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Health promotion through digital media in physical education: a qualitative interview study on student experiences and acceptance

Supplementary Information

The online version of this article (https://doi.org/10.1007/s12662-026-01133-5) contains supplementary material, which is available to authorized users.

Introduction

The digital transformation has permeated almost every area of life, offering schools new opportunities to enhance teaching and learning (Wohlfart & Wagner, 2025). In physical education, digital media are not limited to conventional instructional digital formats such as videos or interactive whiteboards. They also encompass digital tools and platforms such as apps, tracking tools, and social media that facilitate access to health-related information and support individualized learning processes relevant to both health promotion and health literacy development (Sorokolit, Shevtsiv, Bodnar, Shymanova-Stefanyshyn, & Rymar, 2025).

This shift opens up considerable potential for promoting students' health and fostering competencies that enable students to access, understand, and critically reflect on health-related information in digital contexts (Knoke, Woll, & Wagner, 2024). In this sense, health promotion in physical education is closely linked to the development of health literacy, as health-promoting behaviours increasingly depend on students' ability to navigate digital health information and tools. Despite these opportunities, studies suggest that the full potential of digital media for health promotion in PE remains largely untapped, particularly regarding its pedagogical integration and alignment with broader health education goals (Jastrow, Greve, Thumel, & Brandl-Bredenbeck, 2022).

Numerous studies (e.g. Gómez-García, Marín-Marín, & Romero-Rodríguez, 2020; Jastrow et al., 2022) have demonstrated that digital media can improve student motivation and learning outcomes, compared to traditional educational practices. However, there is a lack of systematic analyses examining students' actual experiences with and acceptance of digital media in PE, especially regarding health promotion processes and the development of health literacy (Knoke et al., 2024).

To better understand and optimize this integration, theoretical models such as the Technology Acceptance Model (TAM) and Nutbeam's Health Literacy Model (2000) offer valuable frameworks, but these have rarely been examined or contextually adapted with regard to the subject-specific demands of PE and digital health promotion. Given the rising relevance of both digital and health literacy in school curricula (Gómez-García et al., 2020), exploring how students perceive and accept digital tools and formats in PE is a critical step toward informed implementation strategies for health-promoting practice.

Technology acceptance model (TAM)

The Technology Acceptance Model (*TAM*; Davis et al., 1989) is a widely used theoretical framework for analysing users' acceptance of technology. It was originally developed to predict computer usage behaviour and has since been applied to various domains, including education. The model posits that two central beliefs, *Perceived Usefulness (PU)* and *Perceived Ease of Use (PEOU)*—determine users' attitudes toward a technology, which in turn influence their *Behavioural Intention to Use (BI)* and ultimately their *Actual System Use*.

Perceived Usefulness refers to the extent to which a person believes that using a particular technology will enhance their performance. In physical education, this may include whether digital tools help students better understand movement, improve fitness, or access relevant health information.

Perceived Ease of Use captures how effortless the use of a technology appears to be. This includes aspects such as intuitive design, technical reliability, and the clarity of instructions, important factors when integrating digital tools or formats in PE settings.

Both constructs are influenced by *External Variables*, such as the availability of technical infrastructure, teachers' digital competence, or institutional support,

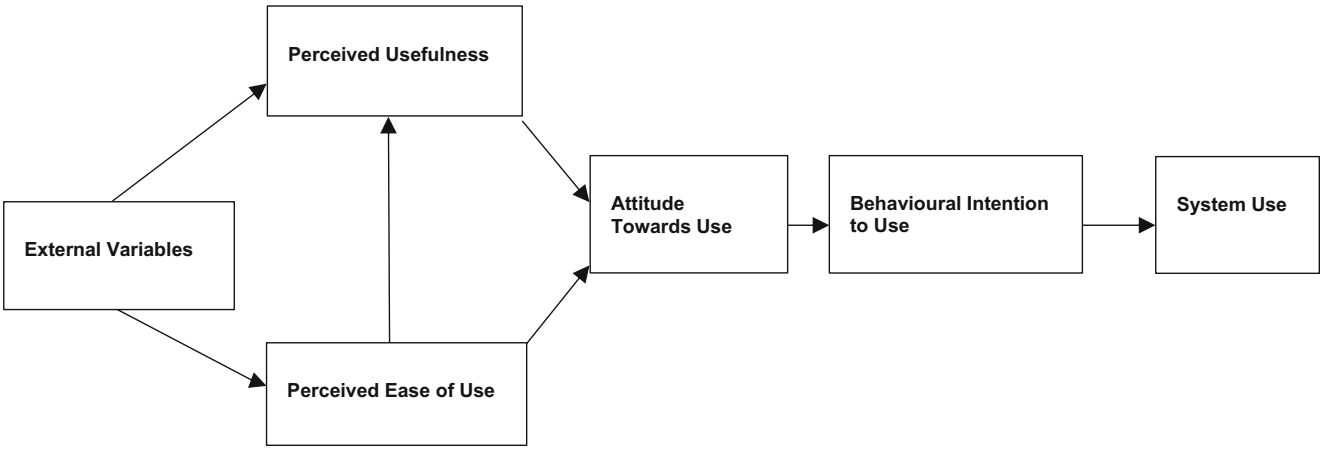

Fig. 1 ▲ The Technology Acceptance Model (TAM) according to Davis et al. (1989). The model illustrates the relationships between perceived usefulness, perceived ease of use, attitude toward use, behavioural intention, and system use, with external variables influencing acceptance processes

which indirectly shape acceptance behaviour. These beliefs shape the *Attitude Toward Use*, which, together with *Perceived Usefulness*, forms the *Behavioural Intention to Use*, leading to the *Actual Use of the System*.

TAM has been extended in many ways (e.g., *TAM2*), but in this study the original model serves as a foundation for examining students' acceptance of digital media in physical education and offers a structured way to interpret the motivational and contextual factors that influence technology use from a school student perspective.

Because technology use in school settings is shaped by contextual conditions, the choice of an acceptance framework required careful consideration. Although extended models such as TAM2 or UTAUT explicitly incorporate constructs such as social influence and experience, the original Technology Acceptance Model (Davis et al., 1989) was deliberately chosen for this study due to its parsimony and strong suitability for exploratory, qualitative research. The aim was not to predict technology use quantitatively, but to gain in-depth insights into students' subjective experiences, evaluations, and acceptance of digital media in school-based physical education.

Contextual factors relevant to the school setting—including voluntariness of use, prior experience with digital media, and social influences from teachers or peers—are captured through the model's external variables and the qualitative interview design. This allows divergent student experiences to be explored while maintaining a clear and transparent analytical framework. Accordingly, the original TAM provides an appropriate and sufficiently flexible heuristic for analysing students' acceptance of digital media in physical education without extending the model to TAM2 or UTAUT (◘ **Fig. 1**).

Health literacy model

Health is widely recognized as a multidimensional construct, encompassing not only physical well-being but also mental and social dimensions (WHO, 1986). In this context, health literacy has emerged as a key determinant of health, reflecting the knowledge, motivation, and competencies required to access, understand, evaluate, and apply health information for decision-making in daily life (Sørensen et al., 2012). In school-based settings, health promotion is closely linked to health literacy, as health-promoting behaviours increasingly depend on students' competencies to access, interpret, and critically evaluate health information, particularly in digital environments (Nutbeam & Lloyd, 2020; Sørensen et al., 2012).

One of the most influential frameworks in this field is Nutbeam's (2000) three-level model of health literacy, which has been widely applied in health promotion and educational research (Nutbeam, 2000; Sørensen et al., 2012). Nutbeam's Health Literacy Model (HLM) distinguishes between three progressive levels: *functional health literacy* (basic reading and writing skills to understand health information), *communicative or interactive health literacy* (advanced cognitive and social skills to actively engage with information), and *critical health literacy* (critical analysis of information and empowerment for informed action) (Nutbeam, 2000). This hierarchical model underscores the idea that health education should move beyond factual knowledge toward reflective and participatory competencies (Nutbeam, 2000; Nutbeam & Lloyd, 2020). Nutbeam's Health Literacy Model (2000) was deliberately selected for this study due to its strong pedagogical and competence-oriented perspective, which aligns closely with the aims of school-based health promotion in physical education.

In contrast to more integrative public health frameworks, such as the model by Sørensen et al. (2012), which conceptualise health literacy primarily as a multidimensional population-level outcome, Nutbeam's model explicitly differentiates between functional, interactive, and critical competencies that can be systematically addressed through teaching and learning processes.

This staged structure is particularly suitable for qualitative, student-centred

research, as it allows learners' experiences with health-related information, communication, and critical reflection to be analysed in a differentiated manner. In the context of physical education, where health learning is embedded in practical, experiential, and increasingly digital environments, Nutbeam's (2000) model provides a clear heuristic for examining how students access, negotiate, and critically evaluate health-related information.

Building on this established framework, the present study operationalises Nutbeam's three levels of health literacy within digitally enriched PE settings. Digital media, including formats (e.g., videos) and tools/platforms (e.g., apps and tracking tools), are interpreted as pedagogical means through which functional (e.g., understanding health-related information), interactive (e.g., exchanging and reflecting on information), and critical (e.g., evaluating credibility and relevance) health literacy can be fostered in subject-specific ways, rather than as a separate form of literacy.

Given the increasing importance of digital media in young people's daily lives, there is growing recognition that traditional models of health literacy—such as Nutbeam's (2000) Health Literacy Model, the WHO's early conceptualizations of health literacy (WHO, 1986), or the integrated model by Sørensen et al. (2012), were primarily developed in contexts dominated by text-based and print-oriented health information.

Accordingly, these models require further specification and adaptation to include visual, auditory, and interactive forms of learning, which are particularly relevant in physical education (Goodyear, Armour, & Wood, 2019a; Riesmeyer, Hauswald, & Mergen, 2019). Digital media can provide alternative pathways to health information that do not necessarily rely on reading or textual comprehension (Knoke et al., 2024).

This highlights an unexploited potential of physical education to serve not only as a setting for physical activity, but also as a platform for fostering health literacy through digital media. Integrating digital health literacy in PE could empower students to make more informed decisions about physical activity and health-related behaviours (Nutbeam & Lloyd, 2020; Papastergiou, Kanaros, & Papamichou, 2021). In this study, health-related learning in physical education is understood in a holistic sense, encompassing knowledge and competencies related to physical activity, bodily responses, and health-related behaviours encountered in students' everyday lives. Accordingly, this study conceptualizes health literacy as a central competence-based pathway through which digital media may contribute to health promotion in physical education (**Fig. 2**).

Empirical state of research

The current state of research on the use of digital media to promote health in physical education (PE) is limited but growing. Initial findings indicate that digital media can have positive effects on PE by enhancing student engagement, motivation, and interaction between students and teachers (Hinojo-Lucena, López-Belmonte, & Cabrera, 2019). Furthermore, studies highlight key success factors for digital PE, such as providing sufficient technical support, offering teacher training in web-based environments, and maintaining ongoing student motivation (Yu & Jee, 2020).

In addition to boosting classroom dynamics, digital media have been shown to make PE content more attractive, even for students who are otherwise reluctant to participate in physical activities (Jastrow et al., 2022). Regarding fitness and health promotion, several studies confirm that fitness technologies can positively influence the development of motor skills and increase adolescents' willingness to participate in PE (Nesterchuk, Rabcheniuk, & Kuriata, 2021). Mobile apps allow the monitoring of health parameters such as physical activity and nutrition, while ex-

Abstract

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Abstract

Introduction. Digital media offer innovative opportunities to support health-related content and optimize learning processes in physical education (PE), yet their pedagogical integration in PE remains underexplored. This qualitative study aims to explore how secondary school students experience, evaluate, and accept the use of digital media for health promotion and the development of health literacy in PE.

Methods. Based on the Technology Acceptance Model (TAM; Davis, Bagozzi, & Warshaw, 1989) and Nutbeam's Health Literacy Model (Nutbeam, 2000), 15 semi-structured interviews with secondary school students were conducted and analysed using qualitative content analysis with MAXQDA. Key factors such as perceived usefulness, perceived ease of use, external factors, attitudes towards use, and behavioural intentions were identified.

Results. The findings indicate that students reported perceived benefits of digital media, including digital formats (e.g. videos) and digital tools (e.g. tracking tools, tablets, and apps), compared to non-digital PE practices, particularly regarding individualised learning and motivational support. At the same time, barriers such as inadequate technical infrastructure, limited digital competencies among teachers, and structural constraints were also noted.

Discussion. The findings suggest that students' acceptance of digital media in PE depends less on the mere presence of digital tools than on their perceived pedagogical value. Digital media were accepted when they supported individualisation, feedback, reflection, and health-related understanding without reducing movement time. The study extends TAM to health-promoting PE by showing that perceived usefulness and ease of use are closely linked to subject-specific conditions, particularly meaningful integration, privacy, and the preservation of PE as a movement-based subject.

Keywords

Physical education · Digital media · Health promotion · Health literacy · Technology Acceptance Model (TAM) · Qualitative content analysis

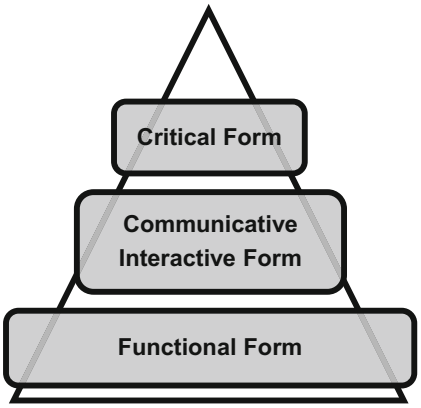

Fig. 2 ▲ Nutbeam's (2000) Health Literacy Model. The model distinguishes between functional, communicative-interactive, and critical health literacy as progressively related competence levels relevant to health promotion and education

ergames and social online learning platforms encourage students to take an active role in managing their health (Papastergiou et al., 2021).

Recent studies have also identified concrete tools for promoting physical activity in PE. Gil-Espinosa, Nielsen-Rodríguez, Romance, and Martínez-Olmo (2022), for example, identified 18 smartphone applications that can help teachers to effectively promote physical activity. Similarly, Villasana et al. (2020) demonstrated the motivational potential of health promotion apps, particularly in the areas of physical activity and healthy eating.

Importantly, digital media already form a natural part of young people's daily lives. Goodyear et al. (2019a) showed that approximately 35% of adolescents use apps or portable tools related to health, with a particular preference for applications focusing on physical activity and nutrition. These findings highlight the strong potential for PE and schools to influence young people's use of digital health technologies. However, young people emphasise the importance of content that is easy to understand and adapted to their personal situations (Goodyear et al., 2019a).

In the context of digital health promotion, it is also essential to consider the role of social media. Riesmeyer et al. (2019) pointed out that children and adolescents are increasingly exposed to health-related trends via social media, such as dietary information, which they may adopt without critical reflection. This underlines the need for media literacy education as part of health promotion in schools.

Further studies on tracking technologies show promising results in terms of increasing physical activity. Goodyear, Kerner, and Quennerstedt (2019b) found that adolescents were more physically active when using smartwatches that provided daily feedback on steps taken and calories burned, as this allowed for self-monitoring and social comparison. Similarly, positive effects on physical activity through digital media in PE were confirmed by Villasana et al. (2020) and Goodyear et al. (2019b), though it remains unclear which specific types of digital media are most effective for this purpose.

Research gap and questions

Despite encouraging developments, research on the systematic use of digital media to promote health literacy in physical education (PE) remains limited. Existing studies primarily address general applications of digital technologies in PE or examine their use outside the specific context of health promotion, while theory-informed, student-centred analyses focusing on health-related learning goals are scarce.

The aim of this study is to explore students' experiences with and acceptance of digital media in PE lessons designed to promote health and develop health literacy. Guided by the Technology Acceptance Model (TAM) and Nutbeam's Health Literacy Model (HLM), the study addresses the following research questions:

RQ1: What experiences do students report regarding the systematic use of digital media for health promotion and the development of health literacy in PE?
RQ2: To what extent do students accept the use of digital media in health-promoting PE lessons?

Methods

This qualitative, cross-sectional interview study explored secondary school students' experiences, evaluations, and acceptance of digital media use for health promotion and health-related learning in physical education (PE). This section describes the sampling and recruitment procedures, data collection, analytical approach, researcher reflexivity, and ethical considerations.

Sample and recruitment

Participants were recruited using purposive convenience sampling, aiming to include students with heterogeneous experiences of digital media use in physical education. Recruitment took place via school mailing lists and local sports clubs, with invitations distributed via email and personal contact. In total, 18 students were invited to participate; 15 provided informed consent and completed the interviews in German language. Three invited students declined participation due to time constraints.

The study sample comprised 15 voluntary participants aged between 12 and 19 years (M = 16.2), drawn from secondary schools. Gender distribution was 46.7% female ($n = 7$), 46.7% male ($n = 7$), and 6.6% identifying as diverse ($n = 1$). Inclusion criteria required current attendance in lower or upper secondary education or recent graduation, as well as prior experience with physical education lessons. All participants were anonymised using pseudonyms. Socio-demographic data (e.g. age, school type, school location, and duration of attendance) were collected following the interviews. In line with Creswell (2013), the sample size is appropriate for qualitative studies.

Data collection

Data were collected through semi-structured interviews, comprising one individual interview and five group interviews. Interviews were conducted online via video conferencing software (Zoom). No non-participants (e.g., parents or teachers) were present during

the interviews. In group interviews, participants were classmates or peers who already knew each other from school contexts.

The interview guide was developed based on the study's research questions and informed by the Technology Acceptance Model (Davis et al., 1989) and Nutbeam's Health Literacy Model (Nutbeam, 2000). It consisted of open-ended questions addressing students' experiences, evaluations, and acceptance of digital media use in physical education, with prompts related to health promotion and health-related learning. The interview guide was pilot-tested with two students of similar age who were not included in the final sample; minor adjustments to wording and sequencing were made.

Interviews lasted approximately 20–30 min., were audio-recorded with participants' consent, and transcribed verbatim by an external transcription service. Brief field notes were taken immediately after each interview to document contextual observations and initial analytical impressions; these notes were used to support interpretation but were not coded separately. No repeat interviews were conducted. Member checking was not undertaken. The transcripts were not returned to participants for comment or correction.

Data collection was discontinued once thematic sufficiency was reached, indicated by repetition of themes across interviews and no emergence of substantially new categories relevant to the research questions. Ongoing analysis during data collection informed this decision.

Data analysis

The analysis followed Mayring's (2000) qualitative content analysis using a structuring approach. MAXQDA (version 2022) was used to support data management and coding. Two researchers independently coded all transcripts. Prior to full coding, a subset of transcripts was jointly discussed to calibrate category understanding and coding rules. Disagreements were resolved through iterative consensus discussions, and coding decisions were documented to enhance transparency (Kuckartz, 2014). A formal statistical measure of intercoder reliability (e.g. Cohen's Kappa) was not calculated, as the analysis followed an interpretive qualitative content analysis approach focusing on consensual coding and iterative category refinement rather than measurement-oriented coding agreement. Instead, analytical rigor was ensured through independent coding, regular comparison of coding decisions, and iterative consensus discussions between the researchers (Kuckartz, 2014; Mayring, 2014).

The coding framework combined deductive main categories derived from the Technology Acceptance Model and Nutbeam's Health Literacy Model with inductively developed subcategories emerging from the data. Inductive subcategory development followed an open coding approach and was iteratively refined and aligned with the theoretical constructs. A concise coding tree (coder matrix) illustrating deductive and inductive categories is presented in **Fig. 3**.

Researcher characteristics and reflexivity

All interviews were conducted by the first author, a female researcher (PhD candidate) with a background in sport science and health education and prior training in qualitative research methods. There were no pre-existing personal relationships between the interviewer and the participants. Although some participants were recruited via school-related contexts or sports clubs, the interviewer was not involved in participants' teaching, assessment, or supervision. Participants were informed about the purpose of the study and the role of the researcher.

The researcher's academic background may have influenced the analytical focus on pedagogical and health-related aspects of digital media use. To address potential bias, the interview guide encouraged open-ended responses, and both positive and critical experiences were explicitly explored. In addition, independent coding by two researchers and iterative consensus discussions supported reflexivity and analytical rigor.

Ethics

The study was conducted in accordance with ethical standards for qualitative research. Ethical approval was obtained from the responsible institutional ethics committee. All participants received written information about the study aims, procedures, voluntary participation, and data protection. Written informed consent was obtained from all participants; for participants under the age of 18, written parental consent and participant assent were obtained. A complete COREQ checklist is provided as Supplementary Material S1.

Interviews were audio-recorded with permission, pseudonymised immediately after data collection, and stored on password-protected institutional servers accessible only to the research team. Personal identifying information was removed during transcription. Audio files were deleted after transcription and verification, and anonymised transcripts were retained for analysis in accordance with institutional data protection and retention policies.

Findings

The findings are structured according to the theoretical frameworks guiding the analysis. First, to ensure conceptual clarity, the presentation of findings is explicitly aligned with the core constructs of the Technology Acceptance Model (Davis et al., 1989), including external variables, perceived usefulness, perceived ease of use, attitudes toward use, behavioural intention, and system use. This is followed by findings related to Nutbeam's (2000) Health Literacy Model, addressing functional, communicative-interactive, and critical forms of health literacy. Themes related to efficiency, individualisation, feedback, and health-related learning are interpreted as perceived usefulness, while aspects of usability, technical reliability, data protection, and information credibility are assigned to perceived ease of use. Students' evaluative statements regarding the appropriateness and desirability of digital media in physical education are interpreted as attitudes toward use, whereas expressed intentions

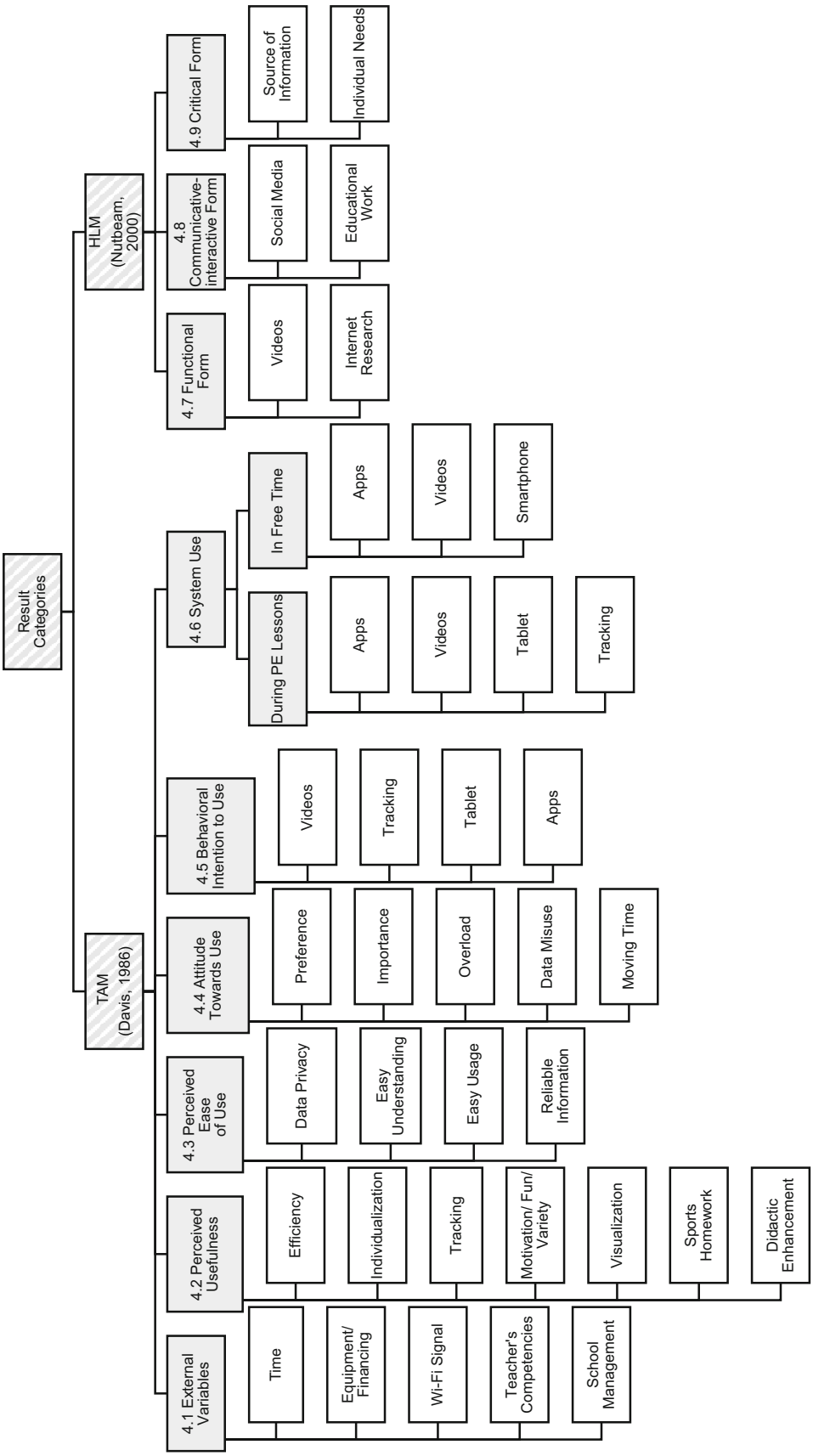

Fig. 3 ◄ Coder matrix illustrating the analytical framework. *Grey boxes* represent deductively derived main categories based on the Technology Acceptance Model (Davis et al., 1989) and Nutbeam's Health Literacy Model (Nutbeam, 2000), while *white boxes* indicate inductively developed subcategories emerging from the interview data. Subcategories were developed iteratively within each main category; differences in subcategory depth reflect empirical salience rather than predefined weighting

Table 1 Salience of Technology Acceptance Model (TAM)-related themes and exemplar quotations

TAM construct	Core theme	Salience across interviews	Exemplar quotation
External variables	Technical infrastructure (e.g., Wi-Fi, devices)	Present in most interviews	"If it just doesn't work, with the Wi-Fi or something, then too much time is lost." (F02)
External variables	Availability of financial and material resources	Reported by several participants	"It's quite expensive to finance […], that's why it's so difficult to finance tablets for students." (M05)
External variables	Teachers' digital competence and support	Present in most interviews	"Some teachers are not quite ready yet […] because they don't have a lot of experience with it." (M02)
Perceived usefulness	Individualisation and differentiation	Present in most interviews	"Different videos for different levels […] would make it much easier." (F03)
Perceived usefulness	Time efficiency and organisation	Reported by several participants	"You save a lot of time in sports lessons." (M03)
Perceived usefulness	Performance feedback and self-monitoring	Reported by several participants	"You can see your own data […] how your body reacts when you do sport." (M02)
Perceived ease of use	Simplicity and intuitive handling	Present in most interviews	"Easy to use, easy to understand." (M06)
Perceived ease of use	Data protection and privacy concerns	Reported by several participants	"Some people don't want to film themselves […] because you can see the face." (F01)
Attitude toward use	Digital media as meaningful complement to activity	Present in most interviews	"Digital media should support sport, not replace it." (F05)
Behavioural intention	Willingness to use digital media in PE	Present in most interviews	"I would like to use digital media more often in PE lessons." (M06)
System use	Limited use in PE, frequent use outside school	Present in most interviews	"We mainly use apps and videos outside PE." (F02)

Quotations are shortened for readability; omissions are indicated by ellipses […]. Salience descriptors (e.g., present in most interviews) are based on qualitative comparison across interviews and are intended to support interpretative transparency rather than quantitative frequency reporting

to use digital media in future PE lessons or everyday contexts are mapped to behavioural intention. Contextual factors such as prior experience with digital media, voluntariness of use, and social influences from teachers or peers are conceptualised as external variables moderating these acceptance processes.

Participant quotations are labelled using anonymised codes indicating gender (F/M/D) and a numerical identifier; no additional identifying information is provided to ensure confidentiality. Quotations were translated from German into English using computer-assisted translation and subsequently checked by the authors against the original transcripts to ensure semantic accuracy. An overview of the salience of TAM-related themes and exemplar quotations is provided in **Table 1**.

External variables

Students consistently described external conditions as decisive for whether digital media can be meaningfully implemented in physical education. Three interrelated external variables emerged across interviews: technical infrastructure, availability of resources, and teacher-related conditions. These factors were frequently perceived as limiting the potential of digital media use in PE.

Insufficient technical infrastructure—particularly unstable or missing Wi-Fi in sports halls—was identified as a major barrier, as technical problems were seen to consume valuable lesson time in an already time-constrained subject. As one student noted:

"If it just doesn't work, with the Wi-Fi or something, then too much time is lost." (F02)

Access to digital equipment and financial resources varied substantially between schools. While some participants reported minimal digital infrastructure, others described well-equipped learning environments. However, high acquisition costs were repeatedly mentioned as a structural obstacle to broader implementation:

"And I would say that it's quite expensive to finance […]. That's why it's so difficult to somehow finance tablets for students from a certain grade or things like that." (M05)

Teacher-related conditions were described as equally heterogeneous. Students emphasized that teachers' digital competencies and didactic ideas strongly influenced whether and how digital tools were used in PE. Some participants felt that teachers lacked sufficient experience with digital media:

"I think that […] some teachers are not quite ready yet. Because they don't have a lot of experience with it." (M02)

In addition, limited support from school management was perceived as a further barrier to implementation. Overall, students framed school-level conditions and teacher preparedness as key gatekeepers for the use of digital media in physical education:

"I think the reason why many PE teachers don't really use social media or digital media […] is just because the conditions at some schools are not so good." (F04)

Perceived usefulness

Most participants perceived digital media as useful tools for enhancing efficiency compared to analogue documentation or teacher-led explanations, supporting individualised learning, and promoting health-related education in physical education. Perceived usefulness was closely linked to the potential of digital tools to optimise lesson time and reduce organisational constraints. For instance, students highlighted that digital media could streamline performance measurement and feedback processes:

"Well, I think you save a lot of time for sports lessons, which you can use more efficiently." (M03)

Digital media were also seen as particularly valuable for differentiation and individualisation, as they allow instruction to be adapted to different performance levels within heterogeneous groups. One student described this potential as follows:

"Above all the different levels of students, I think it would be much easier if you had three different videos and then assigned them to the different […] abilities of the students." (F03)

Tracking technologies were perceived as useful for monitoring individual progress and increasing awareness of bodily responses during physical activity:

"What might be cool would be these sports trackers […]. Where you can see your own data. […] Maybe something like that would be interesting to use in PE to see how your body reacts when you do sport." (M02)

Beyond performance-related aspects, students associated digital media with increased motivation and variety in PE lessons. Visual formats were considered particularly helpful for understanding and analysing movement sequences:

"I think it's even better if you can really see in a video exactly how the movement sequence works […] in slow motion […] then you can go into the individual phases of the movement in detail." (F04)

At the same time, students clearly emphasized that digital media should serve a meaningful didactic purpose rather than being used for their own sake:

"It doesn't make sense to show something just to have shown it, just to have introduced some digital media into your lessons without it really advancing the lesson or adding anything specific to the topic." (F01)

Perceived ease of use

Perceived ease of use emerged as a central prerequisite for students' acceptance of digital media in physical education. Across interviews, digital tools were considered acceptable only when they were simple, intuitive, and technically reliable.

Privacy and data protection concerns were particularly salient in relation to video-based applications. Several students expressed discomfort with being filmed during PE lessons, especially when personal identifiability was involved:

"With the video, it's difficult because maybe some people don't want to film themselves doing it […] because of the data and you can see the face." (F01)

In addition, students criticised the use of poorly selected or inadequately explained instructional videos, which were perceived as disrupting lesson flow and undermining potential efficiency gains:

"There are teachers who […] just pick out videos that explain it badly. […] And then there are always big problems because the teacher always has to […] explain it to everyone again." (M05)

While infrastructural constraints shaped the broader conditions for use (Section 3.1), participants also described usability-related barriers at the instructional level. Ease of use was also closely linked to the reliability and trustworthiness of health-related information provided through digital media. Students emphasised the importance of clear, comprehensible, and safeguarded content:

"Easy to use, easy to understand, and I would say fool proof, so that it is protected against misinformation." (M06)

Relatedly, participants highlighted the general challenge of evaluating online health information, which further shaped their perceptions of usability:

"I think it's really difficult because there's so much information on the internet […] I try not to let myself be influenced too much because I know that it's not a reliable source." (F01)

Attitude toward use

Overall, students expressed a predominantly positive attitude toward the use of digital media in physical education, provided that it supports rather than replaces physical activity. Digital media were valued when they contributed meaningfully to learning processes and complemented the practical character of PE.

Several students highlighted that digital media facilitated their learning and aligned well with their individual learning preferences. In particular, digital tools were perceived as more engaging and accessible than traditional, text-based materials:

"I like learning with digital media or electronic tools. I can simply do it better than from a book." (M06)

Health promotion was also regarded as a relevant and underrepresented component of PE. Students emphasised that PE should not be reduced to purely practical activity but should also address health-related knowledge and understanding:

"I think there's a lack of theory in the basic lessons […] So, I think it's super important to learn about health." (M06)

At the same time, students articulated clear conditions and concerns. Digital overload in everyday school life led some participants to argue that PE should remain a space primarily dedicated to physical activity:

"You actually already use digital media so often in everyday school life […] just let sport be sport." (F05)

In addition, concerns related to data protection, peer pressure, and the potential reduction of movement time were raised. Being filmed or recorded during PE lessons was perceived as problematic, particularly when recordings could be shared without consent:

"If it's allowed to use the mobile phone, someone films it and then posts it on their Instagram […] it doesn't get any easier." (F03)

Overall, students' attitudes toward digital media were positive but clearly conditional. Acceptance depended on whether digital tools were perceived as pedagogically meaningful, respectful of privacy, and compatible with PE's core function as a movement-based subject. Importantly, attitudes were not uniformly positive: several participants rejected digital media in PE, citing digital overload, privacy concerns, and potential reductions in movement time.

Behavioural intention to use

Students expressed a clear intention to use digital media both within PE lessons and in their everyday lives, particularly when digital tools were directly linked to practical activities and health-related reflection.

Within PE lessons, students described concrete ideas for integrating digital media into specific content areas, such as dance or fitness training. Digital tools were seen as supporting practice, feedback, and organisation:

"If you have sports lessons, for example dance, then maybe you can ask the sports teacher […] whether you can do the choreo in sports lessons." (F02)

Tracking technologies were perceived as especially useful for connecting physical activity with health-related reflection. Students emphasised the value of visualising physiological data and linking it to theoretical learning phases:

"Look at the results on the watches and then see […] how high the heart rate was. And then you come back to the theoretical part and transfer the results." (F04)

Beyond lesson contexts, students expressed interest in using tablets and apps to create personalised training or nutrition plans, indicating a transfer of PE-related learning into everyday routines:

"You can create your own training plan somehow […] and maybe also a nutrition plan to set goals." (M03)

Taken together, students' behavioural intentions suggest a strong willingness to engage with digital media when these tools support autonomy, self-monitoring, and meaningful connections between practice and health-related knowledge. While many students expressed strong intentions to use digital tools, others articulated more selective intentions, emphasizing use only when it clearly supported activity or health-related reflection.

System use

Students reported that digital media were already used in PE lessons to a limited extent, while more frequent and autonomous use occurred outside of school contexts, primarily via smartphones and apps.

Within PE lessons, digital tools were mainly used to support documentation, analysis, or efficiency, for example by recording performance data digitally rather than manually:

"We also had an app, and we entered the metres […] because the app calculated that. We didn't have to write everything down on paper." (F02)

Videos were described as particularly helpful for analysing techniques and tactical situations, as they enabled detailed observation and reflection:

"You could see exactly what the technique was in slow motion […] analyse it in detail […] and it was fun, too." (F01)

Overall, tablets and apps were more commonly associated with structured lesson use, whereas smartphones were predominantly used independently outside PE. This distinction highlights differences between institutionally guided and self-directed system use. Reported patterns of current use inside and outside school contexts provide contextual information on system use rather than serving as an outcome measure.

Functional form

At the functional level, students primarily described using digital media to access health-related information and practical guidance, particularly through short-form videos and apps (see **Table 2**). Short-form videos and tutorials were seen as an efficient way to acquire basic knowledge about health and physical activity:

"If I see videos about it on TikTok […] I often bookmark it or download the video. […] It's good to be informed about it." (F01)

Digital platforms were also used to obtain practical guidance, such as recipes or exercise instructions, often combining textual and visual information:

"You can just enter it digitally, and then recipes and precise instructions or even videos […] come up very quickly." (F02)

These statements illustrate how digital media support the acquisition of basic health knowledge without relying exclusively on text-based or formal instruction.

Communicative-Interactive form

At the communicative-interactive level, students emphasised the role of social media as a central source of health-related information and exchange.

Participants described social media as offering access to a wide range of health information that often felt more current or relatable than traditional school materials:

"Social media […] you can find out even better information than what the textbooks might have taught teachers a few decades ago." (F03)

At the same time, students stressed the need for guidance and education to critically engage with such content, particularly regarding nutrition and influencer-driven information:

Table 2 Salience of health literacy dimensions in digitally enriched physical education (Nutbeam, 2000)

Health literacy level	Health-related practices in PE and everyday life	Salience across interviews	Exemplar quotation
Functional health literacy	Accessing health-related information via videos and apps	Present in most interviews	"Videos explain it much better than reading." (F04)
Functional health literacy	Practical guidance (e.g., exercises, routines)	Reported by several participants	"You get instructions and videos very quickly." (F02)
Communicative-interactive health literacy	Social media as source of health information	Present in most interviews	"On social media […] you can find better information." (F03)
Communicative-interactive health literacy	Exchange and discussion about health topics	Reported by several participants	"It's important to talk about […] health." (F01)
Critical health literacy	Evaluating credibility of online information	Present in most interviews	"There is so much contradictory information on the internet." (F01)
Critical health literacy	Individualised interpretation of health advice	Reported by several participants	"What works for one person doesn't work for everyone." (M06)

Note. Quotations are shortened for readability; omissions are indicated by ellipses […]. Salience reflects qualitative prominence across interviews rather than numerical frequency

"It's very important to educate students […], a lot of them tend to just listen to anyone. […] Nutrition is an important topic." (F01)

These findings underline the importance of PE as a context for developing communicative competencies and reflective engagement with health information encountered in digital environments.

Critical form

At the critical level, students highlighted significant challenges related to evaluating and interpreting health information found online.

The abundance of contradictory information was described as confusing and undermining trust in digital sources:

"It's extremely difficult because there is so much information on the internet […] it says […] the opposite […] that's really not a reliable source." (F01)

Students also emphasised that health-related information must be interpreted in relation to individual needs and contexts, rather than applied universally:

"It's different for everyone […]. One thing might work for one person, another for someone else." (M06)

These statements demonstrate emerging critical health literacy skills, particularly in recognising misinformation and the need for individualised application of health advice. Notably, critical reflections were not uniformly articulated across all interviews. While some students demonstrated pronounced scepticism toward online health information, others expressed uncertainty or ambivalence rather than explicit critique. These variations informed the differentiation of critical health literacy as an emerging and unevenly developed competence. This variation strengthens the interpretation of critical health literacy as a developing competence rather than a stable trait.

Discussion

Integration of digital media and TAM in physical education

Taken together, the findings demonstrate a clear alignment between students' experiences and the core constructs of the Technology Acceptance Model, while contextual moderators such as experience, voluntariness, and social influence help explain variation in acceptance. All references to benefits or positive effects in this study refer to students' subjective perceptions and reported experiences, typically in comparison to their prior experiences with non-digital or minimally digital PE instruction, rather than to objectively measured outcomes. To synthesise these findings, **Fig. 4** illustrates how students' accounts can be interpreted within the original Technology Acceptance Model in the context of health promotion in physical education.

Based on the results of this study, students' acceptance of digital media in physical education can be meaningfully interpreted using the original constructs of the Technology Acceptance Model (Davis et al., 1989). External variables identified in the interviews, such as technical infrastructure, financial resources, teacher competencies, organisational support, and available lesson time, shaped students' perceptions of both usefulness and ease of use rather than functioning as independent determinants of acceptance (see e.g. Jastrow et al., 2022).

Students' accounts indicate that digital media were positively received when they were perceived as meaningful complements to physical activity rather than as replacements for movement. In particular, tools supporting performance tracking, visualisation, and access to health-related information were described as useful for understanding bodily processes and supporting learning (e.g., Nesterchuk et al., 2021; Papastergiou et al., 2021). At the same time, students emphasised that acceptance was closely linked to the perceived relevance of digital media to their everyday lives, their motivational potential, and their contribution to learning processes (Goodyear et al., 2019a; Goodyear et al., 2019b). These findings are consistent with a recent feasibility study demonstrating high student acceptance of wearable technologies and digital feedback within health-promoting PE lessons (Knoke et al., 2025).

The findings also highlight the central role of teachers as gatekeepers for the pedagogical integration of digital media

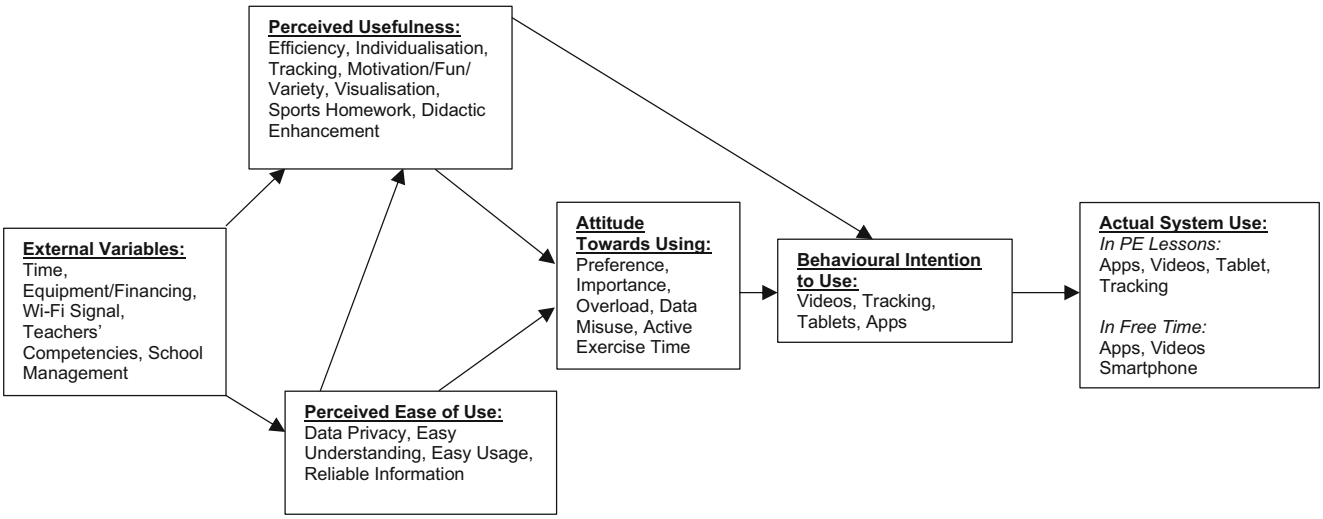

Fig. 4 ▲ The Technology Acceptance Model for Health Promotion in Physical Education (based on Davis et al., 1989). The figure illustrates the original TAM structure, with all core constructs informed by students' accounts. Contextual factors identified in this study (e.g., technical infrastructure, teacher competence, school management) are conceptually located within the category of external variables rather than introduced as additional TAM constructs

in PE. Students repeatedly referred to teachers' digital competencies, attitudes, and the level of institutional support as key conditions influencing whether digital tools were used at all. These observations are consistent with previous research emphasising the importance of teacher digital literacy and organisational conditions for successful implementation (Lupton, 2021; Meates, 2020).

At the same time, students' accounts also highlight important counter-perspectives that temper model-based expectations regarding the use of digital media in PE. Concerns were raised about potential distraction, loss of valuable movement time, data privacy, and peer-related pressure when digital tools are used in physically active settings. In addition, unequal access to devices and infrastructure across schools was perceived as a limiting condition. These aspects indicate that high perceived usefulness or ease of use does not automatically translate into unproblematic implementation. Rather, acceptance appears to be conditional upon careful pedagogical integration that safeguards movement time, protects privacy, and accounts for heterogeneous school contexts. This finding is consistent with previous research emphasising that the educational value of digital media in PE depends strongly on pedagogically meaningful integration and adequate infrastructural support rather than on technology use alone (Jastrow et al., 2022; Yu & Jee, 2020).

Beyond general acceptance, the findings also allow plausible mechanisms to be identified through which digital media may support health-related learning and behavioural engagement in physical education. First, digital tools such as tracking devices enable self-monitoring of performance and physiological responses (e.g., heart rate or activity levels), which can enhance students' awareness of bodily processes and support functional health literacy. Second, immediate visual feedback provided by apps or videos facilitates reflection on movement execution and effort, creating feedback loops that help students link physical activity with health-related outcomes. Third, opportunities for personalisation, such as differentiated instructional videos or individual training and nutrition plans, appear to support autonomy and perceived relevance, thereby strengthening behavioural intention to engage with health-promoting activities. Fourth, social features embedded in digital media, including comparison with peers or shared challenges, can foster motivation and engagement, but may also introduce pressure, highlighting the importance of guided and reflective use. Finally, elements of gamification and variation were described as increasing enjoyment and interest, which may indirectly support sustained engagement with health-related behaviours. These mechanisms can also be interpreted through the lens of the Technology Acceptance Model (Davis et al., 1989). In particular, self-monitoring, personalised feedback, and differentiated learning opportunities appear to strengthen perceived usefulness, while intuitive and visually supported applications may enhance perceived ease of use.

Taken together, these mechanisms illustrate how digital media do not promote health literacy or behavioural change per se, but rather function as pedagogical tools that support reflection, self-monitoring, communication, and personalised learning processes. In line with Nutbeam's (2000) Health Literacy Model, these processes can be linked to functional, communicative-interactive, and critical dimensions of health literacy. The findings therefore suggest that digitally enriched PE may contribute to health-related learning when digital media are integrated in reflective and pedagogically guided ways.

The findings can be translated into concrete pedagogical strategies for the differentiated use of digital media in physical education. First, digital tools enable

within-class differentiation by providing instructional videos or tasks at varying levels of difficulty, allowing students to engage with content that matches their individual abilities while participating in the same lesson structure. This may help address heterogeneous performance levels without increasing organisational burden for teachers. Students' concerns regarding loss of movement time underline the importance of protecting time-on-task. Digital media should therefore be used in a targeted and time-efficient manner, for example through short video inputs, rapid performance documentation, or brief data visualisations that support reflection without displacing physical activity. The findings suggest that structured reflection tasks are essential when using digital media for health promotion. Guided reflection phases, such as interpreting tracking data, discussing bodily responses to exercise, or critically evaluating health-related information from apps or social media, can support the development of health literacy beyond mere tool use. This corresponds with previous recommendations highlighting the importance of reflective and critical engagement with digital health information in school-based health promotion (Goodyear et al., 2019a; Riesmeyer et al., 2019).

Finally, the results point to the value of progressive digital literacy goals in PE. Rather than assuming uniform digital competence, students may benefit from stepwise learning objectives that gradually build skills related to using, interpreting, and critically assessing digital health information. Together, these pedagogical implications illustrate how digital media can be integrated into PE in a differentiated, reflective, and movement-oriented way that aligns with both health promotion and educational goals.

The students in this interview study also referred to the lack of support for teachers from the school management when they wanted to integrate digital media into their lessons. In order to investigate this assumption, a survey of PE teachers on this topic is suggested.

The students' statements in the interviews clearly show that it is important to empower children and young people to use digital media for health promotion and health literacy properly. Due to the thematic connection to social media and fitness trends, PE could provide a platform and corresponding educational work for this. The findings support those of Riesmeyer et al. (2019), who showed that social media has a major influence on students' health perceptions and behaviours.

In this context, the mission of PE could be further expanded to include health and health literacy with digital media, especially because PE has a major influence on the use of digital media for health (Goodyear et al., 2019b). Further, to achieve the goal of using digital media in PE, not only should research in this area be continued but policymakers must also create the appropriate framework conditions (Meates, 2020) to enable schools and teachers to utilise digital media in PE and adapt their lessons accordingly.

An equity and inclusion perspective further nuances the interpretation of digital media use for health promotion in physical education. Students' accounts implicitly point to issues of unequal access to digital devices, reliable internet connectivity, and school infrastructure, which may shape who can meaningfully benefit from digitally supported learning opportunities. Differences between schools in terms of equipment and technical conditions suggest that digital health tools may unintentionally reinforce existing educational inequalities if access is uneven.

In addition, inclusive implementation must consider diverse learner needs, including students with disabilities, limited language proficiency, or varying levels of digital competence. Digital tools that rely heavily on text-based information, complex interfaces, or fine motor interaction may create barriers for some students, whereas multimodal formats (e.g., visual or auditory content) may offer inclusive potential when deliberately designed.

To mitigate such disparities, schools and teachers play a crucial role in ensuring equitable conditions for digital media use in PE. This includes providing shared devices rather than relying on students' private equipment, offering structured guidance and scaffolding when digital tools are introduced, and selecting applications that are accessible, privacy-sensitive, and adaptable to different learner needs. From a pedagogical perspective, digital media should therefore be embedded in PE lessons in ways that promote participation for all students, rather than privileging those with greater prior access or competencies. The findings should also be interpreted in light of relevant boundary conditions. The study sample included students with heterogeneous backgrounds, including participants who were engaged in organised sports clubs beyond regular physical education classes as well as those whose primary exposure to physical activity occurred within school contexts. Consequently, students' experiences with digital media and health-related practices may reflect not only PE lessons but also broader youth sport and leisure contexts.

This distinction is important when interpreting acceptance and perceived usefulness of digital media. While some students may draw on experiences from extracurricular sport settings (e.g., fitness tracking or app use in clubs), the present analysis focuses on how these experiences are reflected upon and articulated in relation to school-based PE. Claims regarding health promotion and health literacy should therefore be understood as referring primarily to pedagogically guided PE contexts, rather than to general youth health behaviour or sport participation outside school.

Practice implications for physical education teachers

Based on students' reported experiences, several practical recommendations can be derived for the pedagogically meaningful use of digital media in health-promoting physical education:

- Use digital media as a complement to physical activity, not as a replacement, to protect movement time and maintain the core character of PE.
- Integrate short, targeted digital inputs (e.g., brief videos, performance feedback, data visualisations) to support reflection without interrupting activity phases.
- Enable differentiation by providing instructional materials at varying

levels of difficulty (e.g., multiple video formats or task variations).
- Use digital tools to support self-monitoring and reflection (e.g., tracking data, movement analysis) to strengthen awareness of bodily responses and health-related learning.
- Provide structured guidance when working with digital health information, especially in relation to social media content and misinformation.
- Pay attention to data protection and students' comfort when using video-based applications or personal performance data.
- Ensure inclusive access by relying on shared school devices where possible and offering support for students with different levels of digital competence.

Implications for the technology acceptance model in physical education

Overall, the findings support the suitability of the original TAM as a heuristic for interpreting students' acceptance of digital media in health-promoting PE, with external variables (e.g., infrastructure, teacher competence, organisational support) shaping perceived usefulness and perceived ease of use. Rather than proposing additional constructs, **Fig. 4** summarises how students' accounts populate the existing TAM components in the PE context.

In line with prior research, students' acceptance was conditional on digital media being used as a complementary tool rather than replacing physical activity (Goodyear et al., 2019a; Hinojo-Lucena et al., 2019).

Students' accounts also underline the relevance of teacher digital literacy and supportive school conditions as enabling factors for implementation (Lupton, 2021; Jastrow et al., 2022), while everyday use of apps and videos outside school points to opportunities for connecting PE with students' lived digital health practices (Goodyear et al., 2019b; Sakellari, Notara, & Lagiou, 2021).

Interpreting the health literacy model (HLM) in digitally enriched physical education

The findings of this study indicate that Nutbeam's (2000) three-level Health Literacy Model remains a suitable framework for analysing health-related learning processes in physical education, but requires contextual interpretation when applied to digitally enriched learning environments. Rather than extending the model by adding an additional level, the results suggest that the existing functional, interactive, and critical dimensions can be meaningfully interpreted through the use of digital media in PE.

At the functional level, students described acquiring basic health-related knowledge through videos, apps, and online platforms, for example in relation to physical activity or nutrition. While Nutbeam emphasises reading and writing skills at this level, the findings show that audiovisual and interactive media function as alternative modes of information access without fundamentally altering the underlying literacy dimension.

At the interactive level, digital media enabled students to exchange information, follow health-related content on social media, and engage with peers or online communities. These practices align with Nutbeam's concept of communicative health literacy and illustrate how digital environments can support active engagement with health information in PE. **Figure 5** illustrates this interpretation of Nutbeam's Health Literacy Model in the context of digitally enriched physical education.

At the critical level, students reflected on misinformation, contradictory health advice, and individual differences in health-related needs. Evaluating the credibility of online content and adapting information to personal contexts emerged as central competencies, highlighting the relevance of critical health literacy in digital settings.

Overall, the findings do not suggest a need for a structural extension of Nutbeam's model, but rather underscore the importance of interpreting its existing levels in light of contemporary digital, visual, and interactive forms of learning that increasingly shape students' health-related experiences.

With regard to framework breadth, the present study deliberately focused on the Technology Acceptance Model and Nutbeam's Health Literacy Model as complementary lenses for analysing students' acceptance of digital media and health-related learning in PE. While other frameworks are highly relevant to digital education, they were not adopted as primary analytical models due to the exploratory and student-centred focus of this qualitative study.

The Technological Pedagogical Content Knowledge (TPACK) framework (Mishra & Koehler, 2006) primarily addresses teachers' professional competencies and instructional design decisions. Although teacher digital pedagogical competence clearly emerged as an important external condition in students' accounts, the present analysis centred on students' experiences and acceptance rather than on teachers' knowledge structures.

Similarly, broader eHealth literacy models (e.g., Norman & Skinner, 2006; Sørensen et al., 2012) extend beyond the scope of this study by conceptualising health literacy as a population-level construct.

In contrast, Nutbeam's model was selected due to its pedagogical orientation and its suitability for analysing functional, interactive, and critical learning processes within school-based PE contexts. The findings suggest that digital media can be meaningfully interpreted within this existing framework without requiring the adoption of an additional health literacy model.

At the same time, the identified mechanisms resonate with motivational frameworks such as Self-Determination Theory (Deci & Ryan, 2000), particularly with regard to autonomy, competence, and relatedness. These connections are discussed as interpretative linkages rather than as theoretical integrations, highlighting opportunities for future studies to combine acceptance, health literacy, and motivational perspectives in a more integrative design.

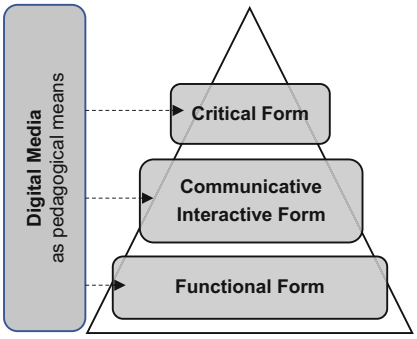

Fig. 5 ▲ Interpretation of Nutbeam's Health Literacy Model (2000) in digitally enriched PE. Digital media are conceptualised as pedagogical means (e.g., videos, apps, tracking tools) supporting functional, communicative-interactive, and critical health literacy, rather than as an additional hierarchical level

Limitations

Several limitations of this study should be acknowledged. First, the findings are based on a small, non-representative sample (N = 15) consisting of students from grammar and secondary schools. Although this is appropriate for an exploratory qualitative design, the results cannot be generalized to all student populations or school contexts. In addition, the wide age range may have influenced students' experiences and perceptions of digital media and health-related learning in different ways.

Second, the study relies on self-reported data from interviews, which may be subject to social desirability and recall bias. Despite efforts to create an open interview atmosphere, students may have emphasized socially accepted or expected views on digital media use and health promotion.

Third, the theoretical framing using the Technology Acceptance Model (TAM) and Nutbeam's Health Literacy Model (HLM) may have shaped both data analysis and interpretation. While these frameworks provided a useful heuristic for structuring the findings, their use may have directed attention toward predefined constructs (e.g., usefulness, ease of use, functional literacy) and potentially limited the emergence of alternative interpretative perspectives. This theoretical lens may therefore have introduced a degree of analytical bias.

Future research directions

Future studies should build on these findings by including larger and more diverse samples across different school types and educational contexts. Longitudinal designs could provide insights into how students' acceptance of digital media and health-related learning processes in PE develop over time.

Further research should also triangulate student perspectives with those of PE teachers and school administrators to better understand structural and organizational conditions influencing digital media use. In addition, combining qualitative and quantitative approaches could help validate and extend the exploratory findings presented here.

Finally, future work may benefit from integrating complementary theoretical frameworks (e.g., TPACK or self-determination theory) to capture pedagogical, motivational, and contextual dimensions beyond acceptance and health literacy, thereby reducing the risk of theory-driven bias and strengthening explanatory depth.

Conclusion

This study represents one of the first qualitative applications of the Technology Acceptance Model (Davis et al., 1989) in PE from students' perspectives, combined with a pedagogically grounded interpretation of health literacy using Nutbeam's (2000) framework. By directly exploring students' experiences, assessments and acceptance of digital media in PE, the study offers theory-informed, exploratory insights into health-promoting learning processes in PE.

Digital media were perceived as beneficial in terms of efficiency, individualized learning, and increased motivation when supported by adequate technical and didactic conditions. At the same time, structural and competence-related barriers emerged as important conditions for meaningful implementation. The findings suggest that both the Technology Acceptance Model (Davis, 1989) and Nutbeam's (2000) Health Literacy Model can be meaningfully interpreted in light of the specific conditions of PE, without requiring structural modification of either framework.

Overall, the study underscores the importance of a differentiated, inclusive, and movement-oriented integration of digital tools in PE. Further research with larger and more diverse samples is needed to extend and contextualise these exploratory findings, with a focus on credibility and transferability rather than statistical generalisation.

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Data availability. The study did not generate quantitative datasets. Anonymized interview transcripts are available from the corresponding author on reasonable request and are not publicly accessible due to data protection and confidentiality considerations. Due to the qualitative and sensitive nature of the interview data and the involvement of minor participants, the full transcripts are not publicly available. Anonymised excerpts supporting the findings are included in the manuscript. Further data may be made available from the corresponding author upon reasonable request and subject to ethical approval and data protection regulations.

Declarations

Conflict of interest. C. Knoke, A. Woll and I. Wagner declare that they have no competing interests.

Consent for publication All participants were anonymized, and consent was obtained for the anonymized use of data for publication purposes.

Ethical approval for the study was obtained from the Ethics Committee of the Karlsruhe Institute of Technology (KIT), reference number: 7534.12. Informed consent was obtained from all participants. For underage participants, legal guardians were additionally

informed in writing and provided consent. Participation was voluntary at all times.

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