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From Classroom to Screen: Digital Transformation of Physical Education Through the Lens of Traditional, Blended and Mobile Learning

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Abstract. In response to the challenges of digital transformation in education, a study was conducted to develop and evaluate criteria for digitally-based *Physical Education* (PE) courses. The bibliometric analysis revealed three thematic clusters in the field of e-learning in PE: Cluster 1 ('Technology') reflects the transition to e-learning and blended learning formats. Cluster 2 ('Pedagogy') emphasizes the human dimension of PE in a digital context and inclusiveness. Whereas, Cluster 3 ('Human interaction') focuses on the intersection of digital learning methodology and learner well-being. Based on the bibliographic analysis of the sources corresponding to the clusters, a criterion framework for comparing PE learning formats has been developed. To evaluate the feasibility of these criteria, a confidential survey was conducted which involved 36 physical education and sports professionals who met the inclusion criteria, in particular, who had experience in teaching PE in both traditional and mixed/distance formats. The factor analysis of the 19-item questionnaire identified four distinct components: 'Feasibility of implementation' (logistical and resource issues), 'Clarity and pedagogical design' (clarity of objectives and quality of materials), 'Relevance and compliance' (compliance with standards and requirements of the educational institution), and 'Engagement and Support' (student motivation and teacher support). The results show generally positive assessment of the criteria and

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confirm that technological, pedagogical, and engagement factors are key elements of the PE assessment framework. Inadequate professional development and lack of technical support can lead to ineffective or misunderstanding of the nature of teaching PE with technology. Teachers need to learn how to design e-learning-appropriate tasks and interpret digital feedback correctly. The findings emphasize the need to integrate digital pedagogy and inclusive practices into teacher training, as well as to ensure that curricula are aligned with national standards and ethical frameworks for data use.
Keywords: educational modalities, physical education, coach learning, digitalization, e-learning, mobile applications, athletics.

Nuo klasės iki ekrano: skaitmeninė fizinio ugdymo transformacija per tradicinio, mišriojo ir mobiliojo mokymosi prizmes

Santrauka. Šis tyrimas atliktas reaguojant į skaitmeninės transformacijos iššūkius švietimo srityje, tyrimo tikslas – sukurti ir įvertinti skaitmeninio fizinio ugdymo (FU) dalykui taikomus kriterijus. Bibliometrinė analizė atskleidė tris teminius virtualaus fizinio ugdymo klasterius: Pirmas klasteris („Technologijos“) atspindi perėjimą prie e. mokymosi ir mišriojo mokymosi formų. Antras klasteris („Pedagogika“) pabrėžia žmogiškąjį fizinio ugdymo aspektą skaitmeniniame kontekste ir įtrauktį. Tuo tarpu trečias klasteris („Žmogiškasis bendravimas“) apima skaitmeninio mokymosi metodologijos ir besimokančiųjų gerovės sąsajas. Remiantis bibliografine šaltinių analize, sukurta fiziniam ugdymui taikomų mokymosi formų lyginimo kriterijų sistema. Šių kriterijų įgyvendinimas vertintas konfidencialia apklausa, kurioje dalyvavo 36 fizinio ugdymo ir sporto specialistai. Pagrindinis atrankos kriterijus buvo fizinio ugdymo patirtis tiek tradicinėmis, tiek mišriomis / nuotolinio mokymosi formomis. Faktorinė 19 klausimų analizė atskleidė keturis komponentus: „Įgyvendinimo galimybės“ (logistikos ir išteklių klausimai), „Aiškumas ir pedagoginis dizainas“ (uždavinių aiškumas ir medžiagos kokybė), „Aktualumas ir atitiktis“ (atitiktis švietimo įstaigos standartams ir reikalavimams) bei „Įsitraukimas ir parama“ (mokinių motyvacija ir mokytojų parama). Rezultatai rodo, kad kriterijai vertinami daugiausia teigiamai, ir patvirtina tai, jog technologiniai, pedagoginiai ir įsitraukimo veiksniai yra pagrindiniai FU vertinimo sistemos elementai. Dėl nepakankamo profesinio tobulėjimo ir techninės paramos trūkumo fizinis ugdymas integruojant technologijas gali būti neveiksmingas arba ne taip suprantama jo esmė. Mokytojai turi išmokti kurti e. mokymuisi tinkamas užduotis ir teisingai interpretuoti skaitmeninę grįžtamąją informaciją. Tyrimo radiniai atskleidė ir tai, kad į mokytojų rengimą būtina integruoti skaitmeninę pedagogiką ir įtraukias praktikas, taip pat užtikrinti, kad ugdymo programos atitiktų nacionalinius standartus ir duomenų naudojimo etikos gaires.
Pagrindiniai žodžiai: švietimo formos, fizinis ugdymas, trenerių mokymasis, skaitmeninimas, e. mokymasis, mobiliosios programėlės, lengvoji atletika.

Introduction

The most recent decades have been marked by significant digitalization in many sectors, including education and training. The scaling-up of distance learning in higher education had already challenged the traditional model even before the pandemic. Meanwhile, the COVID-19 pandemic only emphasized the need to integrate technological innovations to sustainably renew teaching and learning, which has led to a significant increase in education research. Digital transformation is having a significant impact on higher education, and *e-learning* (EL) is becoming an increasingly discussed topic. This transition is especially relevant for such fields as physical education and sports, where face-to-face classes traditionally prevail. There is a growing demand for a transition from traditional teaching methods (F2F) to innovative pedagogical practices based on the evaluation of real-world experience and the feasibility of their implementation. It can be affirmatively stated that EL has become important to support the sustainable development of PE curricula. The digital transformation of PE is manifested in the transition from F2F to

blended (BL) and fully mobile learning formats. There is a need to identify the key features of PE education in the context of digitalization of education in formats other than the 'traditional' ones.

Different models of digital learning are practiced in educational activities, including *Massive Open Online Courses* (MOOCs), BL (including flipped classroom), and EL (or m-learning equivalent to distance learning) learning (Bachman & Scherer, 2015). EL is an important phenomenon in higher education due to the potential flexibility, mobility, and high variability of this learning format (Achuthan, Kolil, Muthupalani, & Raman, 2024). EL is the most common method of distance learning for PE (Ariski, Wahyuri, Khairuddin, & Chaeroni, 2024), compared to MOOCs (Zeide & Nissenbaum, 2018), while BL can combine online (synchronous and asynchronous) and face-to-face sessions (Walker et al., 2021). Overall, e-learning environments appear to be a viable alternative to F2F physical education courses, offering greater flexibility for both students and teachers, potential time and cost savings, and reduced dependence on physical resources and faculty (Işıkgöz, 2024). Effective EL is not just about adapting the F2F format by adding digital solutions. EL requires a reassessment of pedagogical technologies (Tagimaucia, D'Souza, & Chand, 2024; Li & Wang, 2024). Traditional courses offer automatic connections through physical presence and real-time interaction. EL provides independence from place and time, facilitating the organization of learning modules and the creation of problem-based, solution-oriented and professionally relevant materials, as well as flexible learning interactions (Griffiths, Goodyear, & Armour, 2022; Bourke, Bruijns, Saravanamuttoo, Vanderloo, & Tucker, 2024). EL is associated with increased requirements for critical thinking and the use of diverse content (primarily multimedia), while face-to-face classes are associated with diverse and expressive physical activities (Hsia, Hwang, & Hwang, 2024; Gao, Zhu, & Tian, 2025).

EL in PE has faced skepticism and concerns about crystallizing evidence-based best practices (Loh, Bourke, Saravanamuttoo, Bruijns, & Tucker, 2024). However, EL in PE should have the same goals and expected outcomes as traditional face-to-face physical education (Shen, Liang, Xu, & Wei, 2022). The very notion of 'quality' (which is deemed to be related to structural, organizational and implementation features) of e-courses is crucial for student success and preparation for future careers (Kulak & Forder, 2024). Research on the quality of EL in PE spans a variety of disciplines and methodologies, including standards-based assessment systems and student feedback (Haffyandi, Kahri, & Ganeswara, 2024; Tjitroharjo, Nopembri, & Kriswanto, 2024). Key predictors of e-learning course quality include: multimedia, specially selected and organized physical activity, learning schedule, and presentation of learning materials (Lin, 2024; Olobia, 2024; Zhou et al., 2024). The presentation of learning materials and learning schedule are prioritized for quality improvement, while multimedia and specially selected and organized physical activities serve as additional elements (Salimi & Moslehi, 2024; Risma, Bakhtiar, Umar, & Zarya, 2025). The presentation of learning materials in EL can include a variety of forms, such as animations and live demonstrations, and not just sheer text slides (Tian & Guo, 2025; Adams, Belcher, Jenkins, & Goad, 2025).

Digital technologies such as social media, blogs, video analysis, and video games can be effectively integrated into PE to enhance students' learning in EL settings (Mulato, Hidayatullah, Purnama, & Syaifullah, 2024). BL combines the benefits of EL with face-to-face interaction (Indarto et al., 2024). BL lacks a single 'one-fits-for-all' formula because it can be scaled to different PE needs, courses, and teaching styles (Suryadi et al., 2024). Blended courses generally lead to better student learning outcomes in PE (Bikalawan et al., 2025) and, if implemented correctly, it can be more effective than exclusively face-to-face or fully distance formats (Charbonneau-Gowdy, 2018). Blended models improve student retention, reduce dropout rates, take into account the needs of special subgroups of students, and allow for planning academic work according to individual student characteristics (Rathod & Kamppi, 2025). In general, digital pedagogy involves the use of digital technologies and tools to support learning and teaching, promote EL and 'real-life' learning. It enhances and supports learning in new ways, rather than simply replacing traditional methods (Cerezo, Bogarin, Esteban, & Romero, 2020; Li, Wang, & Wang, 2024). The key components of digital pedagogy include active learning (hands-on activities, projects, online forums, simulations, virtual participation, collaboration platforms) (Zhao et al., 2024) and rapid assessment (immediate feedback, personalized help) (Arfi, Wahyuri, Gusril, Rasyid, & Ockta, 2024). The development of e-learning courses in PE is based on self-determination theory and standards, such as recommendations of educational institutions. Although the benefits of digital learning in PE are increasingly recognized, challenges related to course quality, technical infrastructure, effective interaction, and sustained engagement remain (Ariski et al., 2024; Dispo, Magat, Arambulo, & De Guzman, 2024 Işıkgöz, 2024; Tagimaucia et al., 2024).

The results of the preliminary review of relevant literature emphasize a clear shift toward digital learning methods in PE, driven by technological advances and reinforced by global events. What remains unclear is the long–term effectiveness of EL in PE and the selection/modification/development of new pedagogical strategies needed for optimal implementation of digital learning formats, especially with regard to teacher preparation and student outcomes. **The aim** of this study is to thoroughly examine the digital transformation of physical education, focusing on traditional, blended and mobile modalities. The results of: 1) analysis of digital integration in physical education to structure the research field; 2) identification and validation of relevant criteria for comparing physical education courses in different formats for their understanding and critical distinction.

Methodology

At the first stage, a search and analysis of keywords was carried out by using the *Vosviewer v.1.6.19* tool on the development and evaluation of PE courses based on the use of digital technologies. An advanced search of sources was carried out in the WoS database and exported in the text format (full source records). At the preparatory stage, the combined results of the queries were cleared of duplicate and retracted articles by using the *Zotero* tool and exported for analysis in the RIS format. The search strategy along with

the criteria established for selecting keywords and studies for analysis are contained in the supplementary materials (Appendix). The selection of a mixed-methods approach is necessitated by the requirement for a sequential realization of the research objectives. During the initial stage, bibliometric analysis (VOSviewer) was employed as a tool for the objective structuring of the scientific landscape, enabling the identification of conceptual clusters ('Technology', 'Pedagogy', 'Human interaction') to establish a theoretical criteria framework. In the second stage, a purposive survey of specialists was conducted, followed by exploratory factor analysis (PCA with Varimax rotation), serving as a valid empirical method for the verification of the developed criteria. This dual-phase approach facilitated not only the assessment of the practical significance of the criteria involved but also the elucidation of the latent structure of professional perceptions regarding the digital transformation of physical education, thereby ensuring a robust transition from theoretical modeling to empirical validation.

Results and discussion

As a result, we identified key areas for developing criteria for evaluating PE courses in formats other than the traditional one. Figure 1 shows a map of keywords by research area (Fig. 1).

The bibliometric analysis allowed us to identify three separate clusters, each of which represents a thematic core in the field of EL in PE. Cluster 1 focuses on terms such as 'distance learning', 'higher education', 'MOOCs', 'online learning', 'pedagogy', and 'technology'. There is a focus on the widespread transition of traditional learning to blended or full-fledged electronic formats. A combination of these concepts indicates that teaching methods and student outcomes in higher education are closely related to mobile tools. It is noteworthy that the terms date back to the mid-to-late 2010s, which is consistent with the emergence of proposals for working solutions or recommendations for the organization of EL in PE. However, while EL has become a prominent trend in higher education due to the development of mobile technologies, holistic PE courses began to be actively discussed only under the influence of the COVID-19 pandemic. Thus, the transition to virtual classrooms and MOOCs is conceptually linked to the search for ways to improve the efficiency of education and the practical application of digital technologies in and outside of the classroom.

Cluster 2 focuses on terms such as 'adaptive physical education', 'attitudes', 'children', 'online education', 'perceptions', 'physical education', 'physical activity', 'teachers' and 'students'. The main theme of this cluster is the human dimension of PE in a digital context, with a focus on how students and teachers interact with the learning content when it is presented in an electronic or blended format. The presence of the concepts of 'adaptive physical education' and 'children' indicates an interest in inclusivity, while 'attitudes', 'perceptions', 'teachers' and 'students' emphasize the psychosocial factors of EL. The average years of publication of these concepts range from about 2016 to the present, indicating a sustained interest since the beginning of the active discussion of the

transition to digital PE. Conceptually, this cluster combines research on F2F PE issues (e.g., physical activity goals) with EL issues (e.g., maintaining engagement and considering learner perceptions). Thus, the success of EL in PE depends on teachers' adaptation of the content (e.g., modified or 'adapted' curricula) and on understanding teachers' and students' attitudes toward the new format.

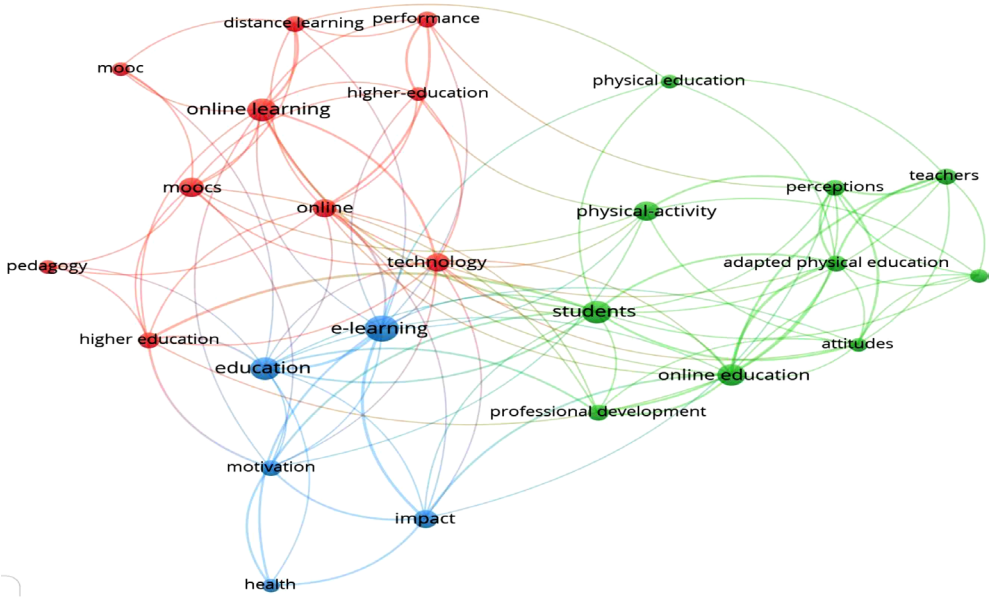

Figure 1. *Keyword research map*

Note. Generated in *Vosviewer* environment.

Cluster 3 focuses on terms such as 'e-learning', 'education', 'health', 'impact', and 'motivation' The thematic core here is at the intersection of digital learning methodology and learner well-being/outcomes. The connection of the terms 'health' and 'motivation' to 'e-learning' indicates a focus on how technology mediated PE affects students' physical health and engagement. The average year for the terms 'health' and 'motivation' (between 2020–2021) indicates that these issues are particularly relevant. The term 'e-learning' has the largest number of links in this cluster, reflecting its centrality. Together, these terms focus on how digital tools or their use in learning models affect learners. Thus, there is a tendency to use mobile technologies not only to deliver content, but also to actively engage, build students' interest in physical activity and support their progression through PE.

Based on the study of the sources corresponding to the selected clusters, a bibliographic analysis was carried out. The selection and relevance of the selected sources was carried out independently by two researchers with the subsequent search for consensus on the lists. In case of contradictions, a third researcher was involved in the discussion. The criteria for selecting sources for review by cluster and the procedure itself are described in detail in the Appendix.

In general, the interrelated clusters focus on the discussion of learning technologies, digital pedagogy, and human interaction in EL as key topics in the digital transformation of PE. Cluster 1 (technology) logically covers tools such as mobile devices, wearable technologies, IoT environments, augmented/virtual reality, and related applications. Mobile tools can enrich PE learning in terms of flexibility, accessibility, and interactivity – 'learning anytime, anywhere' (Kim & Gurvitch, 2020; Indarto et al., 2024; Bikalawan et al., 2025). Similarly, the integration of wearable technology, gamified platforms, or augmented/virtual reality into PE creates more interactive and data-driven learning environments which encourage active participation and improve motor skill development (Kooiman, Sheehan, Wesolek, & Reategui, 2016; Mokmin & Rassy, 2024). Cluster 2 (pedagogy) focuses on the study of blended learning models (flipped classrooms, online modules) and the principles of teaching PE professionals. Online courses for teachers are most effective when developed while using andragogy – through experiential learning, professional self-direction, engagement, and transformative reflection (Sato & Haegele, 2017). Cluster 3 (human interaction) focuses on motivation, inclusion, and social interaction. Technology-enhanced PE increases motivation, engagement, quality of motor learning, and cognitive performance (Li & Wang, 2024). There are concerns that digital inequality, complemented by insufficient teacher training, limits these benefits (Michael et al., 2019; Liu & Zhu, 2020; Rakha, 2025).

Although digital tools open up new pedagogical avenues, realizing their potential in PE depends on addressing issues of equity and support, which has important theoretical implications for PE teaching and teacher training. First, digital methods encourage a shift from F2F, teacher-centered learning to more learner-centered pedagogies (Buchem, Merceron, Kreutel, & Haesner, 2015; Chen, Lowenthal, & Bauer, 2016). Whereas, BL and EL naturally incorporate flipped or problem-based learning, giving students more autonomy (Sankaranarayanan et al., 2020). Courses structured around empirical practice and self-reflection, when the learning content is relevant and personally shaped, are more effective (Lee, Tzeng, Huang, & Su, 2021). PE teachers in the context of digitalization of education should use problem-solving and learner-centered teaching styles to increase student engagement (Kelly, Clinton-Lisell, & Klein, 2022; Rugube, Chibaya, & Govender, 2022). Digital platforms are also changing the role of the instructor from a didactic lecturer to a facilitator or coach. Instead of simply transmitting information, teachers direct inquiries, provide timely feedback through forums or video conferencing, and develop a community of 'practice' (Kelly, 2022; Matolic, Jurakic, & Pedisic, 2024). The technology-mediated PE classroom is an example of social constructivist learning, where knowledge is co-constructed. From a pedagogical point of view, the transformation from classroom to screen encourages rethinking curricula around the basic principles of learning (autonomy, real-world tasks, reflection) rather than simply 'moving physical activity online'.

Thoughtfully implemented technologies can increase students' interest and commitment to PE. Digital tools allow for individualized feedback and self-monitoring (fitness apps or wearable technology), which supports students' sense of autonomy and compe-

tence as the two pillars of self-determination theory (Hsu & Wang, 2019). Wearable devices and gamified activities offer real-time feedback and progress tracking, which also promotes greater autonomy in physical activity (Bachman & Scherer, 2015; Liu, 2023; Olobia, 2024). However, motivation in EL with PE is not inherent and automatic. Students differ in their readiness to learn independently, and those with little and limited previous experience with online learning may feel less motivated (Stallwood, Adu, Tairyan, Astle, & Yassi, 2020; Arfi et al., 2024; Pürgstaller, Schmeling, Barkemeyer, Ullmann, & Koal, 2025). Ensuring engagement requires not only interesting and fascinating technical content, but also the development of students' EL skills.

Accessibility and inclusion are equally important. On the positive side, digital tools can be very inclusive if they are designed with specific groups of learners in mind. Recorded video demonstrations and apps can be paused, repeated, or slowed down for students with disabilities (Beard & Konukman, 2020; Dispo et al., 2024). Online PE modules can include multiple representations (text, audio, visual) and provide self-paced training which meets the principles of universal design for learning (Hawthorne et al., 2025). ELs allow teachers to develop competencies by learning adaptive teaching methods through interactive web courses (Sato & Haegele, 2017; Sato & Haegele, 2018). However, significant barriers remain to be overcome. Digital inequality poses a real challenge to inclusion – since not all students or schools have equal access to devices and high-speed internet. The rapid adoption of technology raises pressing privacy and equality concerns (Barthakur et al., 2022; Lander, Lewis, Nahavandi, Amsbury, & Barnett, 2022). In addition, students with disabilities may require specialized assistive technologies or adaptations (video subtitles, alternative input methods, etc.) that are not automatically provided (Healy et al., 2017). Without careful planning, EL in PE can unintentionally exclude those it is intended to help (Webster et al., 2021). In general, compliance with the claimed benefits of inclusive digital PE depends on adherence to accessibility standards and proactive support for measures to create an inclusive environment in educational institutions.

Overall, the findings suggest that no single format is universally best. Blended approaches often offer a pragmatic intermediate solution, by virtue of combining hands-on activities with digital augmentation. It is crucial that any model is based on sound learning principles, strong social support structures, and equitable design so that to ensure that the classroom-to-screen transition truly benefits all learners.

The synthesis of the cluster analysis results enabled the delineation of three conceptual vectors, which served as the foundation for developing comparative evaluation criteria for PE formats. Specifically, the thematic core of Cluster 1 (technological) informed the selection of criteria pertaining to technical accessibility and content flexibility, both of which are determined by the infrastructural capacities of the digital environment. The essence of Cluster 2 (pedagogical) provided the framework for establishing criteria for methodological effectiveness and instructional inclusivity, emphasizing the adaptation of the content to individual learner needs. Finally, Cluster 3 (human interaction) facilitated the integration of indicators related to student motivation and instructor support into

the framework, both of which are essential for maintaining engagement within mediated learning environments.

The bibliographic analysis allowed us to develop a criterion framework for comparing PE learning in different formats (see Table 1).

Table 1. *Comparative evaluation of traditional, blended and e-formats of physical education*

Criteria	**Format**		
	Traditional	*Blended*	*Electronic*
Accessibility	Limited by time/place and institutional capacity; may exclude remote or mobility-impaired students unless adaptations are made	Partially flexible: e-learning components can be accessed remotely but still require some physical presence; more flexible than traditional but still dependent on available infrastructure	Highest flexibility (accessible from anywhere with internet access); allows for variable pace of learning; however, depends on access to devices and connectivity, which risks excluding students with limited resources
Effectiveness	High for teaching practical skills with immediate feedback; learning can be mechanical and less individualized	Personalized practice supplemented by electronic resources (video, interactive) can enhance learning; effectiveness depends on quality of integration	Effective for providing theoretical content and independent practice; may be less effective for teaching complex motor skills without live demonstration and correction
Motivation	Strong peer interaction and group activities increase motivation; risk of boredom with typical activities	Offers the novelty of technology to re-engage students; balances social contact with personalized learning	Can use gamification and interactivity to motivate; lack of face-to-face interaction may require more external incentives and monitoring to maintain student engagement
Teacher support	Daily personal mentoring, collaborative planning with colleagues; familiar technology requirements	Requires technical and pedagogical support: collaboration with internet and networking specialists, but still some support at the school	Requires robust digital support and training; teachers can feel isolated without the support of colleagues, so online mentoring and communities of practice are critical
Flexibility of content	Rigid timetable and curriculum; limited ability to reuse materials or activities, except for whole-class adaptations	Some components of the curriculum can be easily reused or adjusted; more flexible scheduling than in the traditional format	Content (videos, simulations, reading materials) can be updated, reused and individualized; allows for asynchronous and differentiated learning paths
Assessment	Proficiency tests and paper-based assessments; direct observation provides validity but is time-consuming; some subjectivity/bias is possible	Practical tests in the classroom combined with iterative and project portfolio assessment; use of digital tracking to obtain objective data	Mostly interactive activities, video recordings of learning tasks, physical activity and learning progress data; automated assessment and rich analytics, but concerns about validity and need for digital literacy

Criteria	Format		
	Traditional	*Blended*	*Electronic*
Inclusion	Depends on teacher adaptation and face-to-face adaptive physical education strategies; students with disabilities may require aides or modifications to the classroom setting	Integrate digital adaptive tools (subtitles, adjustable difficulty) and allow for differentiated learning pace; physical limitations still exist; consequently, accessible learning spaces need to be provided	Multimedia and stand-alone modules can be adapted for different needs; but learners with disabilities need built-in adaptations (subtitles, alternative inputs), and some activities may be difficult to reproduce remotely
Sustainability	Requires physical space, equipment, and student travel (greater use of resources)	Reduced travel and use of consumables; still requires maintenance of facilities; potentially achieving a balance in resource use	Environmentally friendly (minimal travel, digital materials); however, potentially increased screen time; pedagogically, very scalable and cost-effective after careful and costly development

The F2F format of a PE course offers directly hands-on skill development activities in a close social interaction environment. The F2F format is limited by a fixed schedule and potential barriers for some students (reduced opportunities for inclusiveness). BL combines traditional and electronic elements, which improves the flexibility and variety of course activities, with continued support for personal contact. EL is characterized by the greatest flexibility of the course and the use of digital learning innovations (personal learning trajectories, total use of multimedia content, etc.), but is highly dependent on access to technology and requires careful design (preferably with the involvement of IT professionals) and organization to maintain inclusivity and motivation.

We need to understand what trade-offs are available to make a positive judgment about the effectiveness of PE learning in different formats. To establish the feasibility of applying these criteria, a questionnaire (whose initial version contained 20 questions) was developed to survey PE professionals (please refer to the Appendix).

For the confidential survey (regarding the participants' awareness of each other), 36 respondents were voluntarily involved. They were invited to participate and specially selected. Out of the planned 60 participants (this number was determined while taking into account the capacities of the research team), we were able to obtain consent to participate from only 36 respondents who met the inclusion criteria: experience as a physical education teacher/teacher for the last 5 years (no later than 2020) without long breaks (no more than 4 consecutive months); mandatory experience in teaching physical education in F2F format for at least 1 academic year; experience in BL/EL for at least 1 academic year. The inclusion criteria were adapted in the format of a consent questionnaire and sent to potential participants (184 consent questionnaires in total) via *gmail* no later than 21 days before the survey to the e-mail addresses that were obtained by analyzing the electronic pages of educational institutions/departments of physical education of higher education institutions. General characteristics of the sample were as follows: 16 respondents continue EL (online/mixed), whereas 20 respondents returned to the traditional format; 16 respondents represent Kharkiv region (EL), 6 respondents represent Kyiv region (F2F), 7 respondents

represent Sumy region (F2F), 7 respondents are from Dnipropetrovsk region (F2F); 12 respondents work in higher education institutions (EL/F2F), 6 respondents represent middle schools (EL/F2F), 2 respondents work in colleges (EL); the respondents' age is 38.60±9.75 years, gender – 12 women and 24 men. The participants were informed about the purpose of the survey, and, 10 days before the survey was conducted, all respondents received a table featuring "*Comparative assessment of traditional, blended and electronic physical education formats*" for review (delivered via *gmail*).

Table 2 presents the results of statistical processing of respondents' answers.

Table 2. *Results of the survey*

№	Question	Statistics	
		S	SD
1	Criteria are clearly defined and understandable without further explanation	3.89	0.57
2	The listed evaluation criteria are comprehensive for comparing physical education course formats	3.94	0.33
3	Assessment practices can be reliably compared across traditional, blended and distance learning formats	4.06	0.63
4	These criteria allow for meaningful comparison of courses with different objectives or content (e.g., physical education, sport-oriented learning, recreational or conditioning)	3.94	0.53
5	Accessibility of physical education courses can be assessed by using standardized survey or observation tools	4.03	0.65
6	I would consider using this framework in my own practice of teaching, learning or evaluating physical education curricula	3.44	0.69
7	I believe that this framework could be used to develop accreditation standards for physical education programs or training programs	3.50	0.85
8	Evaluating the effectiveness of physical education formats based on learning outcomes is practical for me	4.11	0.62
9	I believe that the application of these criteria can help improve the development of physical education curricula	4.03	0.29
10	Student motivation is a criterion that can be consistently measured in all teaching formats	4.11	0.57
11	Teacher support in practice is a measurable and manageable criterion	4.06	0.63
12	Flexibility of content is a significant and measurable criterion in the development of physical education courses	4.17	0.56
13	Sustainable development is a valid and evaluated criterion for the development of physical education courses	4.00	0.63
14	A comparative table makes it easier to understand the differences between learning formats	4.00	0.53
15	The proposed criteria correspond to my professional experience in physical education or sports training	3.97	0.29
16	I am confident in applying these criteria when evaluating or developing a physical education course	3.83	0.65
17	The course evaluation structure can be adapted to different age groups and educational institutions	3.97	0.61
18	The inclusiveness of the learning format can be objectively assessed	4.08	0.50
19	Additional training or guidance is needed to effectively apply the evaluation criteria	3.47	0.81

Question 20 ("These criteria reflect the most important factors of a quality PE course in different learning formats") was excluded from further factor analysis because all participants of the study marked it with 4 points (M = 4; SD = 0). The factor analysis of the 19-item questionnaire (principal components analysis and Varimax) allowed us to identify four distinct components of the survey (Fig. 2). The test (MSA = 0.65) and Bartlett's test (p<0.001) were satisfactory. Together, these four factors account for the bulk of the variance (80.15% of the total variance). Each factor contains several items with loadings >0.70 and minimal cross-loadings. Factor 1 includes eight questions (Q3, Q5, Q8, Q10, Q12, Q13, Q18, Q19) related to the practical feasibility and implementation of the course in different formats. Factor 2 includes five questions (Q1, Q4, Q14, Q16, Q17) related to the clarity of the training and pedagogical quality. Factor 3 includes three questions (Q6, Q7, Q11) about the relevance and consistency of the criteria for evaluating the course content with the relevant educational standards and requirements of the educational institution. Factor 4 includes two questions (Q9, Q15) reflecting student involvement and support. Question 2 had a factor load of 0.67. After it was excluded from the analysis, the composition and factor loadings for the factors did not change. It is important for analyzing the relevance of the selected evaluation criteria. In further cases of using the questionnaire to clarify the results, it will be retained.

The internal consistency of the items indicates reliability of the questionnaire (α = 0.80).

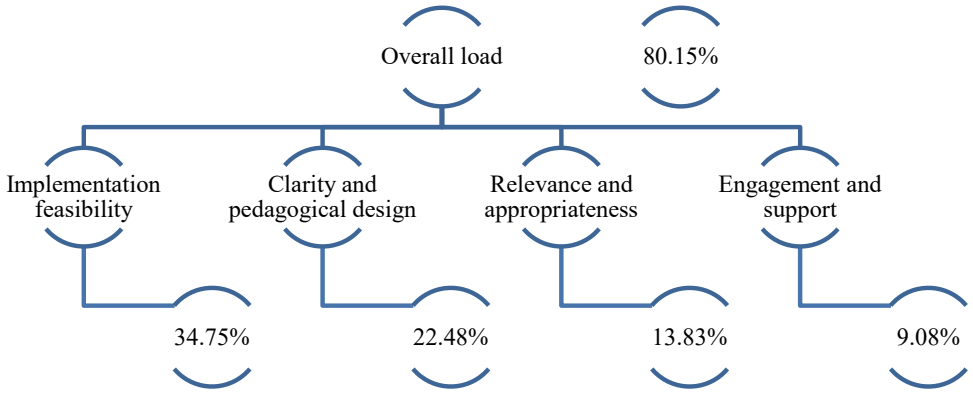

Figure 2. *Factor structure of the survey results*

Note. Developed by the authors on the basis of the research results.

In total, the answers to 18 questions (Q1–Q19, i.e., all questions except for Q2) were used for the discussion. The factors were named according to the common content of the items with high loadings that made up the factor. Factor 1 was labeled "Feasibility of implementation", and its items are related to logistical and resource issues (such as facilities, feasibility, and teacher readiness) that make a PE course feasible to develop and implement. Factor 2 was labeled "Clarity and pedagogical design", and its items are related to the clarity of the learning objectives, coherent course structure, and the quality of learning materials. Factor 3 was designated as "Relevance and appropriateness", and

it included items related to compliance with curriculum standards, requirements, and the course's alignment with the institution's internal regulations. Factor 4 was labeled "Involvement and support", and its items are related to student motivation, opportunities for involvement, and the adequacy of the teacher's leadership in the course. Each factor can be considered thematically separate, which speaks in favor of the completeness of the questions asked.

No significant differences were found between respondents still pursuing EL (online/mixed) and those who returned to F2F (all $p>0.05$); therefore, we report pooled results for the entire sample (n = 36). Overall, the mean scores were generally above the neutral middle, which indicates generally positive evaluations of PE courses in different formats. On average, the items received moderately high scores, and the accompanying standard deviations reflect some variability, but not extreme discrepancy. Examining the specifics of the survey results reveals clear trends. With regard to the "Feasibility of Implementation" factor, items related to practicality (Q8, Q10), usability (Q12), and accessibility (Q18) generally had the highest mean values. The relatively low standard deviations for these items indicate a consensus among the respondents on the sufficiency of the selected criteria for comparing learning formats. The items of the factor "Clarity and pedagogical design" also received above-average mean values. The proposed evaluation criteria were generally perceived by the respondents as clear and well-structured (Q4, Q14). The standard deviations were moderate, within the limits of individual variability in understanding the design or context of the PE course in different formats. For the "Relevance and Appropriateness" factor (such as meeting curriculum standards; Q6 or institutional approval; Q7), the lowest mean scores and greater variability were reported. The teachers were less unanimous in stating that the proposed criteria meet the requirements for the development and assessment of PE courses in their institution. The items of the "Involvement and Support" factor were also rated positively on average. The teachers involved believe that the selected criteria can contribute to the development of quality PE courses in different formats (Q9), taking into account their experience (Q15). The variability of answers was insignificant, which indicates the unanimity of the respondents on the possibilities of successful implementation of their own experience in the development of courses in different formats.

Let us consider the results of the survey in the context of the established cluster structure of digital transformation in physical education. In the context of the main thesis – specifically, the drift of PE courses "from classroom to screen" – concerns about implementation and technology become paramount, a fact that is associated with a moment-by-moment analysis of the feasibility of such a transformation. The practical requirements of different modalities (traditional, blended, e-learning), as well as other specific features of PE course formatting, need to be clearly distinguished. It is essential to develop logistics (selection of equipment, educational infrastructure, training of teachers and staff) for digital PE activities or the use of its elements. The main idea is that proper preparation for the introduction of digital tools is a critical factor in the success of learning. Only in this case can we expect to maintain students' motivation and engagement in the context of 'learning without co-

ercion', which is in line with the concept that technology-enhanced PE is effective if it is pedagogically supported. Accordingly, along with the ongoing analysis of the feasibility of digitalizing PE, there is a constant need for well-designed content and learning, regardless of the way it is delivered. Educational models involve the use of technologies that are pedagogically sound rather than selected on a 'just because' basis. Relevance is often defined as whether the goals of the intervention meet the needs and requirements of the educational institution for PE courses. Thus, all education stakeholders should evaluate courses for their relevance to curriculum and strategic goals – essentially by asking whether digital transformation is 'doing the right thing'.

The synthesis of the empirically identified four-factor model with the cluster analysis results facilitates the formulation of applied recommendations for designing contemporary PE courses. Specifically, the intersection of Factor 1 (implementation feasibility) and Cluster 1 (technology) indicates that course design must commence with a technical accessibility audit and the integration of Universal design for learning principles to mitigate the digital divide. Pedagogical design (Factor 2), aligned with Cluster 2 (pedagogy), should be anchored in andragogical principles, shifting the focus from didactic lecturing to facilitation. More specifically, we propose the utilization of video feedback for the correction of motor skills and the development of problem-based tasks that foster student autonomy. Furthermore, the empirical validation of Factor 4 (engagement and support) within the context of Cluster 3 (human interaction) justifies the incorporation of self-monitoring tools (e.g., wearable devices) and gamification elements, which directly enhance intrinsic motivation according to Self-determination theory. Finally, Factor 3 (relevance and appropriateness) requires developers to align digital innovations with national standards and ethical data frameworks, thereby ensuring the sustainability of the educational process.

Limitations

Despite the significance of the findings, this study is subject to several limitations that should be considered when extrapolating the results. First, the sample size is relatively modest, which is a consequence of the stringent inclusion criteria employed. Expanding the respondent pool in future studies would enhance the statistical power and generalizability of the conclusions. Second, the presence of regional specificity may reflect a particular socio-cultural and infrastructural context, potentially influencing perceptions of the digital transformation in physical education. Furthermore, it should be noted that one-third of the sample consists of representatives from higher education institutions. This composition may introduce a bias, stemming from shifting the evaluative focus toward the academic environment rather than primary/secondary schools or colleges.

Conclusions

In the light of the research topic, the results are explainable and meaningful. The clustering of the research field reflects the multifaceted digital transformation of PE in dif-

ferent modalities. The key area of research in Cluster 1 is related to the development of distance education in PE. Cluster 2 research is consistent with the concept of a 'blended model' of PE. Cluster 3 research focuses on the impact of digital tools that complement F2F classes. The conceptual relationships are clear: Cluster 1's emphasis on technology and pedagogy underpins the understanding of the appropriateness of technologies used in course delivery scenarios in the context of Clusters 2 and 3; Cluster 2's focus on enrollment and attitudes is related to Cluster 3's concerns about engagement and health. In essence, the content of traditional physical education is being rethought through blended/distance methods (Cluster 1), adapted for different contexts (Cluster 2), and enriched with interactive digital tools in order to increase motivation and accessibility (Cluster 3).

The respondents, despite their experience with e-learning, implicitly perceive the opportunities and challenges of digital transformation of PE. When educators consider BL or EL in PE, they naturally separate the question "Can we do it?" from the questions "Will students learn well?" and "Does it meet our goals (or the requirements of the educational institution)?". Thus, the established factor structure provides an empirical basis for evaluating digital physical education formats: it confirms that technology-related feasibility and infrastructure issues stand out as a separate dimension (consistent with calls for sufficient teacher training and equal access), while pedagogical clarity and human engagement remain central educational considerations (in line with theories of effective technology integration). In conclusion, the factor analysis not only reveals the hidden structure of the respondents' attitudes towards the proposed evaluation criteria for PE courses, but also confirms the conceptual framework – technological, pedagogical and engagement factors (and their corresponding evaluation criteria) are indeed the main 'building blocks' of the evaluation framework for PE learning in different formats.

The findings have several practical implications. Teacher education programs should explicitly integrate digital pedagogy and inclusive practices through training in virtual coaching, gamified activity development, and the use of adaptive PE apps. Educational institutions also need to ensure that blended and online PE curricula meet the national standards by defining the range of competencies in digital learning and ensuring its accessibility, as well as developing teacher training programs and creating an ethical framework for the use of data in PE. Without ongoing professional development and technical support, hardware and software may be underutilized or misused. Teachers need to learn how to design appropriate task formats for remote delivery and how to interpret digital feedback. Teachers transitioning to distance learning may miss the collegial support of the classroom environment, which requires the development and maintenance of online communities to counteract the potential alienation of distance learning.

Summary

The study investigates the significant shift in physical education (PE) triggered by global digitalization and accelerated by the COVID-19 pandemic. The transition from traditional face-to-face (F2F) instruction to blended (BL) and mobile/e-learning (EL) formats presents unique challenges for a field traditionally dependent on physical presence. The

primary goal of this research was to examine these different educational modalities and develop a robust framework of criteria to compare and evaluate PE courses in various digital formats.

On the grounds of using *Vosviewer* for bibliometric analysis, the researchers identified three distinct thematic clusters defining the current landscape of e-learning in PE:

Cluster 1 (Technology). It focuses on the transition to distance and blended learning, emphasizing the use of mobile tools, MOOCs, and the general technological infrastructure needed for digital higher education.

Cluster 2 (Pedagogy). It centers on the human dimension, including inclusivity, adaptive physical education, and the perceptions of both teachers and students toward digital formats.

Cluster 3 (Human interaction). It explores the intersection of digital methodology and learner well-being, specifically, how technology impacts motivation, health, and active engagement.

A key outcome of the study is a comprehensive comparative table assessing traditional, blended, and electronic formats across several criteria:

1. Accessibility. While traditional PE is limited by time and place, EL offers the highest flexibility but risks excluding those without stable internet or specific devices.
2. Effectiveness. Traditional formats excel at immediate feedback for practical skills, whereas digital formats are effective for theoretical content and personalized, self-paced learning.
3. Motivation. Peer interaction drives traditional classes, while digital formats rely on gamification and interactive media to maintain engagement.
4. Teacher Role. Digitalization shifts the instructor's role from a didactic lecturer to a facilitator or coach, requiring new competencies in digital pedagogy and feedback interpretation.

To validate these criteria, the authors surveyed 36 PE professionals with experience in both traditional and digital teaching. A factor analysis of the results has identified four main components which are essential for a quality PE course in the digital age:

1. Feasibility of implementation. Logistical issues, resource availability, and teacher readiness.
2. Clarity and pedagogical design. Clear objectives, coherent structure, and high-quality materials.
3. Relevance and Compliance. Alignment with educational standards and institutional requirements.
4. Engagement and Support. Student motivation and the adequacy of teacher leadership.

The study concludes that no single format is universally superior; instead, blended approaches often provide a pragmatic balance. Successful digital transformation requires more than just 'moving physical activity online' – it demands a rethink of curricula based on autonomy, reflection, and inclusive design. The findings emphasize the urgent need

for professional development for teachers to master digital tools and ensure that digital inequality does not lead to educational exclusion.

Author contributions

Andrii Yefremenko: Methodology, Formal analysis;
Serhii Lebediev: Conceptualization, Supervision, Validation, Project administration;
Sviatoslav Koval: Writing – original draft preparation;
Alfiia Deineko: Writing – review and editing;
Ivan Kofanov: Data curation, Visualization.
All authors have read and agreed to the published version of the manuscript.

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Data availability statement

The research data are freely available at the link https://zenodo.org/records/15610813.

Conflicts of interest

The authors declare no conflict of interest.

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Declaration of AI and AI-assisted technologies

This work was supported by artificial intelligence (*Gemini* service), which was specifically employed to assist in formatting the bibliography in accordance with the journal's requirements.

Appendix

Additional materials are made available at the link https://zenodo.org/records/15610813.

References

Achuthan, K., Kolil, V. K., Muthupalani, S., & Raman, R. (2024). Transactional distance theory in distance learning: Past, current, and future research trends. *Contemporary Educational Technology, 16*(1), Article ep493. https://doi.org/10.30935/cedtech/14131

Adams, K., Belcher, D., Jenkins, A., & Goad, T. (2025). Utilizing video feedback for effective motor skill learning in online physical education. *International Journal of Kinesiology in Higher Education, 9*(1), 14–30. https://doi.org/10.1080/24711616.2024.2421764

Arfi, I., J., Wahyuri, A., Gusril, G., Rasyid, W., & Ockta, Y. (2024). Developing engaging audio-visual learning media for basic locomotor patterns through play-based activities for early learners. *Journal of Education, Teaching and Learning, 9*(1), 40–46. https://www.learntechlib.org/p/224749/

Ariski, P. A., Wahyuri, A. S., Khairuddin, K., & Chaeroni, A. (2024). Development of electronic modules in education to understanding through physical activity. *Journal Penelitian Pendidikan IPA, 10*(Special Issue), 749–753. https://doi.org/10.29303/jppipa.v10iSpecialIssue.7179

Bachman, C., & Scherer, R. (2015). Promoting student autonomy and competence using a hybrid model for teaching physical activity. *International Journal of Instruction, 8*(1), 3–18. https://doi.org/10.12973/iji.2015.811a

Barthakur, S., Joksimovic, S., Kovanovic, V., Corbett, F. C., Richey, M., & Pardo, A. (2022). Assessing the sequencing of learning objectives in a study program using evidence-based practice. *Assessment & Evaluation in Higher Education, 47*(8), 1429–1443. https://doi.org/10.1080/02602938.2022.2064971

Beard, J., & Konukman, F. (2020). Teaching online physical education: The art of connection in the digital classroom. *Journal of Physical Education, Recreation & Dance, 91*(6), 49–51. https://doi.org/10.1080/07303084.2020.1785772

Bikalawan, S. S., Kristiyandaru, A., Al Ardha, M. A., Nurhasan, N., Herista, S. V. W., Legeayem, T. R., & Umarushalih, N. (2025). Identifying the evolution of learning methods in physical education: A systematic review of modern approaches and digital integration. *Physical Education Theory and Methodology, 25*(2), 454–466. https://doi.org/10.17309/tmfv.2025.2.28

Bourke, M., Bruijns, B. A., Saravanamuttoo, K., Vanderloo, L. M., & Tucker, P. (2024). Efficacy of a physical activity e-learning course delivered to early childhood educators on preschoolers' physical activity and sedentary behaviors: A cluster randomized controlled trial. *Pediatric Exercise Science*, *37*(3), 302–310. https://doi.org/10.1123/pes.2023-0180

Buchem, K., Merceron, A., Kreutel, J., Haesner, M., & Steinert, A. (2015). Wearable enhanced learning for healthy ageing: Conceptual framework and architecture of the "Fitness MOOC." *Interaction Design and Architectures, 24*, 111–124. https://doi.org/10.55612/s-5002-024-007

Cerezo, R., Bogarin, A., Esteban, M., & Romero, C. (2020). Process mining for self-regulated learning assessment in e-learning. *Journal of Computing in Higher Education, 32*(1), 74–88. https://doi.org/10.1007/s12528-019-09225-y

Charbonneau-Gowdy, P. (2018). Beyond stalemate: Seeking solutions to challenges in online and blended learning programs. *Electronic Journal of E-Learning, 16*(1), 56–66. https://academic-publishing.org/index.php/ejel/article/view/1856/1819

Chen, K.-Z., Lowenthal, P. R., & Bauer, C. (2016). Effectiveness and student perceptions of high-enrolment health studies online courses. *Health Education Journal, 75*(3), 343–357. https://doi.org/10.1177/0017896915581060

Dispo, G. A. N., Magat, S. M. C., Arambulo, A. L., & De Guzman, F. (2024). Lived experiences of students with visual impairment in virtual physical education learning during the COVID-19 pandemic. *British Journal of Visual Impairment, 44*(1), 122–140. https://doi.org/10.1177/02646196241305288

Gao, Y., Zhu, L., & Tian, M. (2025). SWOT analysis of the application of three digital media in OLPE physical education teaching: Edmodo, Zoom, and Google Meet. *BMC Medical Education, 25*(1), Article 243. https://doi.org/10.1186/s12909-025-06826-3

Griffiths, M. A., Goodyear, V. A., & Armour, K. M. (2022). Massive open online courses (MOOCs) for professional development: Meeting the needs and expectations of physical education teachers and youth sport coaches. *Physical Education and Sport Pedagogy, 27*(3), 276–290. https://doi.org/10.1080/17408989.2021.1874901

Haffyandi, R. A., Kahri, M., & Ganeswara, R. (2024). Online physical education (OLPE) and its influence on high school students' life skills. *Multilateral: Jurnal Pendidikan Jasmani dan Olahraga, 24*(1), 18–31. https://doi.org/10.20527/multilateral.v24i1.20759

Hawthorne, I., Bourke, M., Bruijns, B. A., Vanderloo, L. M., Irwin, J. D., Heydon, R., ... Tucker, P. (2025). The efficacy of the TEACH e-learning course at improving early childhood education students' physical activity and sedentary behaviour related self-efficacy, knowledge, intentions, and perceived behavioural control. *Early Childhood Education Journal*, 54, 645–660. https://doi.org/10.1007/s10643-025-01855-5

Healy, S., Colombo-Dougovito, A., Judge, J., Kwon, E., Strehli, I., & Block, M. E. (2017). A practical guide to the development of an online course in adapted physical education. *Palaestra, 31*(2), 48–54. https://www.js.sagamorepub.com/palaestra/article/view/8433

Hsia, L. H., Hwang, G. J., & Hwang, J. P. (2024). AI-facilitated reflective practice in physical education: An auto-assessment and feedback approach. *Interactive Learning Environments, 32*(8), 5267–5286. https://doi.org/10.1080/10494820.2023.2212712

Hsu, H.-C. K., Wang, C. V., & Levesque-Bristol, C. (2019). Reexamining the impact of self-determination theory on learning outcomes in the online learning environment. *Education and Information Technologies,* 24, 2159–2174. https://doi.org/10.1007/s10639-019-09863-w

Indarto, P., Nasuka, N., Hidayatullah, M. F., Sulaiman, S., Setyawati, H., Raharjo, H. P., & Suryadi, D. (2024). What is the learning model of physical education in the digital era?: Literature review of various studies. *Retos,* 61, 156–163. https://doi.org/10.47197/retos.v61.109583

Işıkgöz, M. E. (2024). Traditional classroom management to virtual classroom management: A study on physical education teachers' competencies. *SAGE Open, 14*(2). https://doi.org/10.1177/21582440241305211

Kelly, E., Clinton-Lisell, V., & Klein, K. A. (2022). Enhancing college students' online group work perceptions and skills using a utility-value intervention. *Online Learning, 26*(3), 236–258. https://doi.org/10.24059/olj.v26i3.2807

Kelly, I. (2022). Building on students' perspectives on moving to online learning during the COVID-19 pandemic. *The Canadian Journal for the Scholarship of Teaching and Learning, 13*(1), Article 4. https://doi.org/10.5206/cjsotlrcacea.2022.1.10775

Kim, G., & Gurvitch, R. (2020). Online education research adopting the Community of Inquiry framework: A systematic review. *Quest, 72*(4), 395–409. https://doi.org/10.1080/00336297.2020.1761843

Kooiman, B. J., Sheehan, D. P., Wesolek, M., & Reategui, E. (2016). Exergaming for physical activity in online physical education. *International Journal of Distance Education Technologies, 14*(2), 1–16. https://doi.org/10.4018/IJDET.2016040101

Kulak, J. A., & Forder, M. (2024). Maintaining course quality and integrity across multiple modalities. *Pedagogy in Health Promotion, 10*(3), 262–270. https://doi.org/10.1177/23733799231220657

Lander, K., Lewis, S., Nahavandi, D., Amsbury, K., & Barnett, L. M. (2022). Teacher perspectives of online continuing professional development in physical education. *Sport, Education and Society, 27*(4), 434–448. https://doi.org/10.1080/13573322.2020.1862785

Lee, C.-A., Tzeng, J.-W., Huang, N.-F., & Su, Y.-S. (2021). Prediction of student performance in massive open online courses using deep learning system based on learning behaviors. *Educational Technology & Society, 24*(3), 130–146. http://index.j-ets.net/Published/24_3/ETS_24_3_10.pdf

Li, J., & Wang, R. (2024). Determining the role of innovative teaching practices, sustainable learning, and the adoption of e-learning tools in leveraging academic motivation for students' mental well-being. *BMC Psychology, 12*(1), Article 163. https://doi.org/10.1186/s40359-024-01639-3

Li, S., Wang, C., & Wang, Y. (2024). Fuzzy evaluation model for physical education teaching methods in colleges and universities using artificial intelligence. *Scientific Reports, 14*, Article 4788. https://doi.org/10.1038/s41598-024-53177-y

Lin, S. (2025). Assessment of digital skills of university MOOC instructors: A systematic quantitative study of multidimensional indicators. *Interactive Learning Environments, 33*(5), 3425–3445. https://doi.org/10.1080/10494820.2024.2444530

Liu, Q. (2023). Cloud computing-based online video sports course management. *Soft Computing, 28*(2), 751. https://doi.org/10.1007/s00500-023-08937-9

Liu, Y., & Zhu, T. (2020). Individualized new teaching mode for sports biomechanics based on big data. *International Journal of Emerging Technologies in Learning, 15*(20), 130–144. https://doi.org/10.3991/ijet.v15i20.17401

Loh, I., Bourke, M., Saravanamuttoo, K., Bruijns, B. A., & Tucker, P. (2024). The impact of an early childhood educator e-learning course on young children's fundamental movement skills: A cluster randomized

controlled trial. *Journal of Sports Sciences, 42*(18), 1635–1643. https://doi.org/10.1080/02640414.2024.2404777

Matolic, A., T., Jurakic, D., & Pedisic, Z. (2024). Raising awareness of the Sports Club for Health (SCforH) guidelines in the sports, higher education, and health promotion sectors: Evaluation of an educational online intervention in 34 European countries. *Acta Gymnica,* 54, Article e2024005. https://doi.org/10.5507/ag.2024.005

Michael, R., Webster, C. A., Nilges, L., Brian, A., Johnson, R., Carson, R., & Egan, C. A. (2019). An online course to prepare preservice teachers to promote movement integration. *American Journal of Distance Education, 33*(1), 59–70. https://doi.org/10.1080/08923647.2019.1555408

Mokmin, N. A. M., & Rassy, R. P. (2024). Review of the trends in the use of augmented reality technology for students with disabilities when learning physical education. *Education and Information Technologies,* 29, 1251–1277. https://doi.org/10.1007/s10639-022-11550-2

Mulato, N., Hidayatullah, M. F., Purnama, S. K., & Syaifullah, R. (2024). Optimization of learning physical education in digital era: A systematic review. *Retos,* 54, 844–849. https://doi.org/10.47197/retos.v54.105211

Olobia, L. P. (2024). Tales of online learner autonomy: Highlights and challenges in the disruptive age. *Studies in Self-Access Learning Journal, 15*(3), 564–574. https://doi.org/10.37237/150313

Pürgstaller, E., Schmeling, J., Barkemeyer, L., Ullmann, M., & Koal, K. (2025). Attitudes of physical education teachers and student teachers regarding digital media in physical education: A systematic review. *German Journal of Exercise and Sport Research*, *55*, 1–14. https://doi.org/10.1007/s12662-025-01035-y

Rakha, H. (2025). Promoting online teaching through active learning strategies: Applications and innovations. *Frontiers in Education,* 10, Article 1546208. https://doi.org/10.3389/feduc.2025.1546208

Rathod, P., & Kamppi, P. (2025). Improving online and e-learning education through train-the-trainer model: A case study of European innovation project ECOLHE. *European Journal of Education, 60*(1), Article e12900. https://doi.org/10.1111/ejed.12900

Risma, N., Bakhtiar, S., Umar, & Zarya, F. (2025). Improving students' martial arts skills and fitness through an innovative e-module. *Sport TK-Revista Euroamericana de Ciencias del Deporte,* 14, Article 12. https://doi.org/10.6018/sportk.567171

Rugube, T. T., Chibaya, C., & Govender, D. W. (2022). A software design model for integrating LMS and MOOCs. *Journal of Information Technology Research, 15(1), 1–14. https://doi.org/10.4018/JITR.299375*

Salimi, M., & Moslehi, L. (2023). Identification of qualitative indicators of physical education students' online courses during the COVID-19 outbreak. *International Journal of Learning Technology, 18*(3), 260–278. https://doi.org/10.1504/IJLT.2023.134580

Sankaranarayanan, S. R., Kandimalla, S. R., Cao, M., Maronna, I., An, H., Bogart, C., ... Rose, C. P. (2020). Designing for learning during collaborative projects online: Tools and takeaways. *Information and Learning Sciences, 121*(7/8), 569–577. https://doi.org/10.1108/ILS-04-2020-0095

Sato, T., & Haegele, J. A. (2017). Professional development in adapted physical education with graduate web-based professional learning. *Physical Education and Sport Pedagogy, 22*(6), 618–631. https://doi.org/10.1080/17408989.2017.1310832

Sato, T., & Haegele, J. A. (2018). Physical educators' engagement in online adapted physical education graduate professional development. *Professional Development in Education, 44*(2), 272–286. https://doi.org/10.1080/19415257.2017.1288651

Sato, T., Haegele, J. A., & Foot, R. (2017). In-service physical educators' experiences of online adapted physical education endorsement courses. *Adapted Physical Activity Quarterly, 34*(2), 162–178. https://doi.org/10.1123/apaq.2016-0002

Shen, W., Liang, J., Xu, S., & Wei, Y. (2022). Research on online course teaching of public physical education in universities under the pandemic situation. *Information Resources Management Journal, 35*(3), 1–14. https://doi.org/10.4018/IRMJ.304451

Stallwood, I., Adu, P. A., Tairyan, K., Astle, B., & Yassi, A. (2020). Applying equity-centered principles in an interprofessional global health course: A mixed methods study. *BMC Medical Education,* 20, Article 224. https://doi.org/10.1186/s12909-020-02141-1

Suryadi, D., Okilanda, A., Nofrizal, D., Suganda, M. A., Tulyakul, S., Ahmed, M., & Bastian, R. H. (2024). How does cooperative learning work with students?: Literature review in physical education. *Retos*, 55, 527–535. https://doi.org/10.47197/retos.v55.105256

Tagimaucia, V., D'Souza, G. S., & Chand, S. P. (2024). Exploring online physical education teaching: What have we done and what have we learnt? *International Review of Research in Open and Distributed Learning, 25*(1), 127–151. https://doi.org/10.19173/irrodl.v25i1.7431

Tian, J., & Guo, Z. (2025). Exploring the role of AR in physical education: Challenges and opportunities for socialization. *International Journal of Human–Computer Interaction*, *41*(17), 10527–10537. https://doi.org/10.1080/10447318.2024.2434960

Tjitroharjo, Y., Nopembri, S., & Kriswanto, E. S. (2024). The challenge of implementing mobile learning in physical education: A comprehensive literature review. In *Proceedings of the 2nd Annual International Conference: Reimagining Guidance and Counselling in the VUCA Era (AICGC 2023)* (pp. 25–33). Atlantis Press. https://doi.org/10.2991/978-2-38476-234-7_4

Walker, E. R., Lang, D. L., Alperin, M., Vu, M., Barry, C. M., & Gaydos, L. M. (2021). Comparing student learning, satisfaction, and experiences between hybrid and in-person course modalities: A comprehensive, mixed-methods evaluation of five public health courses. *Pedagogy in Health Promotion, 7*(1), 29–37. https://doi.org/10.1177/2373379920963660

Webster, C. A., D'Agostino, E., Urtel, M., McMullen, J., Culp, B., Egan Loiacono, C. A., & Killian, C. (2021). Physical education in the COVID era: Considerations for online program delivery using the Comprehensive School Physical Activity Program framework. *Journal of Teaching in Physical Education, 40*(2), 327–336. https://doi.org/10.1123/jtpe.2020-0182

Zeide, E., & Nissenbaum, H. (2018). Learner privacy in MOOCs and virtual education. *Theory and Research in Education, 16*(3), 280–307. https://doi.org/10.1177/1477878518815340

Zhao, M., Lu, X., Zhang, Q., Zhao, R., Wu, B., Huang, S., & Li. S. (2024). Effects of exergames on student physical education learning in the context of the artificial intelligence era: A meta-analysis. *Scientific Reports,* 14, Article 7115. https://doi.org/10.1038/s41598-024-57357-8

Zhou, Z., Cai, L., Guo, J., Zhang, Y., Chang, B., Xu, T., & Wang, Y. (2024). ExeVis: Concept-based visualization of exercises in online learning. *Journal of Visualization, 27*, 235–254. https://doi.org/10.1007/s12650-024-00956-4