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Digital technology in physical education: a systematic review of research from 2009 to 2020

Introduction and theoretical background

Digital media permeates the everyday lives of children and youth. The various technologies may change, but their general interpretation follows a similar pattern with many positive attributes including educational innovations or even revolutions (Kerres, 2022). However, digital media is associated with opportunities and risks, such as insufficient physical activity or addiction (Kerres, 2022). Since these can hardly be completely avoided, they must be dealt with in a pedagogical manner. Moreover, schools are tasked with adequately preparing students for life in present and future society, which now also includes a deeply mediatized world (Couldry & Hepp, 2013). Further, school conditions can be both inhibitory and beneficial (Gerick, Eickelmann, & Labusch, 2018).

In this context, digital media and how it should be dealt with is currently a dominant topic in discourse about schools and teaching. Since it is usually not taught as a separate subject, media education must be included as part of traditional subjects, which can have some advantages, e.g., the consequent increased motivation by the addition of media of students across subjects can be seen (Engen, Giaeffer, & Mifsud, 2018). While science-oriented research, for example, tend to meet this challenge openly, in discus-

sions regarding physical education (PE), digital technology has mostly been connected to topics such as lack of exercise. Specifically, PE with its special feature as an esthetic subject in terms of physicality, plays a particular part in these discourses. In addition to the original aims such as promoting health and a physically active life or learning sports-specific skills, PE has to now also deal with media education topics (Greve, Thumel, Jastrow, Krieger, & Süßenbach, 2020). However, the varying didactic designs of PE worldwide have further complicated the handling of digital media. While only a few empirical studies on digital media in PE have been published in German-speaking countries in recent years (Greve et al., 2022)¹, there has been a diversity of research in international publications focusing on topics such as health, gamification, wearable technologies, and cooperative learning with digital media (Casey & Jones, 2011; Goodyear, Casey, & Kirk, 2014). In addition to the emphasis on possibilities and opportunities, there have also been criticisms. While acknowledging digital media as a useful tool in PE, some authors have also noted that it is problematic in this context. More specifically, van Hilvoorde and Koekoek (2018) described the omnipresence of digital technology in our society as capable of undermining

the goals of PE in many ways. However, they also listed the completely new possibilities that are a result of new technologies, such as virtual or augmented reality. These allow for new forms of games with new ways of communication, social contacts, and, above all, different and new movement behavior (van Hilvoorde, 2017). However, as some researchers have highlighted, PE teachers are often alone in class. Therefore, it is necessary to plan the use of digital media in a way that is easy to use and geared towards a goal (van Rossum & Morley, 2018). In particular, user behavior (e.g., obstacles when filming bodies and movement and private text messaging) when using personal mobile devices may upset previously accustomed classroom activities (Steinberg, Zühlke, Bindel, & Jenett, 2020). In this context, Casey, Goodyear, and Armour (2017) argued that there is a considerable gap in relation to the connection between digital technology and pedagogy. Pedagogy in this case is considered the connection among ‘learners and their learning’, ‘teachers and their teaching’, and ‘knowledge in context’ (Quennerstedt, Gibbs, Almqvist, Nilsson, & Winther, 2016). These areas can also be found in a similar way in German-language sport pedagogy. On the one hand, the curricula and educational plans provide educational goals and content, while on the other, the student as an individual subject should (and

¹ The article was published online in 2020 and is therefore included in the review.

Table 1 Databases and search hits for main search					
Database	BISp-surf	FIS	ERIC	PubPsych	Web of Service
Search hits	413	898	924	312	1163
Total	3710				
After removing the doubles	3355				

Table 2 Databases and search hits for the follow-up search					
Database	BISp-surf	FIS	ERIC	PubPsych	Web of Service
Search hits	140	48	111	39	438

can) only form itself and is in focus. This means that while a teacher can design the learning environment and thus prepare and support the learning process, the completion of the learning process, is dependent on the student acting accordingly as a self-forming individual subject (Gröben & Prohl, 2012; Prohl, 2006). Furthermore, there have also been similar discourses internationally. For example, Kirk (2012) argued that learning should be approached in the physical, cognitive, social and affective domains in a coherent manner so that a physically active life can be promoted. In addition, he identified the aforementioned domains as the legitimate learning outcomes of PE, and thus these will be used as categories when reviewing studies in this paper.

Due to the topicality of this issue and the multitude of aspects described regarding the use of digital media in PE as well as the media pedagogic goals in schools, empirical education research is inevitably faced with the question of which goals regarding the use of digital media in PE can be identified. This is where this review makes its contribution by compiling findings on the possibilities and limitations.

Methods

The aim of this systematic literature review (Davies, 2000; Petticrew & Roberts, 2012) is to examine the material pertaining to a particular area (Shulruf, 2010), while the focus is on the examination of potential methodological biases from the perspective of the researchers (Shulruf, 2010). To undertake a systematic literature review of empirical studies on the use of digital media in PE, Shulruf's (2010) five methodological steps were applied

for data collection and analysis. Specifically, the first four steps were used as criteria for the inclusion or exclusion of a study, while the last step was used to analyze the selected studies. This approach recognizes the existing research and aims to synthesize the results while simultaneously recognizing and considering the researchers' biases (Barr, Hammick, Koppel, & Reeves, 1999; Boaz, Ashby, & Young, 2002). Here, it should be noted that the focus of a systematic literature review should be on a specific question, which is as follows for this study: Which goals are pursued by empirical studies regarding the use of digital media in PE? To answer this question, it was subdivided into three research questions:

- Which media usage is empirically verified?
- To what extent has the intended goal been empirically achieved?
- What barriers to the use of digital media can be derived from the research?

Moreover, the basis of this study is an examination of specialist journals, edited volumes, and dissertations that deal with the use of digital media in PE specifically. Overall, the literature reviewed in this article includes empirical studies from 2009–2020 that cover primary, secondary, and special-needs schools.

Research

To identify as much relevant literature as possible (Shulruf, 2010), we searched the ERIC, FIS, Web of Science, and PubPsych databases as well as the BISp research system using the following terms: regarding digital media and technologies, we used the terms 'mobile',

'digital', 'smartphone', 'handy', 'tablet', 'iPad', 'android', 'software', 'notebook', 'laptop', 'computer', 'handheld', 'gaming', 'exergames', 'video', 'technolog*', 'media', 'medien', 'virtual', and 'augmented'. However, for the PubPsych database, we had to separate the search term after 'video' and divide the search into two parts because the input field in the database was not large enough to search for all the terms at once. Meanwhile, for PE, we used the terms 'physical education' and 'Sportunterricht' to avoid hits from other sport settings. The last search run in the main search took place on June 30, 2020.

■ **Table 1** shows the total number of articles found using the aforementioned process in the first search run in all databases. In the second step, duplicates were removed using the reference management program Citavi.

Selection of studies

The decision to include or exclude studies was made on the basis of methodological criteria (Shulruf, 2010). The abstracts of the articles found were reviewed according to the following criteria and, if found suitable, selected for further processing:

- Empirical studies dealing with the topic of digital media and technologies in PE were included.
- Studies in which the research subjects were actors in PE were included.
- Studies in which the methodical procedure of the study was clearly and comprehensibly described were included.
- Approaches and concepts for practical implementation and studies dealing with the development of measuring instruments were excluded.
- Studies published in journals and edited volumes as well as dissertations were included. However, abstract volumes were excluded due to their low information content.
- Predatory journals were excluded.
- Articles written in German or English were included.

The 3355 titles and abstracts from the research in the databases were screened

using Abstrackr software to verify that they met the inclusion and exclusion criteria (Newman & Gough, 2019). This step was independently undertaken by five researchers, with each title randomly assigned and screened twice by two different people. The resulting conflicts were reconsidered and finally assessed by a third person. After this assessment, 135 titles remained.

Each of these 135 studies was read to confirm or reject its inclusion in the review by assessing all of the aforementioned criteria. Afterwards, the studies were coded to facilitate the task of analysis by sifting through relevant material (Potter, 2009). The texts were given preliminary notes about their nature, research focus, and results, allowing us to filter all (or a subset of) data on a particular topic (Lee & Fielding, 2009). Next, we compared the individual codes and contents of the table and either combined and classified them into subcategories or discarded them. In order to avoid biases and increase the reliability of the results, all important decisions were jointly made by the research team (Kitchenham, 2004). Following this procedure, we first included 71 studies in the review. Next, in a second, methodologically identical search in August 2021, studies from July 1, 2020 to December 31, 2020 were added (■ Fig. 1). Due to the limited search options in some databases, the search was conducted for the entirety of 2020. ■ Table 2 shows the search hits from each database.

The hits were again sorted according to the above criteria after reading the titles and abstracts. In the end, 79 studies remained and were subjected to a full-text analysis. The full-text analysis and sorting of studies from the first half of 2020 resulted in seven remaining studies, which were integrated into the review. Thus, a total of 78 studies were finally included.

Risk of bias

Relevant information was extracted from the publications and presented descriptively (Bem, 1995; Döring & Bortz, 2016). Here, the risk of bias was not an exclusion criterion, as this would have resulted in

a significant reduction in the number of eligible studies. In addition, with such an exclusion, we would have had to abandon the goal of providing an overview of research on digital media in PE. To ensure the quality of the eligible studies, the authors independently checked compliance with the inclusion and exclusion criteria for the individual studies.

Results

As not all studies could be described fully in this article, the important information from the studies is summarized in ■ Table 3. The studies identified for the systematic review examined the goals and effects of digital media in PE and were designed very differently. To this end, they examined both teachers and students. The number of people surveyed ranged from 2 to 1421, which also shows the considerable heterogeneity in the study designs. The types of schools examined were elementary, secondary, and special-needs. More specifically, primary schools are described in this context up to grade 6 and secondary schools as grade 7 and above. Moreover, the studies were assigned to different categories: (1) physical, (2) cognitive, (3) social, (4) affective, and (5) school conditions. The aforementioned categories were derived from the key learning outcomes of pupils according to Kirk (2012) and supplemented by those of school conditions (Gerick et al., 2018). The subcategories were inductively derived from the studies, in which different types of media and digital artefacts were used for PE. These revealed various possibilities and limitations, depending on the subject of investigation, and are explained in the following section in order to focus on the result categories.

Digital videography was addressed in 18 of the studies. One usage type was a form of *video self-modelling* (Casey & Jones, 2011; O'Loughlin et al., 2013), which Dowrick (2012) described as 'a form of observational learning with the distinction that the observed and the observer, object, and subject, are the same person.' This allows for a form of teacher-independent video feedback, which Kok et al. (2020) examined in comparison to that which was dependent. In addition

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Digital technology in physical education: a systematic review of research from 2009 to 2020

Abstract

Digital media is currently one of the defining topics in discussions about schools and teaching. In this context, there has been a wide range of research in physical education (PE) in areas such as health, gamification, and wearable technologies. This raises the question of the goals pursued by empirical studies regarding the use of digital media in PE. The present systematic review provides an overview of the state of research in English and German on the use of digital media in PE. To this end, the included studies were those published between 2009 and 2020 in journals or edited volumes or as dissertations. They were found in relevant databases, selected based on criterion-guided screening, and transferred to the synthesis. Overall, this systematic review presents the possibilities and limitations of digital media in PE and highlights the goals regarding the use of digital media in PE that are pursued by empirical studies in the categories of *physical, cognitive, social, affective, and school framework conditions*. While benefits from the usage of digital media in PE—such as in terms of motivation or improving sport-specific motor capabilities and skills—were identified, barriers regarding the preparation of PE teachers were also found. More specifically, the benefits of using digital media to achieve PE-related goals were in the foreground in many of the selected studies. However, only a few specifically addressed learning via media, including topics such as data protection and the effect that viewing images has on students' self-concepts.

Keywords

Physical education · Systematic literature review · Digital media · Technology · Pedagogy · Media education

tion to providing feedback, it can also serve as an option for assessment or assessment support (Casey & Jones, 2011; O'Loughlin et al., 2013; Weir & Connor, 2009). Furthermore, another aspect when dealing with digital videography

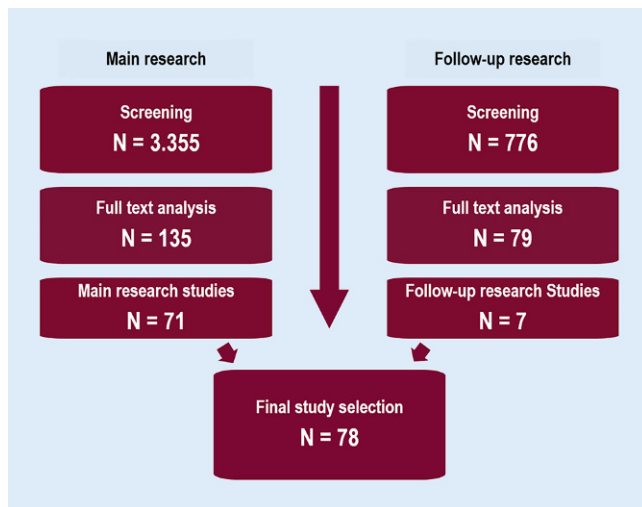


Fig. 1 Selection process

is the improvement of motor or cognitive performance, which has been investigated in many studies, as described below in the results.

Meanwhile, the use of exergames in PE was investigated in 25 studies. In those classrooms, the Nintendo Wii (Nintendo K.K., Kyōto, Japan) or X-Box Kinect (Microsoft Corporation, Redmond, WA, USA) were used with various sport games, such as Wii Sports and Kinect Ultimate Sports or other similar games. A large number of the studies focused on the *Dance Dance Revolution* or other dance-based games (Andrade et al., 2019; Burges Watson et al., 2016; Chen & Sun, 2017; Fogel et al., 2010; Gao et al., 2017; Gibbs et al., 2017; Lwin & Malik, 2012; Quintas et al., 2020; Reynolds et al., 2018; Rincker & Misner, 2017; Sun, 2012; Ye et al., 2018). Thus, studies on using exergames in PE mainly focused on increasing physical activity or involving students in the classroom (Casey & Jones, 2011; Goodyear et al., 2014) while maintaining motivation and joy. Furthermore, heart rate monitors and pedometers were another tool widely used in the studies. They were used to record fitness-specific data and frequently in addition to exergames to record physical activity (Gao et al., 2017; Lee & Gao, 2020; Ye et al., 2018).

In addition to the options just mentioned, there were numerous apps that were used for applied research in the classroom, such as those in fitness for recording data (Cheng & Chen, 2018),

those for video evaluations and tagging movements or game situations such as Coach's Eye (Koekoek et al., 2019; Kok et al., 2020), and those for creating media products (Greve et al., 2022; Steinberg et al., 2020). In addition, two studies worked with wikis to enable students to also collaboratively learn outside the sport hall (André & Hastie, 2018; Hastie et al., 2010), thus, opening up the boundaries of PE.

Physical

The studies from the first category examined the relationship between the use of digital media in PE and physical activity as well as the effects on motor skills or the fitness of students. We identified 30 studies that could be categorized under this topic, which are further described below.

Physical activity

Seventeen studies examined the relationship between physical activity and digital media. Twelve studies were conducted in primary schools (Fogel et al., 2010; Gao et al., 2017; Hansen & Sanders, 2010; Lee, 2018; Lee & Gao, 2020; Reynolds et al., 2018; Shewmake et al., 2015; Sun, 2012, 2013; Wadsworth et al., 2014) and six in secondary schools (Huang & Gao, 2013; Lonsdale et al., 2017; Lwin & Malik, 2012; Nation-Grainger, 2017; Zhu

& Dragon, 2016)². Three studies examined this relationship qualitatively via interviews or field notes (Engen et al., 2018; Hansen & Sanders, 2010; Sargent & Casey, 2019), while 13 examined physical activity quantitatively with, for example, the help of heart rate monitors, step counters, or questionnaires (Zhu & Dragon, 2016; Sun, 2012, 2013; Lee & Gao, 2020; Lwin & Malik, 2012; Lonsdale et al., 2017; Wadsworth et al., 2014; Fogel et al., 2010; Gao et al., 2017; Shewmake et al., 2015; Huang & Gao, 2013; Lee, 2018; Reynolds et al., 2018). Finally, one study was based on a mixed-methods design (Nation-Grainger, 2017).

In addition to the highly heterogeneous research methods, a variety of results and a mixed picture between possibilities and limitations emerged. In the following section, studies involving low physical activity are presented first. Specifically, various studies examined the effects of the use of mobile apps on physical activity in primary school PE and found that it was not effective in improving physical activity and psychosocial beliefs in elementary school children in the short term (Lee, 2018; Reynolds et al., 2018). In some studies, sedentary behavior increased when using digital media and light exercise behavior decreased (Gao et al., 2017; Lee, 2018; Lee & Gao, 2020). In contrast, light physical activity increased in comparison classes without digital media (Lee & Gao, 2020). Unlike light movement, intensive movement increased in these studies (Gao et al., 2017; Lee, 2018). In this context, Zhu and Dragon (2016) showed that there was only a small influence on the increase in physical activity. Further, Huang and Gao (2013) were also unable to detect any increase in physical activity when using an exer-dance game.

Meanwhile, Wadsworth et al. (2014) found that the group playing adapted tennis without digital media took a significantly higher number of steps as compared to those in an exergame. According to the self-assessment of primary school students, they liked the lessons with ex-

² Because of studies that took place in both elementary and secondary schools, there may have been double counting.

ergames better but also felt that they were moving less than usual (Shewmake et al., 2015). Additionally, Sun (2012) showed that an exergaming unit in a primary school did not meet the criteria for moderate physical activity unlike the fitness unit that was used as a comparison.

In contrast, a follow-up study in a secondary school, in which exergaming was compared to traditional PE classes, found that the children exercised more during the exergaming unit (Sun, 2013). Some studies have confirmed this possibility and recorded an increase in light to heavy physical activity (Fogel et al., 2010; Gao et al., 2017; Lonsdale et al., 2017; Lwin & Malik, 2012). Further, the results of the qualitative study by Hansen and Sanders (2010) showed that active play in PE can be used to increase the physical activity levels of children. The students who actively played during PE class demonstrated a determination to play and a voluntary desire to engage in and persist with technology-enhanced physical activity. The case study by Sargent and Casey (2019) showed that from the teachers' perspective, flipped learning (FL) in conjunction with digital media optimized teaching time and allowed for more activity.

Finally, when comparing the studies that took place in primary schools with those from secondary schools, slight tendencies became apparent. The former generally found that physical activity could not be improved or was even negatively influenced, while the latter mostly showed a positive development in physical activity. However, the number of studies was too small to allow for conclusions to be drawn.

Improvement of sport-specific motor capabilities and skills

Ten studies described the relationship between the use of digital media and the improvement of motor capabilities. Two were conducted in primary schools (Rincker & Misner, 2017; Sheehan & Katz, 2012) and eight in secondary schools (Chang et al., 2020; Kok et al., 2020; Kretschmann, 2017; Nowels & Hewit, 2018; Palao et al., 2015; Potdevin et al., 2018; Rekik et al., 2019; Sohns-meyer, 2011). Six studies examined the

improvement of motor capabilities and skills quantitatively, and four were based on a mixed-methods design. However, qualitative studies on this topic were not found.

More specifically, two of these studies described no difference between the test and comparison groups, and therefore found no significant improvement or deterioration in motor capabilities and skills through the use of digital media (Kok et al., 2020; Rincker & Misner, 2017). However, another study showed that the group that used exergames in PE achieved just as significant an improvement in terms of the capability of balancing as the group that used a specific fitness program, while the control group did not achieve this in normal PE (Sheehan & Katz, 2012). Meanwhile, in secondary schools, an improvement in specific capabilities could also be demonstrated through the use of exergames. In three studies, Sohns-meyer (2011) showed that dealing with high-movement table tennis increased game-specific responsiveness.

In addition to exergaming, we found several studies that focused on the help of video feedback. A quantitative study found a significant improvement in motor skills when a gymnastics exercise was learned with the help of video feedback (Potdevin et al., 2018). Nowels and Hewit (2018) were also able to show improvement in the learning of motor skills through video feedback combined with verbal feedback. Further, Palao et al. (2015) used a mixed-methods design to compare teachers' verbal feedback, video and teacher feedback, and video and student feedback. They found that video and teacher feedback delivers the most positive overall results and significant improvements in motor skills. Rekik et al. (2019) examined the effects of different teaching media (videos and images) for basketball. Learning with dynamic videos provided more of an improvement in game performance as compared to that with normal images. Chang et al. (2020) took this further by examining the difference between video feedback with normal videos and augmented reality. First, the two groups' running were rated by teachers. Here, the experimen-

tal group received significantly better ratings for their running style. Overall, the aforementioned studies confirm that using digital media in PE results in an improvement in motoric capabilities and skills.

Physical condition

Six studies examined physical fitness and how it has changed through the use of digital media in PE, with the aim of improving body-related performance parameters. Four of these studies were carried out in primary schools (Bendiksen et al., 2014; Chen & Sun, 2017; Cheng & Chen, 2018; Nation-Grainger, 2017; Rincker & Misner, 2017; Ye et al., 2018). Except for Bendiksen et al. (2014), all studies in this subcategory indicated the possibility of increasing the fitness of students with the help of digital media. Specifically, in an intervention study, Ye et al. (2018) showed that PE classes combined with exergaming had a positive effect on students' BMI and fitness. Further, in their comparative study, Cheng and Chen (2018) also showed that the traditional PE classes that recorded fitness data with the help of apps led to a greater increase in fitness values than those without apps. Chen and Sun (2017) demonstrated that a 6-week program of active videogames was an effective strategy to improve children's cardiorespiratory fitness while maintaining the joy of PE. Finally, using a 6-week intervention study at a secondary school, Nation-Grainger (2017) was able to show that the use of heart rate monitors on the wrists of those in the test group and the resultant individual feedback increased both calories burned and distance run.

In sum, all studies that examined the association between the use of digital media and physical fitness of students showed positive results. However, it should be noted that digital media should not be used to acquire physical fitness without considering and addressing the related data protection issues. Thus, its use for this purpose should be well planned.

Cognitive

Twelve studies examined students' increase in knowledge when dealing with digital media. In other words, their main focus was learning with and through media. The objectives in these studies were to increase knowledge of health issues as well as tactics and play and take care of obesity issues. However, a few studies included learning about media using topics such as data security. Four studies were conducted in elementary schools (Lindberg et al., 2016; O'Loughlin et al., 2013; Quintas et al., 2020) and nine studies in secondary schools (Casey & Jones, 2011; Chen et al., 2016; Gibbs et al., 2017; Jarraya et al., 2019; Østerlie & Mehus, 2020; Palao et al., 2015; Rekik et al., 2019; Weir & Connor, 2009).

In some studies, digital media was used to counteract obesity either by creating motivating movement possibilities for students or by imparting knowledge about health-related aspects. Specifically, in terms of conveying health aspects, digital media played a major role. Chen et al. (2016) showed that a test group with digital step counters on their wrists, which supported learning, understood more about energy balance (the balance between calories consumed and burned) than the comparison group. Here, the step counters allowed for a more precise determination of the calories being burned. Meanwhile, the study by Østerlie and Mehus (2020) showed that the use of FL, consisting of an online video and a separate plan for the lesson, led to more cognitive learning, which in turn led to students having higher levels of health-related fitness knowledge (HRFK).

Besides health issues, some studies have dealt with knowledge of tactics and play. Specifically, Quintas et al. (2020) showed the positive effects of exergaming on basic psychological needs, some flow dimensions, and academic performance. Further, Sohnsmeier (2011) used three studies on a high-movement table tennis game to show that both game-specific responsiveness and action knowledge could be improved.

Moreover, the use of video feedback led to improved articulation and a deeper understanding of throwing and catching

skills (Casey & Jones, 2011). Palao et al. (2015) also showed that video feedback in connection with that from teachers provided a greater increase in knowledge than teacher feedback on its own. Thus, video feedback resulted in a significant improvement in terms of knowledge gained.

Video examples play an important role in acquiring game- or sport-related knowledge, as learning with dynamic videos has been shown to outperform that with static photos in terms of both game understanding and performance (Rekik et al., 2019). The results further indicate less cognitive stress and an improved attitude towards working with videos instead of photos. When using video examples, Jarraya et al. (2019) examined, among other things, the connection between the playback speed of the videos and learning efficiency. There were no significant differences between low- and normal-speed presentation when the complexity of the content was low. However, for content with medium and high complexity, learning with a slow presentation speed was more efficient than that with a normal presentation speed (Jarraya et al., 2019).

In addition to learning with media, a few studies have also addressed learning about media (Greve et al., 2022), and their focus was mainly on learning about the medium being used (Maivorsdotter & Quennerstedt, 2019; Marttinen et al., 2019; Weir & Connor, 2009). While Weir and Connor (2009) mainly perceived the advantages of digital media in subject-related learning with media when using video feedback in secondary schools, they also showed that students felt more confident in dealing with digital media after using video feedback. In addition, some studies went beyond discussing the direct use of the medium but also explored media educational content, such as film language or cinematic means (Goodyear et al., 2014; Greve et al., 2022).

Further, we also identified studies that showed various ways of expanding or influencing the teaching-learning process. Specifically, the forms of cooperative learning in PE expanded through the use of digital media and could be positively influenced (Ma et al., 2018).

Wikis, for instance, offered the possibility of maintaining cooperation in extended practice groups and independently of PE classes (Hastie et al., 2010). In addition, new roles (Goodyear et al., 2014; Greve et al., 2022) gave rise to new forms of consultation and cooperation during PE classes, which succeeded in improving student engagement. For example, some students only participated if the task related to social interaction (Goodyear et al., 2014) or were only ready to work with their peers due to the digital medium (Finco et al., 2015). However, the number of such studies was too small and addressed different topics and thus did not allow for the comparison or drawing of conclusions.

Social

Eleven studies described the use of digital media as a good way to enable students to participate in PE, encourage students who would otherwise not take part to do so, and make PE and its content more attractive for students. Five studies took a quantitative approach (Asogwa et al., 2020; Fernández Basadre et al., 2015; Fernández-Batanero et al., 2019; Fogel et al., 2010; Trabelsi et al., 2020), while the remaining used qualitative (Burgess Watson et al., 2016; Engen et al., 2018; Finco et al., 2015; Goodyear et al., 2014; Greve et al., 2022) or mixed methods (Casey & Jones, 2011). For instance, Casey and Jones (2011) described how marginalized students benefited the most from video feedback because it made them feel involved, while Asogwa et al. (2020) showed that the use of digital media could increase the engagement of hearing-impaired students. Meanwhile, the results of two other studies suggested that new roles, such as being the cameraperson, were crucial for student engagement (Goodyear et al., 2014; Greve et al., 2022). For example, some girls only participated fully in class if the learning content remained within the social and cognitive dimension; in other words, if they could hide behind the camera and did not have to physically participate (Goodyear et al., 2014). Furthermore, Trabelsi et al. (2020) also found an improvement in engagement among female students. Fogel

Table 3 Further Information on included studies

Authors (year)	Aim of the study	Type of school	Country	Sample	Study design	Central results
O'Loughlin, Chroinin, and O'Grady (2013)	To investigate children's perspectives and experiences through the use of videos in primary school PE. The effects on motivation, feedback, self-assessment, and learning were investigated	Primary school	Ireland	22 students (12 male, 10 female) + teacher	Qualitative	Children valued the learning process with digital videos and claimed to have improved in all skills. Self-assessment and self-regulative learning increased motivation and supported learning and led to their improved performance. In addition, the self-assessment process through video feedback was perceived as valid and authentic by the pupils
Casey and Jones (2011)	To evaluate the effectiveness of video technology in promoting student engagement in PE to enable a deeper understanding of throwing and catching	Secondary school	Australia	27 pupils (8 male, 16 female) + teacher	Mixed-methods	Students developed a deeper understanding and improved articulation about throwing and catching skills. There was also an improvement in the quality of the learning environment. Marginalized students benefited the most from the use of digital media as they felt included, and thus their motivation increased. The desire to 'look good' (body image) in the videos is also evident
Fernández-Batanero, Sañudo, Montenegro-Rueda, and García-Martínez (2019)	To determine the level of technological knowledge of PE teachers in terms of students with disabilities	Primary school	Spain	341 teachers (208 male, 133 female)	Quantitative	Teachers saw information and communication technology (ICT) as a useful resource to support learning for people with disabilities but felt that specific training is necessary. Female teachers saw themselves as better prepared than their male colleagues. Young teachers also felt better prepared than older teachers. Knowledge deficits in this area were independent of the special educational needs that the teacher was addressing
Baek, Jones, Bulger, and Taliaferro (2018)	To investigate the perceptions and perceived added value of integrating technology into the PE curriculum of PE teachers in three phases of education (physical education of teacher education [PETE], in-service training and graduate education)	Primary and secondary school	USA	Teachers and PETEs (18 male, 1 female)	Qualitative	Teachers did not use much technology in PE and attributed this to the fact that they did not experience digital media in their lessons as students (K–12). Furthermore, they considered digital media to be a hindrance to physical activity. It is thus important that they experience best practice examples for the integration of digital media in PE, see them in action, and learn about them in training and further education
Weir and Connor (2009)	To assess how digital video could be used in a practical context in PE and to establish parameters for its optimal use	Secondary school	Ireland	453 pupils (203 male, 250 female) of whom 31 completed questionnaires + 12 teachers	Mixed-methods	Digital video was seen as a useful tool for learning and maintaining engagement. Students reported feeling more confident in using such videos after the project. Teachers saw the greatest benefit of digital media in student learning
Legrain, Gillet, Gemigon, and Laffreniere (2015)	To test a model that investigates how ICT is integrated into PE lessons and students' perceptions of teachers' support of students' autonomy can directly and indirectly influence students' cognitive abilities and performance in gymnastics by teaching the satisfaction of basic psychological needs and self-determined motivation	Secondary school	France	96 students (44 male, 52 female)	Quantitative	The more the students' basic psychological needs were satisfied, the more their motivation for PE was self-determined. ICT integrated into PE was positively associated with posttest need satisfaction. For students aged 12–13, an ICT environment led to higher psychological need satisfaction, especially when they perceived that the learning process during PE lessons was carried out by a teacher who was perceived as supportive of autonomy. Self-determined motivation positively predicted students' cognitive abilities and gymnastics performance. Thus, ICT was beneficial for teaching knowledge about dynamic movements
Gibbone, Rukavina, and Silverman (2010)	To explore the attitudes and practices of secondary school PE teachers in relation to the integration of technology and the relationships between attitudes and practice	Secondary school	USA	616 teachers (344 female, 266 male)	Quantitative	The results indicate that teachers had positive attitudes but limited use of technology. They reported a number of barriers affecting technology use, including budget, class size, and training. All attitudinal factors correlated with technology use. PE teachers may be more willing to use technology for instruction if they have the opportunity to prepare, practice, and use appropriate resources

Table 3 (Continued)

Authors (year)	Aim of the study	Type of school	Country	Sample	Study design	Central results
Zhu and Dragon (2016)	To investigate the impact of mobile technology integration on students' situational interest and fluctuation of physical activity in PE classes	Secondary school	USA	53 pupils (38 female, 15 male)	Quantitative	The students in the experimental group reported significantly lower physical activity and situational interest than those in the comparison group. Some results suggested that the steps/minutes increased steadily during the lessons in the experimental group, while it remained relatively stable in the comparison group. Mobile technologies, such as the iPad and applications without direct movement prompts, had little short-term impact on increasing physical activity or situational interest
Sun (2012)	To investigate the impact of exergames on physical activity in the classroom and motivation in PE	Primary school	USA	74 pupils (34 male, 40 female)	Quantitative	The fitness unit achieved the criteria for moderate physical activity with a positive impact on health. However, the exergaming unit did not meet the criteria in this context. Nevertheless, at the beginning of the unit, the students experienced a significantly higher situational interest in the exergaming than fitness unit. Even at the end, the students still experienced a higher situational interest in the exergames in three of the five dimensions (attention, challenge, exploration, enjoyment, and novelty). Over the course of time, the perception of the situational interest of the students decreased in all measured dimensions, with the exception of attention. With regard to the lesson unit, the students in the fitness lesson always rated all dimensions of situational interest lower than those in the exergame unit
Gibbs, Quennerstedt, and Larsson (2017)	To explore the different ways in which a dance exergame can be used to teach dance in upper secondary PE. Special attention was paid to the learning processes in which students were involved when the dance game was used as a teaching tool	Secondary school	Sweden	25 students (13 male, 12 female)	Qualitative	The study demonstrated three different uses of a dance exergame: instructor, facilitator, and inspirer. In relation to these uses, the students were involved in the following learning processes: learning by imitating, repeating, communicating, negotiating, instructing, modelling, and using metaphors. The authors argued that dance exergames can be pedagogically used to teach dance because they focus on movements and steps and allow the teacher to focus on observing, supporting, assigning tasks, and giving feedback
Hastie, Casey, and Tarter (2010)	To investigate the inclusion of wiki technology in PE	Secondary school	England	28 students, their PE teacher, and the school librarian	Quantitative	Interviews with the teacher, librarian, and students revealed that the '24/7 classroom' facilitated by ICT, along with an 'extended community of practice', resulted in a higher quality learning experience in PE for the participants. In fact, all participants were convinced that the quality of the developed games would not have been possible without the ICT component
André and Hastie (2018)	To compare how two different teaching approaches affect the students and their teacher	Secondary school	USA	82 pupils (34 male, 48 female)	Qualitative	The ICT teaching approach was considered a more difficult teaching methodology that required more experience with student-designed games, constructivism, and ICT. Here, more equity was provided among students
Lee and Gao (2020)	To investigate the short-term effects of app integration on students' physical activity and psychosocial beliefs	Primary school	USA	157 students	Quantitative	In the classes with apps, physical activity decreased. However, this tendency also existed in the comparison group. More sedentary activities were observed as well as a decrease in moderate-to-vigorous physical activity. There was an increase in light physical activity in the comparison classes without apps, while there was a decrease in the class with apps. Self-efficacy, social support, and enjoyment increased in the children who participated in the app-integrated PE, although not significantly. In the comparison group, self-efficacy, outcome expectancy, and social support also increased, but again, it was not significant

Table 3 (Continued)

Authors (year)	Aim of the study	Type of school	Country	Sample	Study design	Central results
Lindberg, Seo, and Laine (2016)	To focus on the effectiveness of <i>Running Orthello 2</i> (RO2) as a learning tool as well as its effect as a training tool and the question of how appealing the tool is to the students. The students' perceptions of the game functions and difficulties encountered were also investigated	Primary school	South Korea	61 pupils and the teacher	Mixed-methods	In learning, the playgroup was slightly better than the control group. The game group moved well and was very motivated to do so. However, there were a few technical problems, which could be solved by restarting the game. Overall, it was shown that RO2, by combining physical activity with cognitive content learning, had potential for PE. The authors suggested extending traditional PE with the exergame approach using wearable technological devices
Lwin and Malik (2012)	To investigate the effectiveness and influence of the inclusion of exergames in PE on social cognitive factors and physical activity in children and adolescents	Primary and secondary school	Singapore	506 fifth graders and 606 seventh graders	Quantitative	Exergames significantly influenced the students' attitudes towards physical activity, subjective norms, intentions, and strenuous exercise behavior. Participants in Wii-integrated PE were likelier to have positive attitudes and behaviors. Age significantly influenced the results, with the effect that exergames influenced the younger children more than adolescents. This was true for the areas of attitude and moderate and mild exercise. The authors concluded that the inclusion of exergames in PE classes may be more effective in promoting attitudes and behaviors towards physical activity than regular PE classes, especially for younger children
Lonsdale, Lester, Katherine, White, and Lubans (2017)	To test the effectiveness of a learning intervention (AMPED) for teachers to maximize opportunities for students to be active during PE lessons and increase young people's motivation for PE and sport	Secondary school	Australia	1421 students from 14 schools and the 60 associated sport teachers	Quantitative	AMPED slightly improved moderate to vigorous physical activity (MVPA) and is better when compared to previous face-to-face-only interventions. Online teacher training could help facilitate the widespread dissemination of professional learning interventions
Sun (2013)	To examine the added value of exergames in PE in the face of obesity and its control	Primary school	USA	70 students (30 male, 40 female)	Quantitative	The children moved more in exergaming than traditional PE. However, interest in exergaming decreases over time
Marttinen, Daum, Fredrick, Santiago, and Silverman (2019)	To investigate students' experiences with the Fitness Integrated with Technology (F.I.T.) unit and perceptions of the use of technology in PE	Primary and secondary school	USA	13 students	Qualitative	The use of technology was a motivating factor for some students to increase physical activity, and the use of accelerometers was a welcome addition for students. However, some students expressed concerns about the integration of technology, such as the bulkiness of tracking bracelets, not being able to wear them at sporting events, the novelty effect and the lack of access to technology at home, all of which limited their interaction with their tracking bracelets
Potdevin et al. (2018)	To investigate the effects of using video feedback on the acquisition of motor skills, self-assessment skills, and motivation in PE for beginners learning a gymnastics exercise	Secondary school	France	18 students in the group with video feedback (10 female, 8 male) and 25 students in the control group without video feedback (12 female, 13 male)	Quantitative	The study showed a significant improvement in motor skills between the fifth and all other lessons in the group with video feedback. Self-assessment also improved significantly in the group with video feedback between the first and second lessons and the fourth and fifth lessons. Demotivation decreased significantly in the group with video feedback between the first and fifth hours

Table 3 (Continued)

Authors (year)	Aim of the study	Type of school	Country	Sample	Study design	Central results
Nowels and Hewit (2018)	To examine the use of video feedback and whether it supports motor learning in the context of gymnastics exercises	Secondary school	USA	11 students in the control group without video feedback and 11 students with video feedback	Quantitative	Video feedback combined with verbal feedback improved students' learning, especially when practicing motor skills. Students with video feedback were able to assess themselves better
Burges Watson, Adams, Azevedo, and Haighton (2016)	To investigate the implementation of the dance mat system and provide insights into its acceptability as a physical activity intervention	Secondary school	Great Britain	20 teachers and 120 students	Qualitative	The use of dance mats in some scenarios ensured the inclusion of students who were otherwise difficult to reach. For the original purpose of increasing physical activity, they were used less frequently
Palao, Hastie, Cruz, and Ortega (2015)	To evaluate the effectiveness of the use of video feedback on students' learning in PE, while also investigating teachers' responses to the innovation	Secondary school	Spain	54 students and 1 teacher with 18 years of professional experience	Mixed-methods	The 'video and teacher feedback' condition provided the most overall positive results, with statistically significant improvements in skill performance, technique, and knowledge learning as well as the highest level of practice. Nonetheless, while acknowledging the usefulness of video feedback as a teaching tool, the teacher felt overwhelmed by the demands of the technology, both in terms of his time commitments and his own technological competencies
Chang, Zhang, Huang, Liu, and Sung (2020)	To investigate the effects of augmented reality on motor learning, knowledge about movements, and learning motivation in relation to the subject of running	Secondary school	Taiwan	25 (experimental group) and 27 (control group) pupils	Mixed-methods	In the text about the motor characteristics of running (pre-post), both groups showed no significant differences. In the running itself, both groups were evaluated by teachers, with the experimental group receiving significantly better ratings regarding running style. The same applied to the values regarding learning motivation. Finally, interviews were conducted with the students, which indicated that they rated the experiment as difficult
Koekoek, van der Kamp, Wallinga, and van Hilvoorde (2019)	To investigate the influence of the 'debate of ideas' on the students in terms of the perceived learning effect and agreement in the assessment of tactical situations	Secondary school	Netherlands	20 students (10 female, 10 male), 10 students each in the experimental and control groups	Mixed-methods	Both groups had only a low level of agreement in their evaluation of the tactical decisions of their classmates. This shows that the students perceive the discussed situations differently. Both groups showed little accuracy in their assessment of whether or not a shot at the basket was appropriate for the game situation or not. Moreover, there were no differences between the groups. However, the students with video feedback had a better common understanding of their perceived learning progress compared to the control group, who reflected on the game situations without video material
Kok, Komen, van Capelleveen, and van der Kamp (2020)	To investigate the effects of self-controlled (SC) video feedback (VF) on motor learning and self-efficacy of students in PE (when students receive feedback independently of the SC). The second aim of the study was to investigate the extent to which self-efficacy and self-control predict student motor learning	Secondary school	Netherlands	56 students in three groups of 22, 17, and 17 students	Quantitative	The results showed that distance and technique improved significantly in all groups. Self-efficacy improved after practice for the SC-VF group and the teacher controlled (TG) group but not for the external controlled (EC)-VF group. In addition, the students in the SC-VF group reported a higher perceived learning effect compared to the students in the EC-VF group. No differences in perceived enjoyment were found. Self-efficacy could predict improvements after practice from the pretest to the retention test

Table 3 (Continued)

Authors (year)	Aim of the study	Type of school	Country	Sample	Study design	Central results
Roure et al. (2019)	To compare the effects of video feedback on students' situational interest in gymnastics	Secondary school	Switzerland/Belgium	361 pupils (47.3% male, 52.7% female)	Quantitative	The results showed the crucial role of PE teachers when video feedback was used to improve the situational interest of students in PE classes. In addition, the data showed that the mean scores for situational interest were significantly higher for the video and teacher FB groups than for the other two groups. No differences were found between the teacher FB group and the VFB group
Bodsworth and Goodyear (2017)	To explore the barriers and facilitators to purposeful technology integration in cooperative learning in PE	Primary school	England	36 pupils (11 female, 25 male) and the teacher	Qualitative	Unfamiliarity with the technology and poor group cooperation were identified as initial barriers to students' learning when integrating technology. The study showed that choosing a clearly defined approach (in this case, cooperative learning) that has already been tested and found to support the use of digital technologies does not automatically lead to good learning experiences for students. If teachers want to purposefully use digital technologies in PE and ensure that the technology helps the students to learn optimally, then the SCs should refine and develop their practices through a reflective learning process, such as action research
Wadsworth, Brock, Daly, and Robinson (2014)	To investigate activity behavior and enjoyment in PE while playing active video games and comparable traditional activities	Primary school	USA	132 pupils (69 second grade, 63 third grade), of which 62 were female and 70 male	Quantitative	The study showed that the students took significantly more steps in modified tennis than when playing using Wii. There was no significant difference between the genders in terms of physical activity in the two scenarios. The students found tennis with Wii better than without. Further, 100% of the students had fun playing with Wii and 100% said they would like to play again. Only 45% of the students had played Wii Tennis before, and only 34% of the students had played traditional tennis before. Overall, 89% of the students said they would play Wii in PE if they had the opportunity
Jarraya et al. (2019)	To investigate the effect of perceived complexity of game performance for students learning tactics in basketball with video examples played at different speeds	Secondary school	Tunisia	120 students (78 female, 42 male)	Quantitative	When the complexity of the content was low, students invested the same mental effort regardless of the presentation speed. For content with medium and high complexity, students invested less mental effort with a slow presentation speed than with a normal presentation speed. When the complexity of the content was low, students achieved equal game performance scores, no matter what the presentation speed was. For medium and high complexity content, students achieved higher performance scores at a slow presentation speed than at a normal presentation speed. However, there were no significant differences between the low—and normal—speed presentations when the complexity of the content was low. Conversely, for the medium and high complexity content, learning was more efficient with a low presentation speed than with a normal presentation speed
Ye, Lee, Stodden, and Gao (2018)	To investigate the effectiveness of combined exergaming and PE on children's motor skills and fitness in comparison to conventional PE	Primary school	USA	261 pupils (127 male, 134 female)	Quantitative	The results showed that the combined exergaming program has a positive effect on the BMI and fitness of students, which, according to the authors, indicates that exergaming is a good alternative program to complement traditional PE
Andrade, Correia, d. Cruz, and Bevilacqua (2019)	To determine whether playing exergames had an influence on children's mood during PE	Primary school	Brazil	140 students (59 male, 81 female)	Quantitative	This study examined effects of exergames in PE on the mood of students and showed that playing exergames helped increase strength as well as exhaustion. The authors concluded that 3 h of exergames had an acute effect and improved children's mood during PE

Table 3 (Continued)

Authors (year)	Aim of the study	Type of school	Country	Sample	Study design	Central results
Fogel, Miltenberger, Graves, and Koehler (2010)	To evaluate the effect of exergaming on the activity of four inactive students in PE	Primary school	USA	4 fifth-grade students (2 female, 2 male)	Quantitative	The results showed that exergaming led to higher levels of physical activity and that the students had more opportunities to be physically active than in traditional PE classes. Furthermore, exergaming was socially acceptable for both the students and the SC. According to the authors, exergaming is a promising method to increase physical activity among inactive children. They also view it as a possible intervention against obesity in children
Quintas, Bustamante, Pradas, and Castellar (2020)	To analyze the effects of gamified exergame intervention in PE in primary schools according to psychological variables such as motivation, flow, basic psychological needs, and academic performance	Primary school	Spain	417 pupils from sixth and seventh grades (222 female, 195 male)	Quantitative	The results show positive effects of exergaming on basic psychological needs, academic performance, and a few flow dimensions. Meanwhile, no interaction effects were found on intrinsic motivation, external regulation, and a motivation, although specific improvements in the exergaming group were discussed. The Mechanics–Dynamics–Aesthetics Gamification instructional model and the <i>Just Dance Now</i> exergame may be resources that can have positive psychological effects on school PE
Cheng and Chen (2018)	To analyze the impact of the use of a user-friendly app on physical fitness in primary schools	Primary school	Taiwan	89 students (40 male, 49 female)	Quantitative	This comparative study showed that traditional PE with the help of app use can improve the fitness scores of students more than without its use. Strengthened student' self-efficacy
Maivorsdotter and Quennerstedt (2019)	With the help of an epistemological practice-oriented analysis, gender-specific habits of teenagers when exergaming in PE were examined in order to develop ideas for their use in PE	Secondary school	Sweden	7 students (4 female, 3 male)	Qualitative	The study showed that exergaming reproduces traditional gender roles if the students play in gender-homogeneous groups. Undoing gender becomes visible when playing in gender-heterogeneous groups. The teacher not participating in the play was seen to be a critical factor
Chen and Sun (2017)	To investigate the effectiveness of an intervention of an active video games (AVG) program in primary school	Primary school	USA	65 third and fourth graders. 29 third graders (10 male, 19 female), 36 fourth graders (15 male, 21 female)	Quantitative	A 6-week program (40 min—three times per week) with AVG could be an effective strategy to improve children's cardiorespiratory fitness while maintaining the enjoyment of PA
Steinberg et al. (2020)	To empirically record the sociocultural practices that young people developed through the use of mobile digital technologies in their PE classes. The focus was on dance and the associated process- and product-relevant esthetic teaching—learning collaborations of young people	Secondary school	Germany	10 students observed and six interviews	Qualitative	The results showed that there were some challenges for sport didactics with regard to individualization and the expansion of teaching and learning outside the sport hall on users' mobile devices. In particular, the usage behavior (e.g., barriers to filming body and movement, private text messaging) of personal mobile devices disturbs the traditional classroom experience

Table 3 (Continued)

Authors (year)	Aim of the study	Type of school	Country	Sample	Study design	Central results
Chen, Zhu, Kim, Welk, and Lanningham-Foster (2016)	To investigate how students learn more about energy balance, with an experimental group receiving a learning unit and digital devices (pedometer) and a control group only receiving the learning unit	Secondary school	Taiwan	140 pupils from sixth and seventh grades	Quantitative	The experimental group with the digital devices learned more about energy balance than the control group
Kretschmann (2017)	To examine the impact of a technology-enhanced teaching scenario in PE featuring video feedback on swimming performance, using a tablet computer in particular	Secondary school	Germany	30 pupils of a fifth-grade class	Mixed-methods	The experimental group swam faster than the control group, showing that video feedback can be an effective teaching method to help improve swimming performance in the front crawl. The students found the video feedback to be good
Sheehan and Katz (2012)	To investigate the influence of exergaming as well as a specific fitness program (ABC) on the balance ability of primary school children	Primary school	Canada	67 pupils (38 female, 29 male)	Quantitative	The exergaming group and the ABC group improved their balance ability about equally as well and both did significantly better than the control group
van Doodewaard et al. (2018)	To identify how teachers select students to demonstrate the task in question in instructional videos and discuss what consequences the selection may have for favoring and marginalizing certain students	Secondary school	Netherlands	6 teachers (1 female, 5 male) plus 26 teachers who attended a training on digital media in PE	Qualitative	The authors note that the selection of students for the demonstration video was based on perceived competence to perform well on the video as well as perceived resilience to cope with public scrutiny of their bodies. The teachers constructed hierarchies of desirable bodies that could be placed within the intersecting discourses of ability, gender, and ethnicity. This led to the selection of students who were primarily white and embodied masculine characteristics. All other bodies were made invisible (no students with physical disabilities, hardly any girls, and mostly white students)
Tou, Kee, Koh, Camiré, and Chow (2020)	To investigate and compare the attitudes of PE teachers towards ICT in PE in different demographic groups	Primary and secondary school	Singapore	422 teachers	Quantitative	The results showed that attitudes towards ICT differed significantly between teachers of different genders (men were more positive than women), age (the older they were, the more critical), and teaching experience (the more experienced they were, the less use). However, no significant difference in attitudes towards ICT was found between teachers of different school levels. The results of this study can inform policy makers and stakeholders who are interested in promoting the integration of ICT in PE
Ma, Bekker, Ren, Hu, and Vos (2018)	To investigate how audio augmentation can influence the physical activity of students in PE	Secondary school	Netherlands/China	20 pupils (19 female, 1 male)	Mixed-methods	The results showed that audio augmentation can influence the playful experience of teenagers. Relaxation and expression were positively influenced as were social interaction and perceived competence. However, there were also negative reinforcements in case of failure

Table 3 (Continued)

Authors (year)	Aim of the study	Type of school	Country	Sample	Study design	Central results
Sargent and Casey (2019)	To explore the reasons two UK-based PE teachers gave for why and how they used FL to complement their use of digital technology	Secondary school	England	2 teachers (1 male, 1 female)	Qualitative	The results showed that each teacher used FL and digital technologies in nuanced ways to support their teaching. Despite personal differences, FL was established by both teachers as a consistent practice routine to support the use of digital technologies. Overall, the results indicated that FL, when used in conjunction with digital tech, has the potential to provide pedagogical support to teachers' PE classes. This is particularly relevant given the limited time allocated to PE in the curriculum (some of which are inevitably lost in the changing rooms) and the perceived need for students to be physically active in class
Gao et al. (2017)	To investigate the effect of exergaming on sedentary behavior (SD), light motor activity (PA), moderate to vigorous physical activity (MVPA), and energy expended (EE) over 2 years as compared to regular PE	Primary school	USA	261 second and third graders (134 female, 127 male)	Quantitative	Significant positive effects were found for SB, mild ones for PA and MVPA, but none for EE. Follow-up pairwise comparisons revealed significant increases from pretest to posttest for mild PA, MVPA, and EE with no changes in SB. Conversely, significant decreases in mild PA occurred from pretest to follow-up, with no differences in MVPA and EE over the same period. However, for SB, a significant increase was observed from posttest to follow-up
Goodyear et al. (2014)	To examine using video cameras in cooperative learning to bring about a positive change in the learning environment for girls who have been observed to have low engagement in PE	Secondary school	England	Students from two grade-10 classes (female)	Qualitative	The results suggested that the role of the trainer and the cameraperson was crucial for girls' engagement. Some girls only participated 'fully' in class when learning remained within the social and cognitive dimension, as they could 'hide behind the camera' and did not have to physically participate. The authors suggested that the physical aspect of learning be temporarily removed (at least for some girls) to engage them in PE and influence their longer-term engagement
Finco, Reategui, Zaro, Sheehan, and Katz (2015)	To examine setting up an exergame lab that focused on children and young people who show signs of dissatisfaction in PE	Primary school	Brazil	24 students (12 female, 12 male)	Qualitative	The results showed that students who are normally unmotivated to participate in PE show positive attitudes towards exergaming practices and are willing to cooperate with children of the same age. The authors also found that exergaming created situations in which students could increase the regularity of performing physical exercises
Aktag (2015)	To examine the computer self-efficacy, performance outcomes, personal outcomes as well as the impact and anxiety levels of PE teachers. The influence of teaching experience, computer use, and participation in seminars or in-service programs on computer self-efficacy level was also determined	Secondary school	Turkey	145 teachers	Quantitative	The results of this study showed that there was a significant positive correlation between the teachers' computer self-efficacy, performance outcome, personal outcome and influence and a significant negative correlation between the teachers' computer self-efficacy and anxiety level. They also found that with increased duration of computer use, the teachers' computer self-efficacy increased and the anxiety level decreased
Juditya et al. (2020)	To investigate the feasibility of the digital learning material, POJOK	Secondary school	Indonesia	40 students	Quantitative	The app being studied was found to be suitable for all students in lower secondary school and served to support the learning process in PE, especially in teaching complex games such as basketball, volleyball, and soccer

Table 3 (Continued)

Authors (year)	Aim of the study	Type of school	Country	Sample	Study design	Central results
Hill and Valdez-Garcia (2020)	To identify PE teachers' perceptions of their accessibility to learning technologies, the availability of technical assistance, and specific barriers to integrating technology into their classrooms	Secondary school	USA	201 PE teachers for adapted physical education (APE) or non-APE PE (122 female, 79 male)	Quantitative	Lack of time, incentives, understanding, and access were the primary barriers to the successful use of technology in the classroom. Specifically, 65% of participants reported that they received an adequate level of technical support from their school leadership, while 61% reported that the lack of support was the barrier to integrating digital media into the classroom. Women were significantly likelier than men to cite lack of time as a barrier to using digital media in the classroom
Bisgin (2014)	To analyze the attitudes of PE teachers towards the use of technology and its position in education	Primary and secondary school	Turkey	171 teachers (42 female, 129 male)	Quantitative	The results showed significant differences between teachers according to gender, age, and length of service, but did not show significant differences in terms of their administrative tasks. For example, female PE teachers used technology more often than their male colleagues, and teachers who were 41 years and older used significantly less technology in the classroom. However, there was no significant difference in the evaluation of technological materials
Fernández Basadre, Herrera-Vidal Núñez, and Navarro Patón (2015)	To investigate the habits of using ICT in primary school children and evaluate whether they think that using it facilitates their education or not—especially in the field of PE	Primary school	Spain	100 pupils (57 male, 43 female)	Quantitative	The authors found that 67% of the pupils surveyed thought that using ICT would make their homework easier. Specifically, 70% of the students who participated at least once in an activity such as treasure hunt or orienteering said that ICT would make it more attractive. Further, 81% of the students who were about to finish primary school already owned a mobile phone. The main conclusion for the authors was that technological advances should be used as pedagogical tools to enhance and complement the different areas within the curriculum and take advantage of the great popularity they have among children and young people
Østerlie and Mehus (2020)	To investigate whether and how the introduction of a FL framework in Norwegian lower secondary PE can influence students' situational motivation and HRFK	Secondary school	Norway	206 students (97 female, 109 male)	Quantitative	The results showed a negative motivational change for male students unless there was an explanatory rationale through FL for the activity changes. However, the use of FL led to more cognitive learning, resulting in higher levels of HRFK for both girls and boys. The authors concluded that the current research provides valuable insights into Norwegian students' motivation for PE and stated that cognitive knowledge learning can be influenced when integrating the use of ICT in PE
Marttinen, Landi, Fredrick, and Silverman (2020)	To assess teachers' perceptions of the integration of digital technologies in PE and how these influenced pedagogical practice	Primary and secondary school	USA	12 teachers (6 male, 6 female)	Qualitative	Teachers use digital media in PE when it enhanced rather than replaced PE. It was further found that teachers' attitudes and the material circumstances of schools influenced the way digital media were used
Nation-Grainger (2017)	To improve the movement levels of 10th grade students in PE through wrist-worn movement monitors	Secondary school	Great Britain	10 pupils out of a total group of 47 pupils due to the lowest motivation scores	Mixed-methods	During the 6-week intervention, an increase in identified regulation and an increase in calories burned and distance walked in the experimental group were found. Surprisingly, there was no significant correlation between the two. However, further results indicated that the intervention supported the basic psychological needs of each student in the experimental group. No differences were found in the motivation of the students
Penney, Jones, Newhouse, and Cambell (2012)	To investigate authentic digital forms of assessment with high reliability and provide research-based insights for PE teachers	Secondary school	Australia	5 teachers and 72 pupils	Mixed-methods	Students found the assessment task to be authentic and meaningful and found that the 'practical' and 'theoretical' aspects had been combined well. Teachers found that the task aligned well with the pedagogical intent of the course and provided a valid means of assessing students' skills, knowledge, and understanding of aspects of the course content

Table 3 (Continued)

Authors (year)	Aim of the study	Type of school	Country	Sample	Study design	Central results
Quintas-Hijos, Peñarubia-Lozano, and Bustamante (2020)	To investigate the applicability of gamified exergame interventions in primary school PE	Primary school	Spain	8 teachers (6 male, 2 female) and 417 pupils (222 female, 195 male)	Mixed-methods	Gamification created more enthusiasm and motivation among the students. The exergame itself provided more fun and motoric learning. Exergames with gamification as a method were described as didactically meaningful. Overall, the results showed more fun and motivation, more joy in dancing, less shame in dancing, more creativity, more autonomous learning, and a digital leisure alternative
Rincker and Misner (2017)	To investigate the effectiveness of AVG in terms of children's motivation, physical skills, and satisfaction	Primary school	USA	404 students	Mixed-methods	In all three groups there was a significant increase in the mean mastery score. Thus, the groups did not differ in physical skills; thus, AVGs offer potential as a learning method for cultural dance. Additionally, there was a significant increase in heart rate
Robinson and Randall (2017)	To identify the factors that favor or hinder the use of digital media in PE	Primary and secondary school	Canada	206 teachers (102 male, 80 female, 24 not specified)	Mixed-methods	The results showed that different technologies were used with different frequency. External barriers (time, expertise, and resources) and internal barriers (teachers' beliefs and established pedagogy) were identified
Shewmake, Merrie, and Calleja (2015)	To compare the levels of perceived enjoyment and effort of third and fourth grade students in exergames and traditional PE	Primary school	USA	148 students (71 third graders [34 female, 37 male] and 77 fourth graders [36 female, 41 male])	Quantitative	While the students enjoyed their time with the X-Box Kinect systems significantly more, they felt that they would exert more effort outside of them
Rekik, Khacharem, Belkhir, Bali, and Jarraya (2019)	To analyze the impact of instructional media (photo or video) on learning outcomes, cognitive load, and attitudes of secondary school students	Secondary school	Tunisia	68 pupils (61.76% female)	Quantitative	Learning with dynamic videos outperformed static photos in both game comprehension and performance. The results also showed less cognitive load and improved attitudes towards working with videos instead of photos
Hansen and Sanders (2010)	To investigate children's experiences of participating in active play during PE	Primary school	USA	6 students (3 female, 3 male)	Qualitative	The results of this study suggested that active play could be used in 21st century PE to increase children's physical activity levels. Students who played actively during PE demonstrated a 'persistence to play' as well as a voluntary desire to engage and stay engaged in technology-enhanced physical activities
Bendiksen et al. (2014)	Primary school children were compared in terms of heart rate response to different types of PE as well as the fitness effects of a short-term PE training program with high versus low-to-moderate aerobic intensity	Primary school	Denmark	93 students (50 male, 43 female)	Quantitative	Average heart rate and time spent in the aerobic HI zone in young school children participating in ball games were significantly higher than in circuit training, running, and Nintendo Wii games. In addition, a short-term intervention with HI ball game exercise classes resulted in a significant improvement in intermittent exercise performance and lower cardiovascular stress during submaximal exercise. It was also observed that small-sided ball games in the school setting elicited high heart rate values in all participants, regardless of gender, fitness level, BMI, and participation in sport clubs
Huang and Gao (2013)	To investigate the influence of previous experiences with the situational interest and physical activity levels of the students and the relationships between situational interest and physical activity levels in <i>Dance Revolution</i>	Secondary school	USA	135 pupils (70 male, 65 female)	Quantitative	Based on the descriptive analyses, the students showed moderate situational motivation towards <i>Dance Revolution</i> . However, the results showed that the students were not physically active in this unit

Table 3 (Continued)

Authors (year)	Aim of the study	Type of school	Country	Sample	Study design	Central results
Kretschmann (2015)	To investigate the relationship between PE teachers' computer literacy and their use of technology in PE	Secondary school	Germany	57 PE teachers (26 male, 31 female)	Quantitative	The use of ICT, such as laptops, internet, and digital cameras, by PE teachers showed statistically significant differences in their computer skills (low, average, and high). The PE teachers surveyed tended not to use technology in PE lessons. However, the higher their computer skills were, the likelier they were to include technology in PE lessons
Lee (2018)	To investigate the impact of integrating mobile apps into PE on children's physical activity and psychosocial beliefs	Primary school	USA	157 pupils	Quantitative	App-based PE appeared to not be effective in improving primary school children's physical activity and psychosocial beliefs in the short term; instead, the opposite was partly the case. Sedentary behavior increased in the group of app users, and sedentary behavior of light exercise decreased. Intense movement, on the other hand, increased
Engen et al. (2018)	This study explored (1) whether and how wearable technologies can be used to support learning in and across different subjects and (2) what concerns wearables raise in relation to cyber-ethics	Secondary school	Norway	21 students (13 male, 8 female) and the teachers for the subjects	Qualitative	Students were surprisingly not concerned about privacy issues related to the use of smartwatches. Instead, introduction of Fitbits in PE was a motivating factor for them. The fact that physically passive students were motivated to be more active was a positive side effect
Greve et al. (2022)	To investigate the possibilities and limits for educational processes (with regard to PE, general education, and also media education) that can be reconstructed	Primary school	Germany	39 students	Qualitative	From the analysis of the interviews, a system of categories was developed that describes the phenomena of an expanded approach to the experience of physical activity in PE. These were titled 'New Creative Roles and Tasks' (subdivided into the two subcategories 'The Empowered Camera Child' and 'The Cool Actor') and 'Focused Products' (subdivided into the three subcategories 'New Adoption of a Product', 'Improvement and Development of the Product', and 'Appreciation and Recognition of the Product'). The results show that the children's main focus is on experiencing movement
Sohnsmeyer (2011)	To investigate the conditions under which the engagement with a digital movement-sensitive table tennis game had an influence on both the speed and the correctness of anticipatory decisions in table tennis. In addition, the potential of digital games for the acquisition of table tennis-specific action knowledge was explored	Secondary school	Germany	students	Quantitative	These three studies showed that exposure to a movement-intensive table tennis game could improve game-specific reaction abilities and action knowledge. Simultaneously, none of the three studies demonstrated an effect on the accuracy of anticipation performance. In this context, it was argued that the requirements of the digital game used are not sufficiently dimensioned to develop the necessary competences with regard to accuracy in terms of decision-making
Reynolds, Benham-Deal, Jenkins, and Wilson (2018)	To determine physical activity while playing a dance-based video game	Primary school	USA	27 pupils of a fifth-grade class	Quantitative	No significant difference was found between the on-game and off-game physical activities. Students achieved 16% of the required physical activity in both settings
Marin-Marín, Costa, Moreno-Guerrero, and Lopez-Belmonte (2020)	To examine whether the use of <i>Makey Makey</i> influences various psychosocial and pedagogical dimensions in the subject of PE	Secondary school	Southern Spain	177 pupils (41.24% male, 58.76% female)	Quantitative	The teaching method in which <i>Makey Makey</i> was used led to more success in several areas compared to conventional PE. The data showed that the teaching-learning process with the <i>Makey Makey</i> system had the greatest impact on motivation, teacher-student interactions, collaboration, and teacher evaluation

Table 3 (Continued)

Authors (year)	Aim of the study	Type of school	Country	Sample	Study design	Central results
Rojo-Ramoz et al. (2020)	To show the level of digital literacy of PE teachers working in the Spanish public school system	Primary school	Spain	201 teachers (109 male, 92 female)	Quantitative	Digital media was used predominantly by young teachers, who consequently further developed their competences. Differences between men and women existed only at the highest level of competence. There, the proportion of men was five times higher than the proportion of women. The teachers' self-assessment was often below their actual competence level
Asogwa et al. (2020)	To investigate the effect of a video-based intervention on the school engagement of hearing-impaired students	Secondary school	Nigeria	46 students	Quantitative	The results showed that the video-based educational intervention significantly improved the academic engagement of hearing-impaired adolescents in the intervention group compared to those in the control group
Vega-Ramirez, Notario, and Avalos-Ramos (2020)	To analyze the use of smartphones among teenagers and the level of satisfaction with the <i>Polar Beat</i> application in the context of PE in high school	Secondary school	Spain	40 students	Quantitative	The app gave students a better understanding of the lesson content. Likewise, the motivation of the students improved, so the app can be seen as a good, innovative way to use it in PE. There was a greater effect on female participants
Moreno-Guerero, Alonso Garcia, Ramos Navas-Parejo, Campos-Soto, and Gomez Garcia (2020)	The main objective of this paper was to analyze the impact of training interventions through the use of augmented reality in PE on the development and acquisition of spatial orientation	Secondary school	Spain	140 pupils (58.33% male, 41.67% female)	Quantitative	The results show that all dimensions (learning time, collaboration, autonomy, etc.) had a very high, significant correlation. The largest difference, on average, was observed in motivation. In contrast, the smallest, albeit significant, difference was in the grades given by the teachers themselves. The conclusion was that the method of teaching through augmented reality was effective in PE for high school students, especially for the acquisition of spatially oriented content
Trabelsi, Gharbi, Masmoudi, and Mrayeh (2020)	This study primarily aimed to explore the impact of peer-to-peer feedback interactions on female adolescents' engagement in PE and the potential of video technology to enhance this experience	Secondary school	Tunisia	47 female pupils	Quantitative	Data analysis revealed that the video-based peer feedback approach was more efficient in terms of its ability to enhance the studied population's engagement in the learning process during PE classes. Indeed, the positive effects of vision-based peer feedback interactions were observed only on female students' emotional engagement, whereas the video-based peer feedback interactions were potent enough to enhance female students' motor, cognitive, emotional, and sociointeractional engagement in PE classes
Papastergiou, Natsis, Verinakis, and Antoniou (2020)	To assess the impact of the integration of tablets and a mobile application for fitness development on primary education students' intrinsic motivation in PE lessons	Primary school	Greece	145 students (75 male, 70 female)	Quantitative	Lessons yielded student satisfaction. Student interest and enjoyment after the lesson in which tablets and the app were used were higher than those after an equivalent lesson without technology
Østerlie and Kjelaas (2019)	To examine the perceptions of adolescents of a FL framework applied to enhance student motivation and learning in PE	Secondary school	Norway	10 students (7 female, 3 male)	Qualitative	The students had a positive perception of preparing for PE classes if the preparation material was in the form of a video. FL seemed to have a positive effect on student understanding and learning and promoted a change in how the students valued the subject

PE physical education, BMI body mass index

et al. (2010) confirmed that exergaming is a good method to help inactive children be more physically active, and this included PE as well. Meanwhile, Burges Watson et al. (2016) showed that the use of dance mats had no effect on physical activity but in some scenarios ensured that students who were otherwise difficult to reach could be included. Finco et al. (2015) showed that students who were normally unmotivated in PE had a positive attitude towards exergame practices and were willing to work with other children. Finally, Engen et al. (2018) also described this in their study as a positive side effect in PE.

Affective

This category contains subcategories such as motivation or attitudes caused by the use of digital media in PE.

Motivation and situational interest

Besides physical activity, motivation, and situational interest were among the most researched topics in terms of digital media in PE. The concept of situational interest relates to specific actions led by interest and is described as a unique situation-specific motivational state (Krapp, 1995). Therefore, it is relevant to the study of active involvement. Specifically, 21 studies could be categorized under this topic. Eight studies were carried out in primary schools (Hansen & Sanders, 2010; Lindberg et al., 2016; Marttinen et al., 2019; Quintas et al., 2020; Quintas-Hijós et al., 2020; Sun, 2012, 2013; Papastergiou et al., 2020) and 13 in secondary schools (Chang et al., 2020; Huang & Gao, 2013; Legrain et al., 2015; Østerlie & Kjelaas, 2019; Marttinen et al., 2019; Nation-Grainger, 2017; Østerlie & Mehus, 2020; Potdevin et al., 2018; Roure et al., 2019; Zhu & Dragon, 2016; Marin-Marín et al., 2020; Vega-Ramírez et al., 2020; Moreno-Guerrero et al., 2020). Specifically, five studies examined qualitatively—through, for example, interviews or field notes—while nine examined physical activity quantitatively and five were based on a mixed-methods design. Overall, the majority of studies reported increasing situational interest

or motivation through the use of digital media.

As early as 2009, as a main finding of their study, Weir and Connor noted that the use of digital media was suitable for maintaining student engagement. Further, in their qualitative study in secondary schools, Marttinen et al. (2019) confirmed that the use of digital media was a motivating factor for students to increase their physical activity. Marin-Marín et al. (2020) also found a significant difference and thus an improvement in the motivational domain. In addition, in their study, Moreno-Guerrero et al. (2020) were also able to name the biggest difference in the motivational areas for students.

In their qualitative study, O'Loughlin et al. (2013) showed that self-evaluation, self-assessment, and self-regulatory learning through digital videography led to increased motivation. Legrain et al. (2015) and Vega-Ramírez et al. (2020) also found increased self-determined motivation in PE. In their study at a secondary school, Potdevin et al. (2018) showed that the use of video feedback significantly reduced demotivation between the first and fifth hour. Furthermore, other studies have demonstrated the crucial role of teachers when using video feedback in PE classes in terms of improving the situational interest of students. They found that this interest of the group when there was a teacher and video feedback was significantly higher than in groups with only one of the two (Roure et al., 2019). In addition, Østerlie and Mehus (2020) also showed a decrease in motivation among male students if no additional explanation was provided by a teacher.

The connection between exergames and motivation has also been examined in many studies. Quintas-Hijós et al. (2020) found that gamification by means of exergames increased motivation from the students' perspective. In their study on active video games in PE, Hansen and Sanders (2010) emphasized the above finding and perceived a determination to play as well as the voluntary desire to participate in physical activities and to persist with them. Sun (2012) examined students' motivation in a fitness unit that was

run using exergames, finding that while situational interest decreased over time, it was consistently higher than in the fitness unit without exergames. Further, in their study using a previously developed game, Lindberg et al. (2016) also confirmed that the motivation in the group with exergames was very high. A decrease in motivation over time in both groups was also shown by Sun (2013) in her quantitative study on the use of exergames in a secondary school.

Chang et al. (2020) examined the effect of augmented reality on learning motivation during a lesson about running and found that the experimental group achieved significantly higher levels of learning motivation than the comparison group. Meanwhile, Zhu and Dragon (2016) examined physical activity as well as the motivation to move. Their results point to less situational interest in the test group with digital media than in the comparison group. However, Nation-Grainger (2017) found no differences in motivation when comparing a group of students using heart rate monitors on their wrists with one without such devices. In their study using a dance simulation in PE, Huang and Gao (2013) also detected only moderate situational motivation.

Overall, many studies have indicated that motivation and situational interest in PE can be increased for a short period of time. In the long term, however, there are indications that situational interest declines over time (Sun, 2012, 2013). This may be due to the digital medium used or to its novelty in PE. Further, even though there have been studies and research on this subject for over 10 years, its use in everyday life at schools is still rare in PE. It has also been shown that situational interest strongly depends on additional interactions with teachers (Østerlie & Mehus, 2020; Roure et al., 2019).

Enjoyment

In conjunction with gamification and exergames in particular, the connection between the use of digital media and enjoyment was examined in five studies. Apart from one mixed-methods study (Quintas-Hijós et al., 2020), only quantitative studies have been used to deal with this

topic (Andrade et al., 2019; Kok et al., 2020; Shewmake et al., 2015). Here, various questionnaires and scales, such as the Brunel Mood Scale, were used for this purpose.

Specifically, Andrade et al. (2019) showed that the use of exergames improved the class atmosphere during lessons. Quintas-Hijós et al. (2020) found that a lesson with exergames could be an effective strategy to improve cardiorespiratory fitness in children while maintaining the enjoyment of physical activity. Here, the gamification method generated more enthusiasm, while the exergame itself made motor learning more fun (Quintas-Hijós et al., 2020). Shewmake et al. (2015) examined the degree of perceived enjoyment in elementary schools with and without the use of exergames and found that the students liked the former to a significantly greater extent. However, in their study on self-controlled video feedback during shotput, Kok et al. (2020) were unable to show any difference in perceived enjoyment.

Attitudes and self-efficacy

The studies in this subcategory examined the relationship between the use of digital media and changes in self-efficacy and attitudes towards PE topics. They found that the use of digital media can significantly influence students' attitudes towards physical activity. For example, participants in exergames-based PE tended to develop positive behavior and attitudes as well as a better understanding of their perceived learning progress (Koekoek et al., 2019; Lwin & Malik, 2012). Further, the use of exergames had a greater influence on younger students than older ones. Attitudes were also more positively influenced with the help of audio augmentation. Relaxation and expression were positively influenced as were social interaction and perceived competence. However, in the event of failure, there was negative reinforcement (Ma et al., 2018). Meanwhile, Kok et al. (2020) examined self-efficacy in dealing with digital media—more precisely with video feedback. Their main finding was that video feedback only improves students' self-efficacy if the video feedback is

controlled by the student and not others (Kok et al., 2020). Penney et al. (2012) were able to show that the use of digital media and the digital recording of student results, in particular, in the form of video recordings, for example, was perceived by students as authentic and meaningful.

School conditions

The studies in this subcategory examined the conditions in school when digital media was used in PE. Most of the studies had teachers as a sample. Their results indicated that teachers tended to have positive attitudes towards digital media (Gibbone et al., 2010; Legrain et al., 2015; Tou et al., 2020). However, there were differences regarding age, experience and gender: for example, women used digital media more often than men (Bisgin, 2014; Rojo-Ramos et al., 2020).

More specifically, Penney et al. (2012) showed that teachers perceived the use of digital media as a valid means of assessing the capabilities, knowledge, and understanding of students. Quintas-Hijós et al. (2020) found that teachers viewed exergames as a good opportunity to increase students' motivation. In addition to direct forms of feedback using digital media—for example, digital videography—Gibbs et al. (2017) found that digital media also provided more time and consequently gave teachers the opportunity to give feedback, among other things.

This category also includes studies that show limitations and challenges on a structural level, thus, making barriers to the use of digital media clear. This includes, for example, a high time requirement or lack of training. A total of 13 studies presented results on this topic: six were quantitative in nature (Aktag, 2015; Bisgin, 2014; Fernández-Batanero et al., 2019; Hill & Valdez-Garcia, 2020; Legrain et al., 2015; Rojo-Ramos et al., 2020), four adopted a qualitative approach (Baek et al., 2018; Marttinen et al., 2019, 2020; Steinberg et al., 2020), and two used a mixed-methods design (Kretschmann, 2015; Robinson & Randall, 2017).

They found that the lack of resources was often a major reason for not including digital media in PE. Specifically, regarding barriers influencing the use of digital media, teachers named class size as well as lack of access to media, support, time, expertise, and budget (Hill & Valdez-Garcia, 2020; Legrain et al., 2015; Robinson & Randall, 2017). The given resources also influenced the way in which digital media were used in the classroom (Marttinen et al., 2020).

Moreover, in a survey, teachers did not consider themselves well prepared for the use of digital media in PE and believed that specific training was necessary for their use (Fernández-Batanero et al., 2019). Besides the lack of training, teachers stated that they used digital media less (Baek et al., 2018; Legrain et al., 2015) because they had never experienced digital media in their own lessons as students (Baek et al., 2018). In addition, there were differences in terms of gender and age. Women used digital media more often in PE and felt better prepared for its use than their male colleagues. Further, the older the teachers were, the less that technology was used (Fernández-Batanero et al., 2019; Hill & Valdez-Garcia, 2020; Rojo-Ramos et al., 2020). Finally, knowledge of the medium used also played a role in the studies. For example, the better the computer skills of sport teachers, the likelier it was that they also used them in PE (Kretschmann, 2015; Rojo-Ramos et al., 2020) and the lesser the anxiety before use (Aktag, 2015).

Discussion

This review presents the goals pursued by empirical studies regarding the use of digital media in PE as well as the current state of research on the possibilities and limitations of this use. We found that the studies use different technologies that have changed over time and will continue to change. It also became clear that a research focus is needed that not only refers to software and hardware but also takes a didactic perspective. This is reflected in PE as described by Kerres (2022) for studies in the area of digital media in schools.

In addition to the understanding of the digital medium and its influence, the understanding of PE influences the use of digital media, and the studies reveal very different understandings of PE. There are some at the international level that are similar to that of the German discourse (Prohl, 2006; Kirk, 2012, 2013), but most studies focus on the physical condition and activity and the functional use of digital media. The emphasis on these areas in the literature could possibly be explained by experience in the use of digital media in professional sports. Video feedback, for example, has been used for a long time in the club sport settings. Due to traditional understandings of PE, this practice has often been introduced into schools, especially PE. Further, this feedback can be a great way to improve sport-specific capabilities and skills. When using it, however, the teacher must consider that seeing oneself can have an impact on one's self-image. Nevertheless, only a few studies paid attention to these effects, and they found that students had the desire to look good in the videos (Casey & Jones, 2011; Greve et al., 2022) and that hierarchies of desirable bodies were unconsciously produced by the teachers (van Doodewaard, Knoppers, & van Hilvoorde, 2018). Thus, these effects, which can play a role unrelated to the improvement of performance, must be reflected on by teachers when using digital media. Meanwhile, mutual filming and its associated new roles and tasks offer the opportunity to make more students enthusiastic about sport-specific topics. In this context, the functional use of digital media to achieve the goals of PE—learning with media—was the focus of a large number of the studies. However, only a few studies showed a specific interest in learning about media as well, addressing questions of data protection, legal aspects, or other media education topics. In interventions with digital media, including those not involving PE, students did not seem concerned about issues such as data protection related to the use of smartwatches (Engen et al., 2018). At this point, the opportunities for children to learn something about media were often not used by setting goals related to digital media use in PE. This is often based on the expectation that

digital media is to be used as a tool to increase performance and activity.

As Marttinen et al. (2019) reported, the use of digital media for teaching and learning still has a long way to go. While digital media as a tool for use in PE is becoming more widespread, the didactic perspective has remained less illuminated in the empirical context. This is where the gap between the use of technology in PE and the didactics behind it becomes visible. On the one hand, curricula specify objectives and content in relation to digital media, while on the other, the pupil at the center and as an individual subject can only educate themselves. This means that the teacher can design the learning environment with digital media and thus prepare and support the learning process. However, the completion of the learning process depends on the student as a self-forming individual subject acting accordingly (Gröben & Prohl, 2012; Prohl, 2006). Here, the advantage of digital media is that it plays a major role in the everyday world of the students and thus, as can be seen in this review, increases the motivation for the self-educational process among students. In this way, the use of digital media influences the educational and didactic goals of PE. In addition, the possibilities of using digital media to adapt learning materials and content in PE to enable students to learn were made clear in this review. Despite this focus on physical activity and the mixed results in this regard, it is worthwhile to use digital media to integrate students who would otherwise not participate at all into classes (Goodyear et al., 2014) or to enhance learning through self-assessment and self-regulatory learning (O'Loughlin et al., 2013). Additionally, digital media can also create a connection between the media world inside and outside of school and were often used successfully as motivational aids to increase activity, motivation, and enjoyment. However, when using exergames in PE, for example, there is a high level of effort in terms of preparation and high costs in the purchase of equipment, which is certainly a limiting factor for its implementation in PE. In this context, students also mentioned the bulkiness of the devices and the lack of

their accessibility at home as problems (Marttinen et al., 2019).

Limitations

For this overview of the research results on the use of digital media in PE, certain inclusion and exclusion criteria were used, which formed an important condition for the development of this systematic review. Since certain search terms were required for this process, it is conceivable that important studies that did not include any of the above-mentioned search terms in their titles, abstracts, or keywords were not included in the systematic review. Furthermore, this review only included English and German texts and excluded, for example, the large number of studies that have been published in Spanish. However, country-specific peculiarities in the education systems, and especially in the perceptions of PE, limit the transferability of individual study results across national borders.

Here, it should also be noted that the authors from the working group of this systematic review were involved in one of the listed studies.

Conclusion

While there are benefits of using digital media in physical education (PE)—for example, in motivating or improving sport-specific motor capabilities and skills—barriers in terms of the preparation of PE teachers was demonstrated in this review. Thus, for its successful use, teachers need better training and preparation, since the effect of digital media in PE depends largely on presentation in an appropriate form and additional instructions given by the teacher (Østerlie & Mehus, 2020; Roure et al., 2019). The main focus should consequently be on preparation and training in terms of didactic, methodological, and media educational content, as the tools being used will continue to change over time. In addition, the studies reviewed also emphasized that teachers need to use digital media to focus on thinking critically about media content (De Araújo, Knijnik, & Ovens, 2020) and that they need to be provided with a reflexive

approach to the use of digital media (Bodsworth & Goodyear, 2017). The understanding of PE also strongly affects how and why digital media are used in PE: Is PE about performance in the sense of sport-specific skills, or is it also about learning beyond them? For these reasons, preservice teachers should already be trained during their studies to use digital media in ways that go beyond performance-oriented goals in PE. Moreover, the focus of the examined research reflects the understandings of PE. Most studies were centered on improving physical performance or activity and rarely went beyond this. Thus, additional insights into students' experiences with and learning about media in PE have not yet been considered. In this context, learning with and about media as well as about the influence of digital technologies on the body and one's own sporting activities must be addressed in research and school in order to meet the demands of school.

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Declarations

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