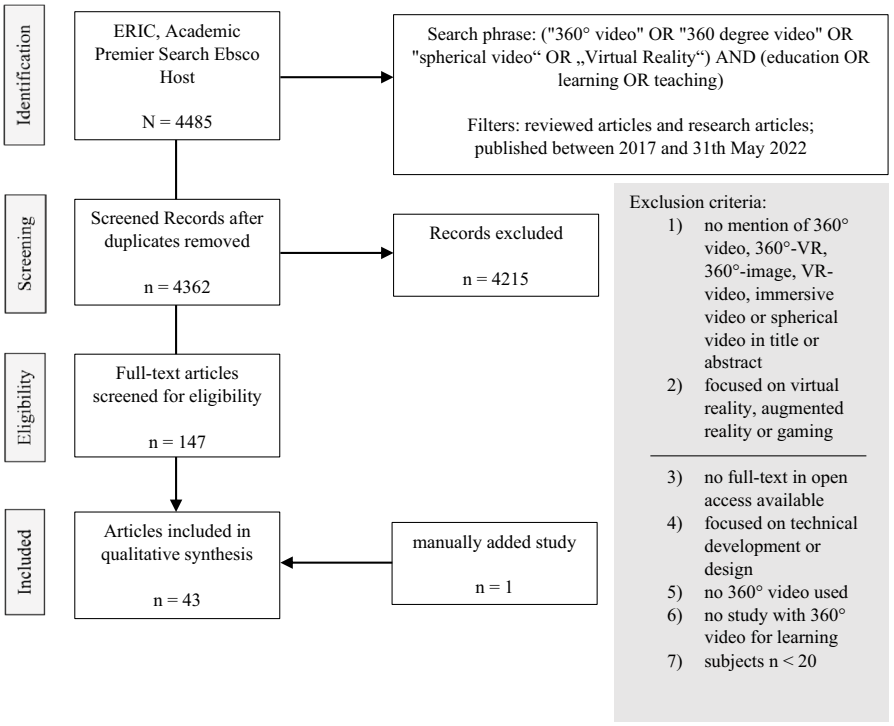

Fig. 1 PRISMA-Flowchart for identification and selection of research articles

4.2 Keywords

The first step to obtain an initial overview of 360° videos in education was to conduct an unsystematic preliminary search of 360° videos on Google Scholar based on a funnel model. An unclear classification of 360° videos into sub-concepts, categories and synonyms emerged, as presented in the previous chapter. Reviews of VR (Dhimolea et al., 2022; Pellas et al., 2020) also address 360° videos. However, we understand 360° videos as a specific video format which has characteristics of VR but is to be distinguished from it due to the creation process or the predominantly limited DoF. The focus of our research was therefore to include only articles which clearly address a use of 360° videos for educational processes. Because it could be expected that only a small selection of relevant contributions would contain the term "360° video" as a single keyword, "Virtual Reality," under which 360° videos can also be categorized due to their lack of a clear definition, was added as a keyword. In addition, other terms such as "spherical videos" were added, which were found during the unsystematic preliminary search. The literature search was extended to the setting of education or teaching and learning purposes in a Boolean search string:

4.3 Data extraction

Using ERIC and Academic Search Premier EBSCO databases between April 2021 and 15 June 2022, a total of 4485 articles were identified. After duplicates were removed, 4362 studies were reviewed for thematic relevance based on their titles and abstracts by two independent coders. By using the additional search term "Virtual Reality", a large number of articles were found, but neither the title nor the abstract showed a thematic match to our exclusive research focus of 360° videos for education. In order to clearly distinguish 360° videos from VR and to prevent conceptual confusion, only articles which clearly used the term 360° video or term synonyms (360° VR, 360° image, VR video, immersive video, spherical video) either in the title or in the abstract were included as potentially relevant articles in our full-text analysis. For a further detailed analysis, articles with full-text availability were required. 147 contributions were considered relevant and analyzed in more detail. Articles that did not apply an empirical study or focused on technical aspects, camera technology, network transmission or the design of 360° videos were excluded. In 57 articles, both coders were able to establish a clear thematic reference to 360° video in the title or abstract. For 69 articles, both coders could not rule out the possibility that it was 360° video on the basis of the title or summary, even though the terms "360° VR", "360° image", "VR video", "immersive video" or "spherical video" were used. One study was added after studying literature references (Mohd Adnan et al. 2020). The verification of the coding agreement of the titles and summaries according to their thematic assignment and relevance by the two coders showed an agreement of 98%. The adjusted reliability estimate with the Cohens-Kappa coefficient was $K = 0.81$, which can be classified as a moderate agreement. After the full text analysis, 44 articles (Table 1) could be included in the review as relevant for an overview of areas of use (RQ1) and purposes (RQ2) of 360° videos

in education. Articles using 360° video technology as a teaching-learning medium within a study were evaluated as relevant. To minimize exploratory concept ideas, study relevance was determined with more than 20 subjects. First, included articles were inductively categorized according to the different disciplines and purpose of 360° videos in education. Second, the potentials of 360° video technology for teaching and learning processes are discussed on the basis of the categorized application areas and purposes in connection with the current state of research (RQ3).

5 Results

The focus was initially on identifying individual subject disciplines in order to obtain an overview of the use of 360° videos as a teaching-learning medium. Subsequently, the intended uses of 360° videos were inductively categorized. As per the third research question, the potentials were inductively derived from the analyzed studies.

5.1 Disciplines using 360° videos as a teaching–learning medium

After a numerical count of the frequency of use of 360° videos within different disciplines, the individual studies were divided into different categories depending on their content. After analyzing the 44 articles, the main disciplines that use 360° videos as a teaching–learning medium (RQ 1) are medicine ($n=9$), language ($n=8$), teacher education ($n=7$) and natural science ($n=7$) as shown in Table 1. However, the separation of the individual categories was not always clearly definable. For example, a first-aid course to learn cardiopulmonary resuscitation (Barsom et al., 2020) can be assigned to both the medical category and general education, while traffic education measures (Barić et al., 2020), such as alcohol consumption in road traffic (Ma, 2020), were assigned to the area of general education. Articles with different publication dates or publication media were counted individually, even if their literature indicated that they were the basis of large, comprehensive studies (Boda & Brown, 2020a, b; Ferdig & Kosko, 2020; Kosko et al., 2019; Theelen et al., 2019, 2020a, b).

The language category included all the main topics dealing with language comprehension (e.g., Huang et al., 2020; Repetto et al., 2021), actual speaking and reducing anxiety to speak in front of an audience (e.g., Vallade et al., 2021). Reducing speech anxiety is also addressed with 360° videos in the separate category of teacher education (e.g., Theelen et al., 2020a), where contributions to improving classroom perception were also summarized. Studies using 360° videos in geography (Barnidge et al., 2022; Chang et al., 2020; Jong et al., 2020) were assigned to the natural sciences category to illustrate theory and practice (Boda & Brown, 2020a, b) or to realistically present learning content in authentic environments (Barnidge et al., 2022; Chang et al., 2020; Jong et al., 2020). The authenticity of 360° videos is also used for cross-cultural learning (Chien & Hwang, 2022; Shadiev et al., 2021). In addition, singular disciplines such as history (Calvert & Abadia,

Table 1 Overview of included literature $N = 44$

Author	Subject	Study Design	Participants	Content	Type of Learning	Key findings
Mohd Adnan et al. (2020)	Language	Questionnaire and group discussion	$n = 560$	Comparison of subjective experiences between 360° videos, VR and traditional foreign language learning: • usefulness • usability • overall impression	Not mentioned	• 360° videos and virtual reality rated as useful learning media, especially the possibility of repeating independent of time and space and controlling the learning rate and cognitive load
Barić et al. (2020)	Driving school	Randomized controlled trial	$n = 274$	Comparison of the effect on attitude towards traffic behavior involving alcohol on the road with 2 different types of media: • 360° video • traditional video	Reflection	• Sense of reality was rated high • Application was rated as immersive by the majority • 360° videos were rated to have an influence on future driving behavior
Barnidge et al. (2022)	Geography	Randomized controlled trial	$n = 134$	Comparison of learning about a report on the effects of climate change in Greenland with 3 different types of media: • VR (360° video + HMD) • 360° video + Desktop • text	Observation	• Subjects rate immersion significantly distinct ($p < .001$), highest for 360° videos + HMD followed by 360° videos + desktop and text • Results show no direct effects of 360° videos + HMD on learning about climate change • 360° videos + HMD and 360° videos + desktop achieve high sense of presence

Table 1 (continued)

Author	Subject	Study Design	Participants	Content	Type of Learning	Key findings
Barsom et al. (2020)	First aid	Randomized controlled trial	$n = 40$	Comparison of learning cardiopulmonary resuscitation with 2 different types of media: • VR (360° video) • traditional video	Observation	• No significant difference in knowledge test scores between 360° videos and traditional videos ($p = .064$) • Significant knowledge increase, highest in 360° video group in pre–post comparison ($p = .035$) • The 360° video group was significantly more successful in adhering to the correct sequence of cardiopulmonary resuscitation steps ($p = .006$) • Both groups feel competent but higher self-confidence was demonstrated in the 360° video group
Boda and Brown (2020a)	Natural science	Randomized controlled trial	$n =$ almost 400 (no exact specification)	Generating interest in science to demonstrate an experiment in an authentic and known environment with 360° video + HMD	Observation with visual cues such as overlaid text	• 360° videos enable learning growth and knowledge comprehension by relevance recognition through authentic presentation in familiar contexts (familiar environment) • High theory–practice linkage with 360° videos • 360° videos can increase interest in science due to authenticity in familiar context

Table 1 (continued)

Author	Subject	Study Design	Participants	Content	Type of Learning	Key findings
Boda and Brown (2020b)	Natural science	Randomized controlled trial	n = almost 400 (no exact specification)	Generating interest in science to demonstrate an experiment in an authentic and known environment with 360° video + HMD	Observation with visual cues such as overlaid text	• 360° videos enable learning growth and knowledge comprehension by recognition of concept relevance through authentic presentation in familiar contexts (familiar environment) • High theory–practice linkage with 360° videos • 360° videos can increase interest in science due to authenticity in familiar context
Calvert and Abadia (2020)	History	Randomized controlled trial	$n = 79$	Comparison of learning between high school and university students about a World War II military campaign and the life of a soldier with 2 different types of media: • VR • 360° video	Observation	• VR group show significantly higher mean scores for engagement ($p < .001$, $d = 0.74$) sense of presence ($p = .014$, $d = 1.13$) and empathy ($p < .001$, $d = 0.85$) • Almost twice as many university students (80%) had no experience with VR when compared with high school students (47%) • 360° video group also rated immersion and engagement positively • VR group criticizes the difficulty of interacting with hand coordination and low realism • 360° video group criticizes the lack of interaction in general

Table 1 (continued)

Author	Subject	Study Design	Participants	Content	Type of Learning	Key findings
Chang et al. (2020)	Geography	Controlled trial	$n=44$	Comparison of learning about the principle of erosion and geological change by creating or using spherical video content	Creation Observation	• No differences in learning success between both learning approaches • No differences between motivation seen through both learning approaches
Chang et al. (2019)	Medicine	Randomized controlled trial	$n=64$	Comparison of learning performance in childbirth education with 2 different types of media: • spherical video-based VR (360° VR video + HMD) • traditional video	Observation	• 360° video group is significantly more motivated ($p<.05$, $\eta^2=0.121$) • No significant difference in critical thinking • 360° video group is significantly more satisfied with the learning scenario and their learning outcomes ($p<.01$, $\eta^2=0.177$)
Chao et al. (2021)	Medicine	Randomized controlled trial	$n=32$	Comparison of learning about History Taking and Physical Examination Skills with 2 different types of media: • 360° VR video (360° video + HMD) • traditional video + HMD	Observation	• 360 video group achieve better learning skills ($p=.04$) for History taking and Physical Examination Skills • 360° video group mention more fun to learn with risk for motion sickness • Both groups do not differ much in terms of total cognitive load

Table 1 (continued)

Author	Subject	Study Design	Participants	Content	Type of Learning	Key findings
Chen et al. (2021)	Engineering	Randomized controlled trial	$n = 84$	Comparison of learning in a problem-based context in engineering to find solutions and present it in English using 2 different types of media: • VR (360° video) • text	Observation with visual cues such as overlaid text	• 360° video group achieve higher learning gains for English • 360° video group is more motivated to use English • No significant difference in problem solving test ($p = .06$, $\eta^2 = 0.04$)
Chen and Hwang (2020)	Language	Controlled trial	$n = 93$	Comparison of learning English and reducing anxiety to speak in front of an audience with VR (360° video + HMD) and conventional learning methods	Observation	• 360° video group perform significantly better in the oral presentation performance than conventional learning methods ($p < .05$, $\eta^2 = 0.323$) • 360° video group show significantly lower speech anxiety after intervention ($p < .001$, $\eta^2 = 0.160$) • 360° video group exhibit higher motivation
Chen et al. (2022)	Language	Randomized controlled trial	$n = 59$	Comparison of improving writing performance with 2 different types of learning methods: • spherical video-based VR (360° video) • traditional learning method	Observation Reflection with visual cues such as overlaid text	• Significantly higher improvement of writing skills ($p < .01$, $\eta^2 = 0.126$) (e.g. linguistic expressiveness and creative thinking) • No significant difference in thematic coherence • Higher learning engagement in 360° video group

Table 1 (continued)

Author	Subject	Study Design	Participants	Content	Type of Learning	Key findings
Chien and Hwang (2022)	Cross-cultural learning	Randomized cross-over trial	$n = 60$	Comparison of Intercultural Learning with 360° Videos + HMD and with 2 different learning methods: • with guiding questions for observations • without guiding questions for observations	Observation with visual cues such as overlaid text	• The group with guiding questions performed significantly better in culture presentation (p .000 < .001, d = 0.66) • Significantly higher technology acceptance for group with guiding questions (p = .014 < .05, d = 0.65)
Dolgunsöz et al. (2018)	Language	Randomized cross-over trial	$n = 24$	Comparison of improving writing performance by writing a summary after watching documentations of 2 different types of media: • VR (360° video) • traditional video	Observation	• The traditional video group performed significantly better in writing than the 360° video group (p < .05) • 360° videos activate and motivate because of authenticity, sense of involvement and immersion • Students have little experience with VR

Table 1 (continued)

Author	Subject	Study Design	Participants	Content	Type of Learning	Key findings
Ferdig and Kosko (2020)	Teacher education	Randomized controlled trial	$n = 34$	Comparison of improving perceptual and attentional skills by watching recorded math lessons with 3 different types of media: • 360° video + HMD • 360° video + Desktop • traditional video	Reflection	• Both 360° video groups showed significantly higher results for immersion ($p = .004$) and presence ($p = .010$) than traditional video • No significant effect for immersion ($p = .613$) and presence ($p = .251$) between both 360° video groups • 360° videos + HMD improve attention and perceptual ability • Traditional video group perceived more detail after the first viewing, but both 360° video groups added more detail after second viewing
Han et al. (2022)	Teacher education	Randomized controlled trial	$n = 148$	Comparison of sense of presence and improving empathy by watching 360° videos with 2 different levels of immersion and with 2 different types of perspective: • VR video (360° video) + HMD • VR video (360° video) + desktop • First-Person perspective • Observer perspective	Observation	• Significant higher immersion for HMD group ($p < .001$, $\eta^2 = 0.14$) • No significant effect for empathy (p .90, $\eta^2 < 0.001$) between HMD and desktop group • Slightly significant effect for empathy for Observer perspective ($p = .0052$, $\eta^2 = 0.026$)

Table 1 (continued)

Author	Subject	Study Design	Participants	Content	Type of Learning	Key findings
Hebbel-Seeger et al. (2021)	Media management	Experiment	$n = 214$	Comparison of learning about materials management by following lectures with 2 different types of media • 360° video • traditional video	Observation	• No significant difference in objective learning performance • The own learning performance is subjectively rated significantly better by the traditional video group ($p < .001$, $r = 0.322$) • Teacher-centered lecture in a 360° video is not a suitable didactic scenario despite authenticity and realism • More break-off reasons due to cybersickness were observed in the 360° video group
Huang et al. (2020)	Language	Randomized controlled trial	$n = 65$	Comparison of learning Chinese after watching a route to the Jade Mountain with 2 different types of media • spherical video-based VR (360° video) • traditional video	Observation	• 360° video group demonstrated significantly better writing performance regarding the content ($p = .01 < .05$) and appearance ($p = .01 < .05$) but not vocabulary ($p = .88$) • No significant differences in intrinsic ($p = .16$) or extrinsic motivation ($p = .42$) • More positive evaluation of 360° videos than traditional videos

Table 1 (continued)

Author	Subject	Study Design	Participants	Content	Type of Learning	Key findings
Hwang et al. (2022)	Medicine	Randomized controlled trial	$n=60$	Comparison of learning nurses' safety behaviors in chemical accidents with 360° videos: • spherical video-based VR (360° video) • traditional video + lecture	Observation and Interaction with visual cues such as overlaid text	• Higher sense of presence for 360° video group ($p=.000$, $r=0.52$) • Greater learning achievement for 360° video group ($p=.008$, $r=0.32$) • Greater problem-solving tendency for 360° video group ($p=.000$, $r=0.64$) • Greater critical-thinking awareness for 360° video group ($p=.000$, $r=0.54$) • More positive evaluation of technology acceptance and usefulness of 360° videos than traditional videos
Jiang et al. (2021)	Natural science	Experiment	$n=39$	Generate interest among underrepresented cultural groups in careers in science with 360° video	Observation	• Growing interest in STEM professions and High sense of presence • High sense of immersion with 360° videos when viewed with google Cardboard • Higher sense of satisfaction when watching 360° videos with google Cardboard
Johnson (2018)	Religion	Experiment	$n=53$	Learning about different religions with 360° videos	Reflection Observation	• Benefits like immersion, participation and sense of presence of 360° videos were rated positively • Motion sickness was mentioned as a negative aspect

Table 1 (continued)

Author	Subject	Study Design	Participants	Content	Type of Learning	Key findings
Jong et al. (2020)	Geography	Controlled trial	$n=566$	Learning about physical geography with two types of media in three categories of secondary schools: • spherical video-based VR (360° video) • text	Observation with visual cues such as overlaid text	• Significantly better learning performance with 360° video units than with conventional teaching methods in all three categories of secondary schools (cat a: $p<.05$, $d=0.28$; cat b: $p<.001$, $d=0.60$; cat c: $p<.001$, $d=0.51$)
Kosko et al. (2019)	Teacher education	Randomized controlled trial	$n=34$	Comparison of improving perception and attention skills by watching lessons in math with 3 different types of media: • 360° video + HMD • 360° video + Desktop • traditional video	Reflection Observation	• Higher improvement in perception ability was seen in the 360° video group + HMD than in other groups
Lanzieri et al. (2021)	Social work	Experiment	$n=30$	Learning about the working environment in social work by watching 360° videos	Observation with visual cues such as textual dialogues	• Only half of the students have experience with VR • Benefits are seen in reflection • The main benefit sought was an immersive and authentic experience
Lee et al. (2017)	Business Science	Randomized controlled trial	$n=34$	Comparison of learning about a climbing tour with 2 different types of media: • 360° video + HMD • 360° video + desktop without movement	Observation	• Significantly higher enjoyment ($p<.05$) and interest ($p<.05$) in learning with 360° videos • No significant differences in comprehensibility • 360° videos + HMD offer authenticity and realism and lead to higher learning motivation • No benefit for a pure mediation of content

Table 1 (continued)

Author	Subject	Study Design	Participants	Content	Type of Learning	Key findings
Lee et al. (2020)	Medicine	Experiment	$n = 60$	Learning about patients with schizophrenia by watching VR (360° video + HMD)	Observation	• High realism and immersion • High motivation in learning with 360° videos • 360° videos provide a safety learning environment
Ma (2020)	Driving school	Randomized controlled trial	$n = 107$	Comparison of reducing risk behavior about alcohol on the road by watching 2 different 360° videos: • 360° video + HMD • 360° video + Desktop	Observation	• 360° video + HMD resulted in lower intentions to drink alcohol and drive only among female participants • High immersive 360 videos have the potential to prevent risky behavior but gender identification with recorded models has to be considered

Table 1 (continued)

Author	Subject	Study Design	Participants	Content	Type of Learning	Key findings
Pagé et al. (2019)	Sport	Randomized controlled trial	$n = 27$	Comparison of improving perceptual skills and decision making in game situations in basketball with 3 different types of media: • VR (360° video + HMD) • Computer Screen (360° video + Desktop) • traditional video	Reflection	• No significant improvement in decision-making skills between 360° video + HMD and 360° video + desktop ($p = .27$, $\eta^2 = 0.07$) • Significantly improvement in decision-making skills with 360° videos ($p < .001$, $\eta^2 = 0.73$) • Both 360° video groups performed significantly better on the practical decision making in known game situations ($p \leq .001$) • For unknown game situations, only the 360° video group + HMD showed significantly better performance in decision-making skills ($p \leq .002$) • 360° videos + HMD enable a higher sense of immersion and presence leading to more authentic and realistic movements especially of the head
Repetto et al. (2021)	Language	Randomized controlled trial	$n = 104$	Comparison of learning English by watching several documentations with 2 different types of media: • 360° video • traditional video	Observation in Blended Learning	• Almost twice as many correct words were learned by the 360° group compared to the traditional video group

Table 1 (continued)

Author	Subject	Study Design	Participants	Content	Type of Learning	Key findings
Ros et al. (2021)	Medicine	Randomized controlled trial	$n = 89$	Comparison of learning about a surgery through 2 different lessons: • traditional lecture • VR (360° video with annotations and additional information)	Observation	• Participants who attended the traditional lecture showed significantly better results in the oral examination ($p < .001$). • 360° video group performed the procedure significantly more efficiently with fewer errors. They also completed practical implementation in less time ($p < .01$)
Rupp et al. (2019)	Education (not specific)	Randomized controlled trial	$n = 136$	Comparison of learning about the International Space Station through 360° videos with different playback media • 360° video + Smartphone • 360° video + Smartphone + HMD • 360° video + Low-end HMD • 360° video + High-end HMD	Observation with audio cues that provided information	• Better learning outcomes associated with high immersion • Higher engagement and interest associated with high immersion • High immersion associated with higher cybersickness
Shadiev et al. (2021)	Cross-cultural learning	Experiment	$n = 21$	Intercultural Learning with 360° Videos in the Exchange of Chinese and Uzbekistani Students: • 360° video for self-introduction • 360° video local culture introduction	Observation	• Improving cross-cultural understanding • High sense of presence ($M = 5.6$, $SD = 0.949$) and immersion ($M = 5.61$, $SD = 1.014$) within the 360° video scenario (Scale between 1 = completely disagree and 7 = strongly agree)

Table 1 (continued)

Author	Subject	Study Design	Participants	Content	Type of Learning	Key findings
Singh et al. (2020)	Medicine	Controlled trial	$n = 34$	Comparison of learning about and improving interdisciplinary communication with 2 different types of media: • VR (360° video) • traditional video	Observation	• Higher authenticity and immersion in real clinical scenarios with 360° videos • 360° videos represent a possible alternative to experiencing personal immersion in learning environments
Tak et al. (2022)	Medicine	Randomized controlled trial	$n = 30$	Comparison of learning to assess 360° VR self-learning media for a periodontal instrument operation with 3 different types of media: • text • traditional video • 360° VR (360° video + HMD)	Observation	• Significant difference in improvement between VR group and text group ($p < .0167$) • 360° VR showed higher learning efficiency than normal 2D videos
Tan et al. (2020)	Teacher education	Experiment	$n = 62$ (Video 1) $n = 43$ (Video 2)	Learning and improving attention with 360° classroom videos with different playback media for analyzing perceptual and attentional skills	Observation	• Cues can direct users' attention, too many cues are distracting and cause stress about missing something • Learning with 360° videos requires a deep understanding about media design, speech, gesture and use of room space
Tauber et al. (2022)	Natural Science	Experiment	$n = 30$	Prepare for a chemistry experiment in the lab and improve understanding in the lab environment with the 360° video lab tour	Interaction with visual cues such as buttons	• Improvement of learning outcomes and understanding of laboratory behaviors • Positive evaluation especially due to the individual repeatability

Table 1 (continued)

Author	Subject	Study Design	Participants	Content	Type of Learning	Key findings
Taubert et al. (2019)	Medicine	Experiment	$n = 72$	Learning about palliative care and radiotherapy from a patient's perspective with VR (360° videos + HMD)	Observation	• Highly positive evaluation and recommendation of 360° videos
Theelen et al. (2019)	Teacher education (not specific)	Experiment	$n = 141$	Improving perception and attention skills by watching lessons with 360° video combined with traditional lectures	Reflection	• 360° videos lead significantly ($p < .01$, $d = 0.8$) to the improvement of the ability to perceive teaching situations • 360° videos combine theory and practice • Watching 360° videos with HMD had no effect on users' observational skills
Theelen et al. (2020a)	Teacher education (not specific)	Experiment	$n = 141$	Reducing preservice teachers' anxiety by watching lessons with 360° video combined with traditional lectures	Interaction	• Combination of 360° videos and lectures led significantly to lower anxiety ($p < .01$, $d = 0.3$) & increased self-efficacy ($p < .05$, $d = 0.2$) • 360° videos make it possible to practice teaching in front of a group
Theelen et al. (2020b)	Teacher education (not specific)	Experiment	$n = 141$	Learning and linking theory with practice by watching lessons with 360° video combined with traditional lectures	Observation Reflection	• Combination of theoretical lectures and 360° videos were useful in teacher education

Table 1 (continued)

Author	Subject	Study Design	Participants	Content	Type of Learning	Key findings
Ulrich et al. (2021)	Medicine	Randomized controlled trial	$n=81$	Comparison of learning in physical therapy in 3 different lessons: • VR (360° video + HMD) • traditional video • traditional lecture	Observation	• No significant superiority of 360° videos in learning effectiveness ($p=.227$) • No significant difference between 360° videos and traditional videos in learning effectiveness ($p=.135$) • 360° videos are significantly less effective in student learning satisfaction than traditional videos or lectures ($p=.007$)
Vallade et al. (2021)	Language	Experiment	$n=86$	Reducing anxiety to speak in front of an audience with 360°video + HMD	Interaction	• Participants rated 360° videos as useful for practicing graduation speeches • High realism and authenticity reported because of real people in the video (as opposed to programmed VR people)
Yang et al. (2021)	Language	Randomized controlled trial	$n=40$	Comparison of learning Chinese by discovering an island environment and diving tour with 2 different types of media • spherical video-based VR (360° video) • traditional video	Observation with visual cues such as questions	• 360° video group showed significantly better results in writing performance ($p=.017$) • Higher learning motivation and interest demonstrated in the 360° video group

2020), engineering (Chen et al., 2021), media management (Hebbel-Seeger et al., 2021), religion (Johnson, 2018), social work (Lanzieri et al., 2021), business (Lee et al., 2017), sports (Pagé et al., 2019), and education (Rupp et al., 2019) could be identified.

5.2 Purposes of using 360° videos as a teaching-learning medium

In summary, our analysis a total of three different purposes for 360° videos: observation and presentation of learning content in a 360° video scenario (e.g., Barnidge et al., 2022; Jong et al., 2020), immersive and interactive theory-practice teaching (e.g., Boda & Brown, 2020a, b; Ros et al., 2021), and self and peer-reflection (e.g., Johnson, 2018; Theelen et al., 2019, 2020a, b).

The all-round view makes 360° videos particularly suitable for observational learning. Most studies compare the use of different teaching–learning media such as text, conventional videos, 360° videos or VR and their impact on learning motivation and success (e.g., Chang et al., 2019; Chao et al., 2021; Hwang et al., 2022; Tak et al., 2022). Some studies found a positive impact on learning engagement and motivation (e.g., Calvert & Abadia, 2020; Chang et al., 2019; Chen et al., 2022; Lee et al., 2020; Yang et al., 2021), while other studies found no difference in learning motivation despite the use of different teaching–learning media (Chang et al., 2020; Huang et al., 2020). Similarly, no clear positive or negative effect on learning success can be identified through the use of 360° videos. For example, Dolgunsöz et al. (2018) found higher learning motivation with of 360° videos compared to traditional videos but no difference in learning success in language learning. In contrast, Yang et al. (2021) found both higher motivation and higher learning success in Chinese learning. These divergent statements on the influence on learning success and learning motivation are also based on learners' previous experiences with 360° video technology. Although 360° videos offer a panoramic view, the opportunity can also be distracting and have a negative impact on learning success, while learning motivation could be more positive due to the novelty of the technology (Hebbel-Seeger et al., 2021). In addition to pure observation, 360° videos can be provided with additional tasks which can be used both during and after observation (e.g., Barsom et al., 2020).

Three-hundred-and-sixty-degree-videos can also be used to present content in an immersive way to increase interest in science and research and motivation to learn (e.g., Boda & Brown, 2020a, b). They can be viewed on a desktop with a low immersion level or experienced with a highly immersive HMD (e.g., Barnidge et al., 2022; Han et al., 2022; Lee et al., 2017). The immersion level of the playback media influences both the immersive experience and the learner's motivation to learn. Highly immersive 360° videos seem to promote learning motivation and the immersion experience more strongly (Han et al., 2022; Lee et al., 2020; Ma, 2020). In particular, for foreign language learning, 360° videos enable immersion in foreign cultures and regions and allow students to apply language skills in real digital environments (e.g., Huang et al., 2020; Yang et al., 2021). The interaction capabilities of 360° videos beyond controlling gaze direction or solving integrated tasks were identified in one article (Vallade et al., 2021). Participants were able to interact with the 360° video

scenario in combination with HMD, using the immersion effect to learn a language and reduce the anxiety of speaking in front of a virtual audience. Participants interacted not only with the learning content, but also with the technology itself. Realistic and authentic learning scenarios may also be implemented with 360° videos to reduce prospective teachers' classroom anxiety and allow student teachers to practice teaching (Theelen et al., 2020a). Due to the multi-perspective presentation possibilities and immersion through low and high immersive playback media, learning scenarios can be designed more authentically, realistically and more immersive compared to conventional videos (e.g. Chao et al., 2021; Hwang et al., 2022; Pagé et al., 2019).

In addition to observation and interaction, 360° videos are also useful for reflection. Theelen, van den Beemt and den Brok (2019) used 360° videos to identify teaching situations of prospective teachers and found an improvement in their perceptual ability. Ferdig and Kosko (2020; Kosko et al., 2019) also showed improved perceptions of prospective teachers through reflections on classroom situations. Outside of teacher training, Pagé et al. (2019) were also able to achieve an improvement in recognizing and deciding tactical game situations in basketball with 360° videos.

5.3 Potentials of 360° videos as a teaching–learning medium

The analysis of the included articles reveals 360° videos have a high potential for illustrating theory and practice through observation or reflection, increasing motivation and interest, creating authentic and realistic learning experiences and fostering interactive and immersive learning processes. However, it is also important to point out the limitations and restrictions of 360° videos as a teaching–learning medium.

In particular, 360° videos for observing and acquiring knowledge content are especially well suited to illustrate theory and practice (Ros et al., 2021). Theory-practice linkage has been demonstrated in the studies of Boda and Brown (2020a, b) on the use of 360° videos for scientific phenomena and experiments in naturalistic settings. They can also be used to practically demonstrate single theoretical steps or theoretical procedures, e.g., for first aid (Barsom et al., 2020) or surgery (Ros et al., 2021). Reflective possibilities of 360° videos in combination with knowledge transfer in lectures can also be applied to illustrate social skills and interpersonal skills of the teacher–student relationship in a practical teacher education setting (Theelen et al., 2020b).

The studies also show the high learning motivation potential of 360° videos. Even if the suitability of 360° videos to increase learning motivation cannot be clearly demonstrated, the majority of studies do indicate higher learning motivation through its use (e.g., Chen et al., 2021; Lee et al., 2017, 2020). However, there are also some studies that found no difference in learning motivation through 360° videos (Chang et al., 2020) when compared to other learning media (Huang, Hwang & Chang, 2020). Only in medicine did Ulrich et al. (2021) find negative satisfaction and evaluation of 360° video technology as a teaching–learning medium for knowledge transfer compared to conventional physical therapist training.

The 360° video technology enable authentically perceived observation, interaction and reflection of recorded learning situations due to their all-round view.

Learning content such as in social work (Lanzieri et al., 2021), can be illustrated in a realistic learning environment using video recordings of future workplaces. Perspective changes, for example the perception of patients in medical training courses, can also be conveyed more realistically with 360° videos (Lee et al., 2020; Taubert et al., 2019).

Compared to traditional video, the individually selectable 360° panoramic view increases the viewer's sense of presence, both on the desktop and with HMD. The vast majority of studies show significantly higher sense of presence and sense of realism ratings for 360° videos compared to traditional videos (e.g., Barnidge et al., 2022; Ferdig & Kosko, 2020; Lee et al., 2020; Pagé et al., 2019; Singh et al., 2020). Compared to programmed VR, which can still evoke higher immersion due to interaction possibilities and action manipulations, the study by Vallade et al. (2021) cites the realistic representation of people in a 360° video as an important added value of immersion and the perception of realism, although no action manipulations are possible. The immersion can be used to train presentations in front of an audience, reduce speech anxiety (ibid., Chen & Hwang, 2020) or prepare teaching situations in teacher training (Theelen et al., 2020a). The degree of immersion of the playback media has a significant impact on the effect of 360° videos as a teaching-learning medium, e.g. on the motivation to learn, the realistic and authentic feeling or even the learning success. Therefore, 360° videos with different immersion levels have been used in some studies (e.g., Ferdig & Kosko, 2020; Han et al., 2022; Kosko et al., 2019; Lee, et al., 2017, Ma, 2020). Regarding the immersion effect, Rupp et al. (2019) found a positive correlation between viewer engagement with the learning material and their interest in watching 360° videos through playback media with increasing immersion levels.

However, the immersive potential of 360° videos is positively evaluated even at low levels of immersion (Calvert & Abadia, 2020; Johnson, 2018; Lanzieri et al., 2021), especially when compared to traditional videos (e.g., Ferdig & Kosko, 2020, Hwang et al., 2022) that are also viewed through the same playback medium, e.g., an HMD (Chao et al., 2021).

In addition to the analyzed potentials, however, the limitations of 360° video technology must also be considered. Besides there being no clear statements on the influence on learning success, it is also necessary to select the appropriate learning arrangement. For example, Hebbel-Seeger et al. (2021) found in their experiment that teacher-centered lecture recordings with 360° videos have no added value when compared to conventional video recordings, despite their high authenticity and realism, because the desired camera focus is mostly frontal and the possible all-round view of 360° videos is not used. Theelen et al. (2020b) were also unable to identify any added value from 360° videos for pure theory teaching. Likewise, Ulrich et al. (2021) showed that the predominantly positive motivational potential of 360° videos as a teaching–learning medium does not necessarily apply to a practice-oriented physiotherapy education. For a targeted use of 360° videos as a teaching–learning medium, it is therefore imperative that suitable didactic concepts are developed on the basis of potentials, which, depending on the subject discipline, also take into account the teaching arrangement. The degree of immersion of the playback media also plays an important role within the didactic concept in the evaluation of learning

success. For a high learning success in observation tasks, a playback medium with a high degree of immersion is basically not always necessary.

As with other media, there are technical points of conflict and potential complications with 360° video technology. In addition to visual artifact issues or distortion within the 360° graphic video display, network and signal interference with playback media, as well as physical negative effects of the technology, are also possible (Azevedo et al., 2020). Despite the potential for immersion, the effect of potential motion sickness in users must be considered, which was also rated as a negative feeling by study participants (Hebbel-Seeger et al., 2021; Johnson, 2018; Rupp et al., 2019; Ranieri et al., 2022).

6 Discussion

The included articles show that 360° videos can be used for different purposes and disciplines and have specific potentials. In addition to the potentials we have already been mentioned from the literature analysis (see Chap. 5), further opportunities of 360° videos as a teaching–learning medium can be derived from the previous state of research on traditional videos and VR (see Chap. 3). In addition to the previous reviews, the potentials of 360° video technology can be derived with both traditional video technology and VR. On the one hand, 360° videos as a specific video format taps the potential of traditional video technology; on the other hand, 360° videos can also be viewed with immersive playback media equipment such as HMD, and the potentials of VR can be tapped into. Combining the four analyzed potentials of 360° videos as a teaching–learning medium from Chap. 5 and the presented potential of traditional videos and VR from Chap. 3, a total of five categories of 360° video technology potentials in the context of education can be discussed.

6.1 Motivation and interest

In their systematic literature review, Gaudin and Chaliès (2015) attest to videos' high motivational potential due to the authentic presentation possibilities of conventional video technology. Kavanagh et al. (2017) also find high motivation potential in VR due to its immersion and interaction possibilities. Authentic presentation, immersion and interaction possibilities are all exhibited in 360° videos. Chen and Hwang (2020) report a higher motivation score when using 360° videos to reduce anxiety when speaking in front of an audience. Dolgunsöz, Yildirim and Yildirim (2018) report that viewing and summarizing a documentary in 360° video format leads to higher motivational values than traditional video technology due to greater authenticity and immersion. In contrast, Huang et al. (2020) did not find any motivational differences between traditional video technology and 360° videos in language learning, although 360° videos were rated more highly as a learning medium. However, the vast majority of studies in our analysis attest high motivational potential and higher learner interest and engagement to 360° video technology (Calvert & Abadia, 2020; Lee et al., 2020) and confirm the findings of existing research (Pirker

& Dengel, 2021; Ranieri et al., 2022; Snelson & Hsu, 2020). The influence on learning motivation can be explained not only by the actual subject interest of the learner, but also by the degree of immersion of the playback medium. A high degree of immersion obviously leads to higher learning motivation (Lee et al., 2017, Rupp et al., 2019). Since 360° videos have a higher immersion than conventional videos even with low immersive playback media, learning motivation can be increased in comparison to traditional videos (Chang et al., 2019, Chao et al., 2021, Yang et al., 2021).

6.2 Authenticity and realism

Yousef et al. (2014), Gaudin and Chaliès (2015) and Noetel et al. (2021) address the potential of realistically and authentically presenting learning content using traditional video technology. Kaplan-Rakowski and Gruber (2019) and Radianti et al. (2020) also see the strengths of VR in the realistic representation and action controls that it allows. 360° videos do not allow direct action control, but the all-round view they provide makes it possible to create and perceive film locations even more realistically (Barić et al., 2020). Boda and Brown (2020a, b) used 360° videos to present scientific experiments outside of research laboratories in familiar surroundings. According to the authors, the authentic and realistic recreation of the experiments led to a higher interest in the participants in scientific research. The possibilities of such learning experiences through 360° video recordings are also used by Lanzieri et al. (2021) for social work and by Lee et al. (2020) in the medical-therapeutic field to design digital learning situations that are as close to work as possible. Especially with HMD, 360° videos have the ability to create learning experiences that appear far more realistic than traditional videos (Lee et al., 2017; Pagé et al., 2019).

Unlike programmed VR, 360° video, like traditional video technology, captures footage of the real environment. The depiction of the real environment achieves a high sense of reality for learners (Roche et al., 2021; Vallade et al., 2021). Compared to traditional videos, 360° videos offer a more realistic presentation of learning content and, through HMDs, take advantage of VR to add even more authenticity.

6.3 Immersion and interactivity

Immersion and interaction, such as action control in VR, enable participation in the learning medium that is perceived as realistic and have positive effects on learner motivation and engagement (Kavanagh et al., 2017; Kaplan-Rakowski & Gruber, 2019; Radianti et al., 2020). To evaluate the immersion potential of 360° videos, a distinction of immersion levels is necessary. Kucher Dhimolea, Kaplan-Rakowski and Lin (2022) show in particular the effects of highly immersive applications in language learning. Particularly positive motivating effects with highly immersion playback media can also be identified

in the included studies (Chang et al., 2019; Chen & Hwang, 2020; Lee et al., 2020). Three-hundred-and-sixty-degree-videos enable multiple levels of immersion depending on whether users choose to view them on a desktop or through HMD. With HMD, the sense of presence is perceived as highly immersive (e. g. Barnidge et al., 2022; Calvert & Abadia, 2020; Ferdig & Kosko, 2020), although action control is not possible as it is in VR. The high motivation potential of perceived real participation in the VR learning medium (comparison with Chap. 3) is also present in 360° videos (Dolgunsöz et al., 2018; Rupp et al., 2019). The sense of presence and participation is evaluated to be positive (e. g. Barić et al., 2020; Johnson, 2018) and increases in combination with immersive HMD (Barnidge et al., 2022; Rupp et al., 2019).

However, it is also important to note that in addition to using different immersive output media, 360° videos typically have a lower number of DoF compared to VR which in turn also affects immersion (Huang et al., 2017). Unlike conventional videos, 360° videos nevertheless enable immersive teaching–learning experiences and use the resulting motivational effects as in VR. Although the six DoF, and thus interaction, in VR is greater than in 360° videos, which typically feature only three DoF but allow for choice of viewing direction or control of camera focus, these possibilities can also be used for discovery-based learning.

In general, the degree of immersion seems to influence the motivation to learn as well as the perception of realism and has to be taken into account in conceptual didactic considerations for the use of 360° videos as a teaching-learning medium.

6.4 Observation and reflection with multi-perspectivity

Both Gaudin and Chaliès (2015) and Yousef et al. (2014) mention the potentials of conventional video technology for reflection processes. With videos, multiple perspectives with different video footage can be viewed to reflect on actions. The 360° all-round view expands the observation possibilities (Barić et al., 2020; Ferdig & Kosko, 2020; Kosko et al., 2019; Pagé et al., 2019; Theelen et al., 2019, 2020a, b). With text panels or buttons, which can also be implemented within the 360° videos as with conventional videos, attention and visual focus can thus be directed in the 360° panoramic view and thus support the learning process (Boda & Brown 2020a, b; Tauber et al., 2022). For instance, in teacher education, 360° videos can be used to record one's own teaching units and reflect on the reaction of the learners. Likewise, subject-specific learning content can be represented, which is acquired through observation, for example.

6.5 Individuality and learning control

Both conventional video technology (Noetel et al., 2021) and VR (Jensen & Konradsen, 2018; Radianti et al., 2020) offer the possibility of adapting learning content to

individual pace and progress, for example, through the option of repeating content without a time limitation. As a specific video format, 360° videos also have individual control options and can adapt to the individual learning process especially when it comes to the repetition of educational content in a safe, authentic and realistic environment without risk. For instance, 360° videos are suitable for first aid courses (Barsom et al., 2020) or for driving lessons in driving schools (Barić et al., 2020). In addition to the individual playback options of conventional videos, the panoramic view of 360° videos also offers greater individual observation, reflection and analysis options. The 360° video technology thus enables greater individual learning processes and is not limited to a predefined camera focus within the video recording.

6.6 Limitations

While a positive effect on learning motivation and student engagement through 360° video technology has been substantiated by the analysis, there is no clear evidence for the use of 360° videos or its advantages with regard to learning success. Positive, consistent and negative effects on learning success were all found through the use of 360° videos as a teaching–learning medium. In addition, no clear statements can be made about the effect of immersive content and different degrees of immersion on learning success either.

The different study designs, learning prerequisites and learning objectives in the various disciplines, as well as different expectations and prior experience in dealing with 360° videos, also make it difficult to compare learning outcomes. A cross-disciplinary statement about the effects on learning success is therefore not possible.

For a targeted study of whether 360° videos improve learning success, didactic concepts will be needed that implement their potential in suitable learning arrangements. It is noticeable that 360° videos already used as a teaching-learning medium are less based on a specific learning theory but are rather used exploratively. It is not just a matter of trying out 360° video technology on the basis of technical enthusiasm, but rather of making good use of its possibilities and potential from a pedagogical perspective. For example, the multi-perspective viewing possibilities of 360° video technology can be used both for observational learning processes in the sense of a cognitivist learning theory or also to open up learning environments in an individual constructivist way. Three- hundred-and-sixty-degree-videos can be used for illustration and understanding of learning content or they can instruct in the context of demonstration and imitation. For a comprehensive statement on 360° videos and their influence on learning success, a differentiated consideration of the relevant didactic concepts is necessary.

It is also important to clearly define the teaching-learning objectives to be achieved. For example, 360° videos can be used to acquire content-related learning skills as well as process-related skills such as independent exploration.

Depending on the subject discipline and learning task, both highly immersive and low-immersive playback media can be used for 360° videos. For observational tasks, a highly immersive playback medium does not seem to be necessary to achieve high learning success. In order to be able to make clear statements in the future about the

potentials and effects on the learning effects of 360° videos and to compare them with other teaching-learning media, it is necessary to consider not only a clear definition and classification of 360° videos, but also the degree of immersion of the playback media and the possible DoF.

Likewise, the experience with 360° video technology as a teaching-learning medium itself and the duration of use must be taken into account in making clear statements about the learning success.

7 Conclusion

We deliberately chose to exclusively present the potentials and possible uses of 360° videos as a teaching and learning medium in order to clearly differentiate them from VR even though the research field on VR as a teaching-learning medium offers interesting approaches. Our analyzed articles show a variety of potentials of 360° videos as a teaching–learning medium. It can be used across disciplines for observational, reflective or interactive learning, to illustrate theory and practice to increase learning motivation or for immersive learning experiences.

For further discussion and research of 360° videos as a teaching–learning medium, it is also advisable to use the term clearly and distinguish it from VR. VR enables a higher degree of interaction and action manipulation, which can have an impact on learning processes. The extent to which these advantages of VR can also be compensated for by appropriate methodological-didactic concepts with 360° videos must be investigated in further studies.

As an advanced video format, 360° videos enhance the motivational potential of conventional videos and offer design options for authentic teaching–learning scenarios which can be experienced realistically. Even though 360° videos allow less interaction due to the lower DoF in contrast to VR, they still have an increased motivation potential compared to conventional video technology. A significant added value when compared to conventional video technology is the individually controllable omnidirectional view of 360° videos.

However, the results of our systematic literature review also reveal a lack of empirical engagement with 360° videos as a teaching and learning medium to date, most statements about learning success are premature. While some studies have demonstrated learning success through the use of 360° videos, these cannot be generalized or applied to other contexts. For a valuable use of 360° videos as a teaching–learning medium, methodological-didactic concepts are therefore necessary which take up the identified potentials and implement them in suitable learning arrangements on the basis of corresponding learning theories such as observational or discovery learning.

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