Phygital in games: a systematic review of trends, characteristics, the user experience, technologies, and tools

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ABSTRACT

In the 21st century, the evolution of phygital technology has transformed various sectors, including retail, marketing, heritage, education, edutainment, and gaming. However, phygital interfaces are dynamic, continuously evolving alongside technological advancements and user expectations. This study aims to identify trends, characteristics, user experiences, and the tools or technologies used in phygital gaming. A systematic literature review (SLR) was conducted using the preferred reporting items for systematic reviews and meta-analysis (PRISMA) framework, analyzing 26 publications from Web of Science (WoS), Scopus, and IEEE Xplore. The findings revealed seven key characteristics of phygital interfaces and six positive impacts on user experience. Additionally, various phygital technologies and tools were identified as essential in the education, edutainment, and entertainment contexts of gaming. These technologies enhance engagement, interactivity, and immersion by seamlessly integrating physical and digital elements. Therefore, this study contributes to improving user experiences and expanding knowledge in the context of phygital interfaces. Future research should explore potential challenges in adopting phygital technologies, particularly from educators' perspectives, to uncover new insights into their implementation and effectiveness.

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1. INTRODUCTION

The convergence of physical and digital elements, commonly referred to as phygital, is redefining interactive experiences across diverse domains, particularly in gaming. Phygital interfaces blend tangible physical components with the flexibility of digital environments, enabling rich, multisensory, and immersive gameplay [1]. These hybrid interfaces create novel opportunities for user engagement but also introduce design and technical complexities, including synchronization issues, delayed response times, and the physical degradation of components [2]. Addressing these challenges requires interdisciplinary collaboration between fields such as game design, human-computer interaction (HCI), and engineering.

Phygital technologies have gained increasing attention in various fields, including education, retail, and marketing [3], [4], with evidence of positive behavioral and developmental impacts, especially among children. However, in the gaming context, the literature remains fragmented. Previous studies often examine isolated applications or specific user experiences without offering a consolidated understanding of how phygital interfaces function holistically in games. As noted by Vecchio *et al*. [5], the lack of conceptual clarity and synthesis in the phygital domain limits both academic progress and practical innovation.

Despite the growing use of physical-digital interfaces in game-based learning and interactive entertainment, there is currently a lack of systematic literature review (SLR) focused exclusively on phygital gaming. Most existing reviews either focus on broader mixed-reality experiences or touch upon phygital elements only tangentially. Moreover, the role of phygital games in supporting children's socio-emotional development remains critically underexplored, despite emerging evidence of their developmental potential.

This study presents a SLR that consolidates and analyses existing research on phygital interfaces specifically in the context of games. It identifies key trends, design characteristics, user experience impacts, and enabling technologies and tools. In doing so, this study not only bridges existing gaps in the literature but also provides a structured foundation for future research and game development, particularly for applications aimed at enhancing learning, engagement, and emotional development in children.

2. METHOD

The literature review was conducted transparently and methodically using the preferred reporting items for systematic reviews and meta-analysis (PRISMA) framework [6]. This methodology reduces bias and offers a clear framework for the review process, from developing the research topic to synthesizing the results [7].

2.1. Identification

The systematic review starts by selecting appropriate studies to address research inquiries. This study conducted a comprehensive search on the Web of Science (WoS), Scopus, and IEEE Xplore to identify relevant papers. The first search query yielded 845 articles, with 557 sources from WoS, 169 from Scopus, and 119 from IEEE, as depicted in Figure 1. The search string was employed to query 845 items, which prompted the specified keywords to include "phygital", "physical-digital", "physical and digital", and "games". The subsequent terms were selected to investigate the phygital games based on prior research.

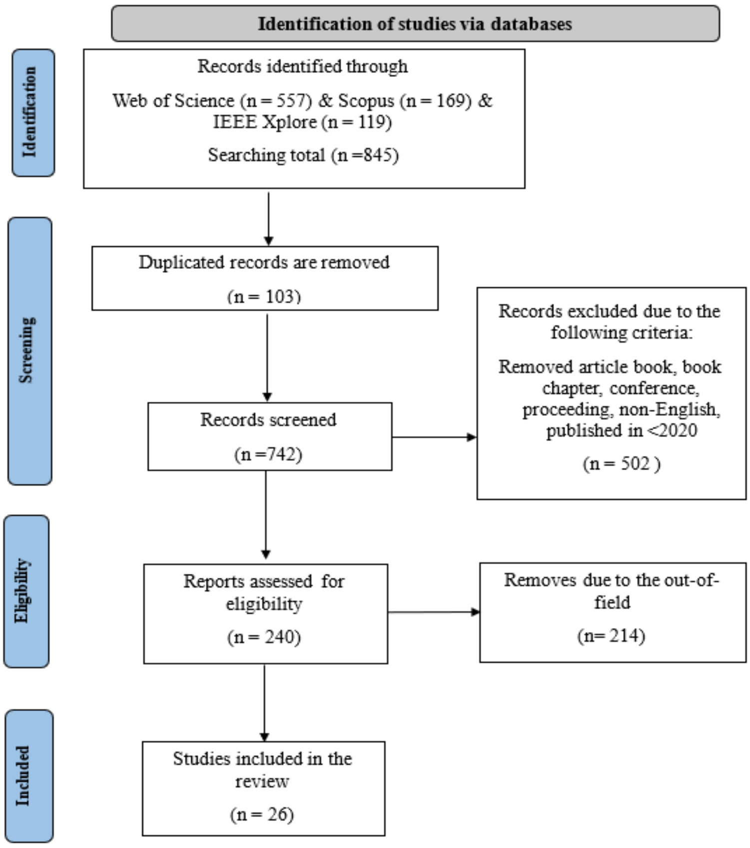

Figure 1. Flow diagram of the proposed studies for review

2.2. Screening

The screening step considered several criteria to identify relevant materials. Only journal articles written in English, published between 2020 and 2024, and categorized as research articles were included. Excluded materials comprised those written in other languages, published before 2020, or categorized as non-research items such as conference papers, books, notes, editorials, letters, and short surveys. During this process, 103 duplicate articles were eliminated from the initial dataset. Subsequently, 502 out of 742 articles were excluded for not meeting the inclusion criteria.

2.3. Eligibility

The articles were initially gathered and filtered through identical eligibility reviews. During the third stage, known as eligibility, the titles and essential contents of all articles were carefully examined to ensure they met the inclusion criteria of the current study. After reviewing the selected papers from the initial stage, 214 were eliminated as they were irrelevant to the specific area of study.

2.4. Included

Following the eligibility screening, the total number of pertinent papers to be examined in this study was 26, as in Figure 1. These studies were carefully selected based on predefined inclusion criteria to ensure relevance and quality. The final dataset forms the basis for the analysis of phygital interface trends, user experiences, and enabling technologies in games.

2.5. Data analysis

Synthesis analysis recorded in an excel spreadsheet: this study compiled a comprehensive inventory of the selected publications in an Excel spreadsheet. The inventory included key information such as author(s), year of publication, title, country, research samples, characteristics of the phygital interface, tools or technologies used, and aspects of user experience. Only studies published between 2020 and 2024 were considered to ensure the relevance and currency of findings. The characteristics of phygital games were examined to capture essential interface elements, while the analysis of user experience focused on how the phygital context contributes to engagement and interaction. Phygital tools and technologies used in the games were also documented to identify prevailing trends. The data was then summarized, tabulated, and interpreted to organize and explain the key discoveries across the included studies.

3. RESULTS AND DISCUSSION

For this study, 26 papers were chosen to address the research topics. Figure 2 displays the findings of this study, which examined the attributes and user perceptions of phygital interfaces and tools utilized in prior studies. These selected studies provide valuable insights into the evolving trends, key design characteristics, and user experience dimensions associated with phygital gaming environments.

3.1. Trend of using phygital interface in games

The pandemic has accelerated the digitalization process as we must adjust to the physical separation and quarantine policies during the crisis. However, we started to adjust to the real world when the quarantine was lifted. As a result, we face a phenomenon known as the phygital experience, in which the distinction between the real and virtual worlds is becoming less clear [8]. With the advancement of technology, Lawry [9], mentioned that the boundary between the physical and digital worlds has become increasingly blurred. A growing trend from 2020 to 2024 demonstrates the progression of incorporating phygital interfaces, which combine physical and digital elements to enhance the gaming experience and create new opportunities for user interaction and immersion.

The integration of physical and digital interfaces in gaming allows for interactive and deeper gameplay levels, allowing for more realistic and dynamic interactions. The phygital interface provides users with a sense of agency and personalization through tangible interfaces and haptic feedback devices, allowing them to shape their gaming environment [10], [11]. This approach promotes active learning and behavioral skills, making learning more engaging and interactive [12]. Using a phygital interface also facilitates cross-platform connectivity, enhances social interactions, and encourages real-world activities, enhancing teamwork and gameplay collaboration [13], [14]. Overall, integrating physical and digital elements in gaming enhances teamwork and gameplay collaboration.

The research trends on the utilization of phygital interfaces in gaming revealed that they can improve user experience and interaction. Besides that, these advancements can foster deeper social connections and encourage collaboration among users. Therefore, this study intended to understand the characteristics of phygital interfaces to study how they can improve user engagement and interaction.

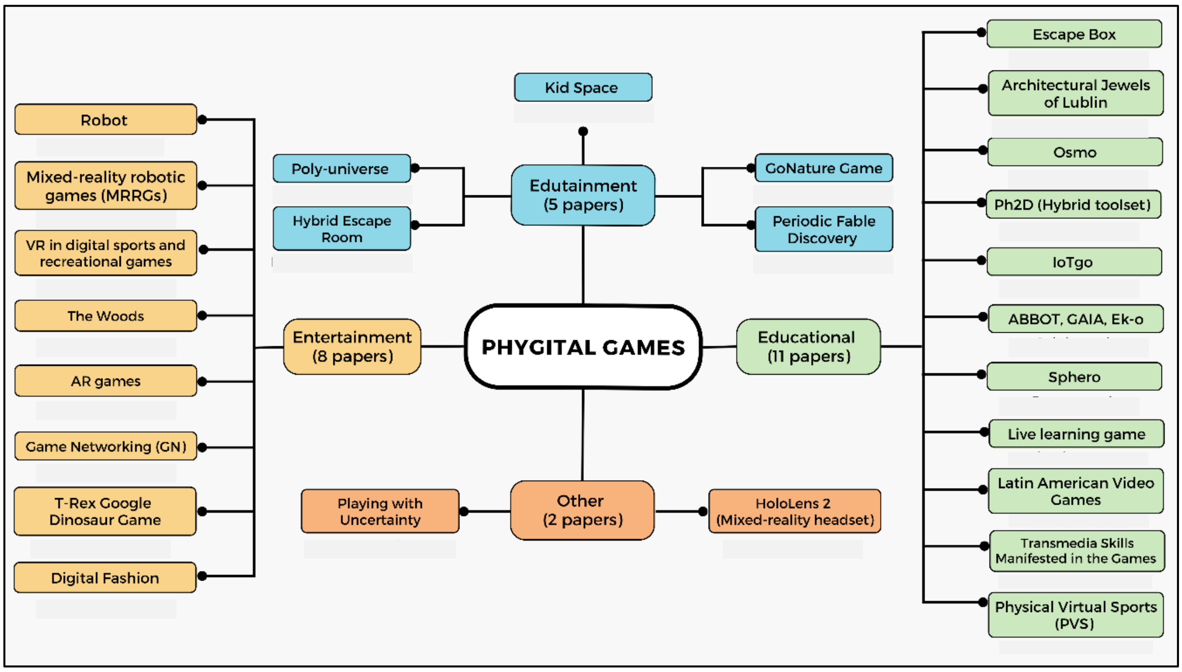

Figure 2. Findings

3.2. Characteristics of phygital interface

The analysis of existing studies has identified several key characteristics of phygital interfaces, as shown in Figure 3. The most frequently highlighted features include interactivity, technology integration, hybridization, and multisensory elements, indicating a strong focus on enhancing user engagement through blended physical-digital experiences. Less frequently discussed aspects, such as contextual relevance and personalization, suggest opportunities for deeper exploration in future research.

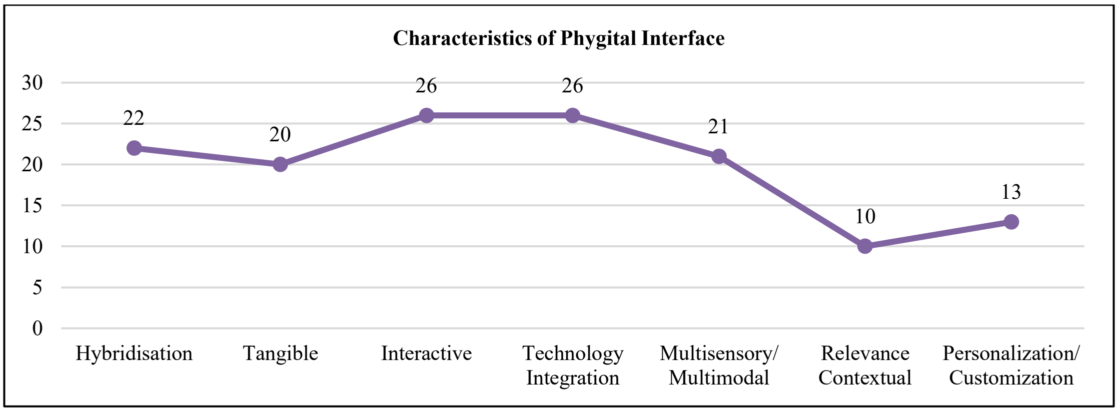

Figure 3. Number of studies for characteristics of phygital interface

3.2.1. Hybridization

The phygital interface is a unique gaming experience that blends physical and digital elements, allowing users to interact with tangible objects and virtual environments [15]. This hybrid environment allows users to shape the game world through actions and view the consequences of their decisions through companion apps like Bonkers Borders, an augmented reality (AR) game [16]. In phygital learning, Chaturvedi *et al.* [17] discussed that a blended learning approach that combines physical and digital educational elements, offering a unique and interactive gaming experience that combines the physicality of the real world with the limitless possibilities of the digital realm.

3.2.2. Tangibles

Another characteristic of the phygital interface in games is tangible interaction. Tangible interaction refers to the ability of players to interact physically with objects or elements within the game. Tangible objects in the phygital interface provide a more natural, intuitive way of interacting with the technology [18]. Prattico and Lamberti [19] mentioned that tangible user interfaces allow users to manipulate digital data physically and combine physical artefacts with computationally mediated digital information. One of the phygital technologies, Reflex, can manipulate physical items while interacting with multimedia content on a tablet screen enhancing the user experience [12]. In general, tangible interaction allows players to have a more tactile experience, bridging the gap between virtual and physical worlds.

3.2.3. Interactive

Many studies found that the phygital interface provides interactivity that enhances user engagement by enabling real-time feedback and responsiveness to user actions, fostering agency and control [19]–[21]. Through interactive elements such as touchscreens, motion sensors, gestures, eye tracking, and haptic feedback, users can manipulate digital content, navigate interfaces, and customize their experiences based on their individual preferences [22], [23]. In short, the interactivity in gameplay facilitates dynamic user engagement and interactive play experience.

3.2.4. Personalized/customized

Personalization and customization are integral aspects of phygital interfaces. Tailored and adapted experiences cater to individual users' unique needs and preferences [24]. These interfaces leverage user data and contextual information to deliver content and interactions that are relevant and meaningful to each user. Research suggests that personalized experiences can enhance user satisfaction, engagement, and retention by providing content that aligns with users' interests, preferences, and past interactions [25], [26]. Phygital interfaces adapted and evolved personalize content delivery and customize options through user profiles, preferences settings, and recommendation algorithms.

3.2.5. Multisensory/multimodal

Phygital interfaces engage users through multiple senses and modalities, including sight, sound, touch, and smell. It creates rich and immersive experiences that stimulate different senses simultaneously and make the game more realistic and enjoyable [27], [28]. By integrating various sensory inputs, the interfaces enhance user engagement and comprehension while promoting the development of various development skills [29], [30]. Multisensory and multimodality design principles emphasize interfaces that appeal to users' diverse sensory preferences and capabilities. According to Toh and Kirschner [31], it can enable players to communicate and collaborate effectively. The incorporation of audio cues, tactile feedback, and visual animations can provide additional layers of information and feedback, enriching the overall user experience in the phygital interface.

3.2.6. Contextual relevance

Contextual relevance in phygital interfaces refers to the ability of these interfaces to provide meaningful content and interactions based on the user's environment, situation, and preferences [32], [33]. By integrating real-time information and virtual content, phygital interfaces can adapt and tailor user experiences, enhancing engagement, satisfaction, and task performance [23], [34]. Studies have shown that relevant experiences make the game feel closer to the user's experiences, using location-based tracking, environmental sensors, and context-aware computing to understand and respond to users' context [12], [21]. Overall, contextual relevance in phygital games can improve user experiences.

3.2.7. Technology integration

Phygital interfaces integrate with technology and physical playthings with mechanical and digital affordances can creating a hybrid game form in the toy industry [10]. These interfaces leverage various technologies, including sensors, displays, and connectivity, to create interactive and immersive experiences [21], [35]. Technology integration is essential for the seamless interaction between physical and digital elements in the phygital interface. In sum, the integration of technologies such as the internet of things (IoT), AR, virtual reality (VR), and robotics can offer novel interactions and functionalities for a better quality of life [36]. Therefore, the phygital interface integrates seven key characteristics that enhance the user experience by blending physical and digital elements. Tangibles incorporate physical objects for interaction, while hybridization merges physical and digital components. It is interactive, allows dynamic engagement, and supports personalization/customization to adapt to user needs. Multisensory/multimodal features enhance immersion through touch, sound, and vision, while contextual relevance ensures meaningful interactions. Lastly, technology integration embeds advanced digital tools for improved usability. These elements make the phygital interface a valuable asset in education, entertainment, and interactive learning.

3.3. Phygital interface improves user experience while playing games

The reviewed studies identified key user experience aspects in phygital games, as seen in Figure 4, with active participation, connectedness, and collaboration emerging as the most prominent. Elements like playfulness and motivation were also noted for sustaining user engagement, while seamless integration appeared less frequently, suggesting a gap for future research. These insights underscore the importance of designing phygital games that promote engagement, social interaction, and enjoyable experiences.

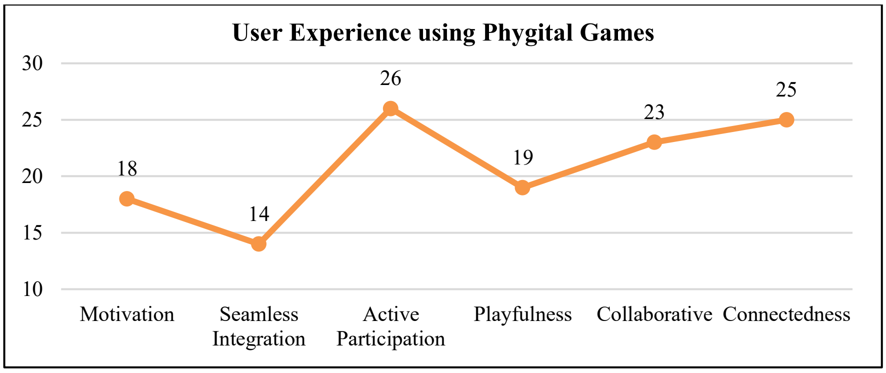

Figure 4. Number of studies for user experience using phygital games

3.3.1. Immersive

Phygital interfaces create immersive experiences by blending physical and digital elements, which envelop users in an interactive environment. Through AR, VR, or mixed reality (MR) overlays, spatial sound, vision, and haptic feedback, users engage with content in a highly immersive that creates a more realistic experience [37]. Some research indicated that immersive experiences foster users' long-term engagement, motivation, and learning gains [38], [39]. Furthermore, users are immersed in the digital environment, leading to deeper interaction and emotional connection [40]. Overall, users who are immersed in phygital interfaces experience a memorable user experience, leading to engagement, personalization, and empowerment [41].

3.3.2. Motivation

Motivational design principles are crucial in encouraging positive user engagement, persistence, positive emotions, exploration, and a sense of achievement [42]. Game design elements like leaderboards, gamification, rewards systems, and progress tracking motivate users to achieve their goals and complete tasks with purpose and enjoyment [43]. Studies have shown that motivational design can enhance user motivation, satisfaction, and task performance by tapping into intrinsic motivators such as autonomy, competence, and relatedness [44]. Through playful interactions and incentives, phygital interfaces inspire users to engage with content and achieve meaningful outcomes actively.

3.3.3. Seamless integration

One of the crucial elements in the phygital interface is seamless integration. Physical interfaces blur the line between real and virtual worlds. Seamless integration refers to the smooth integration of different elements or technologies that create a cohesive experience and increase immersion, engagement, and satisfaction [33]. An empirical study by Gelsomini *et al.* [12] used Reflex mode, which provides interactive feedback and rewards, where users can manipulate objects. As a result, the platform contributed to improved technology performance and user satisfaction. Overall, the interfaces provide users with seamless, easy-to-use interactions by integrating different technology aspects, including sensors, displays, and actuators.

3.3.4. Connectivity

Connectivity in the context of phygital interfaces refers to the ability of devices and platforms to seamlessly communicate and interact, enabling users to exchange data, share resources, and collaborate effectively [45], [46]. This connectivity is facilitated through Bluetooth, Wi-Fi, near field communication (NFC), and IoT, which enable devices to exchange data and commands wirelessly [13], [47]. It connects users to the game and the phygital interface as it involves them in physical actions and gestures that enhance the sense of presence and embodiment [48]. Besides that, it also enhances the mobility and flexibility of phygital interfaces, allowing users to transition between different devices and platforms while maintaining continuity in their user experience.

3.3.5. Playfulness

Phygital interfaces incorporate playful elements that encourage users to interact with the environment. These interfaces transform mundane tasks into playful experiences that captivate users by incorporating game-like mechanics, whimsical animations, superimposing animated digital characters, and interactive feedback [49], [50]. Playfulness enhances user experiences by fostering a sense of curiosity, exploration, and experimentation, which encourages users to discover and interact with content creatively [20], [51]. Through playful interactions, phygital interfaces make tasks more enjoyable, which increases user satisfaction and engagement.

3.3.6. Collaboration

Phygital interfaces enhance user experience by promoting collaboration and social interactions. These interfaces integrate digital and physical elements, allowing real-time collaboration regardless of the user's location [23]. They provide spatial affordances that encourage collaboration, allowing multiple users to share ideas, achieve goals, and provide feedback [32], [52]. Phygital interfaces facilitate communication and cooperation between team members by offering a shared workspace, leading to more productive and successful teamwork. This collaborative design platform is essential for enhancing user experience and productivity [53].

3.3.7. Engaging/active participation

Phygital interfaces are interactive and gamified tools that enhance user experience by encouraging active participation and creativity. They use interactive elements to motivate users to engage with content, fostering a sense of agency, autonomy, and enjoyment [48], [54]. Users can personalize their experiences by choosing avatars, adventures, decisions, and actions according to their preferences [55]. Immersive technologies like AR, VR, and MR enhance immersion and engagement by providing tactile and sensory-rich interactions [56], [57]. Thus, phygital interfaces provide positive engagement and active participation, contributing to users' unique experiences.

In conclusion, seven key findings summaries that the phygital experience seamlessly integrates physical and digital elements to create an engaging and interactive environment. By incorporating key aspects such as immersion, motivation, seamless integration, connectivity, playfulness, collaboration, and active participation, phygital experiences enhance user engagement and provide meaningful interactions. As technology continues to evolve, the potential for phygital experiences to enrich learning, social interactions, and digital engagement will only expand, offering innovative ways to connect users with both physical and virtual worlds.

3.4. Phygital tools or technologies used in games

Phygital interfaces blend physical and digital elements to offer a new way of interacting with technology. Within this realm, games are critical components used across various fields. Games that use phygital interfaces have proven effective for learning, entertainment, and therapy [17], [58]. In general, the researcher has identified four fields that use the phygital approach: entertainment, education, edutainment, and other domains.

3.4.1. Entertainment games

Entertainment games are primarily designed to provide enjoyment and immersive experiences rather than serve educational or serious purposes [59]. Over the years, advancements in phygital tools have transformed the gaming landscape, integrating digital and physical elements to enhance user engagement. Technologies such as AR, VR, robotics, and machine learning are shaping modern game design, making entertainment games more interactive and dynamic, as shown in Figure 5.

One significant trend is the rise of mixed-reality and robotics-based gameplay, as seen in mixed-reality robotic games (MRRGs), VR in digital sports and recreational games, and the woods. MRRGs utilize tracking software, headset-based AR, and robot control to create engaging real-world interactions [19]. VR-based digital sports integrate VR glasses, digital tracking, and sensory equipment to enhance gaming experiences, particularly in fitness and sports applications [32]. Similarly, The Woods combines game engine technology, AR, and tabletop gaming, utilizing the Photon Unity Network for seamless connectivity [33]. Despite these innovations, challenges such as hardware limitations, high costs, and user accessibility continue to hinder widespread adoption. Additional research is needed to explore cost-effective solutions and improve usability [60].

Beyond robotics and VR, entertainment games are also evolving through game networking and digital fashion, both of which focus on personalization and connectivity. Game networking incorporates digital twins, reinforcement learning, and wireless communication technologies, advancing artificial intelligence (AI)-driven interactions [61]. Meanwhile, digital fashion merges AR, virtual closet apps, and non-fungible tokens (NFTs) to revolutionize in-game customization and bridge gaming with e-commerce and the metaverse [62]. While these innovations provide commercial opportunities, concerns surrounding data privacy, blockchain environmental impact, and digital asset ownership require further discussion [63], [64].

Another notable development is the adaptation of traditional games into phygital formats. Minecraft Earth, EduPark, and UrbanAR integrate AR, touchscreen devices, and social interaction platforms to modernize gameplay while preserving cultural gaming elements [52]. These games not only entertain but also offer cognitive and social benefits, encouraging collaborative play and problem-solving [52]. However, maintaining long-term user engagement and ensuring device compatibility remain key challenges. Similarly, the T-Rex Google Dinosaur Game has been enhanced with phygital components, including pressure-sensitive chambers, machine learning algorithms, and Arduino microcontrollers, making the game more interactive through Python programming and wireless communication [65]. Therefore, phygital adaptations influence player motivation and learning outcomes.

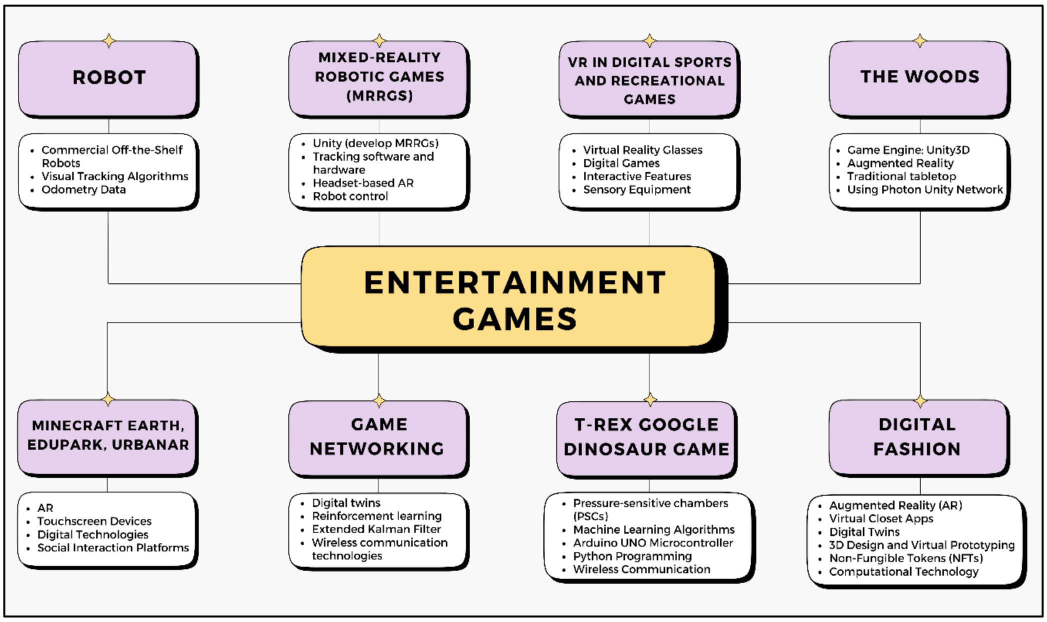

Figure 5. Phygital tools in entertainment games

3.4.2. Educational games

Educational games are designed to support learning by making the process more engaging and interactive. With the rise of phygital technology, which combines physical and digital elements, learning has become more immersive, allowing children to interact with both tangible objects and virtual content [59]. These games integrate AR, robotics, AI, and IoT-based tools to create meaningful learning experiences. As shown in Figure 6, several phygital educational games utilize different technologies to enhance learning in unique ways.

One key advantage of these games is their ability to provide multisensory interaction, which helps children develop cognitive, motor, and problem-solving skills [12], [66]. For instance, Osmo, Escape Box, and Live Learning Games use physical objects, AR, and digital tracking to create interactive challenges. These games encourage hands-on learning, allowing children to manipulate real-world items while receiving instant feedback from digital elements [50]. Similarly, Sphero and physical virtual sports (PVS) incorporate robotics and AI-driven motion tracking, promoting both learning and physical activity [20], [67]. These games help children develop coordination and spatial awareness while making learning more engaging.

In addition, phygital games enhance personalized learning by using AI and IoT to adapt to individual needs. For example, IoTGo and transmedia skills manifested in the games use cloud-based AI to provide real-time feedback, ensuring that children receive guidance based on their progress [68], [69]. The PH2D Hybrid Toolset, which integrates 3D printing and digital twin technology, allows learners to interact with virtual models in real-world settings, fostering creativity and critical thinking [70]. However, while these tools offer great benefits, concerns about privacy, accessibility, and digital dependency must be addressed to ensure responsible and effective use [71].

Phygital games are also valuable for cultural and contextual learning. Cultural heritage serious boardgames and Latin American video games incorporate RFID-based interaction and AR, helping students explore history and cultural narratives in a more immersive way [20]. Likewise, live learning games use interactive storytelling and spatial learning techniques to make cultural education more engaging [67]. While these approaches help preserve heritage, maintaining cultural authenticity in digital formats remains a challenge [70].

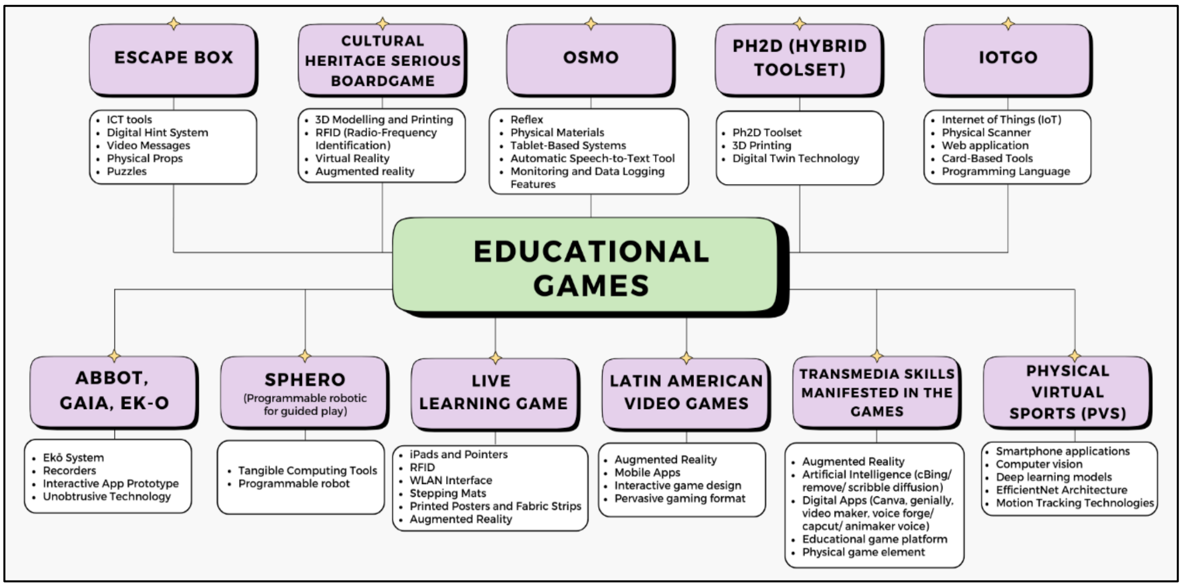

Figure 6. Phygital tools in educational games

3.4.3. Edutainment games

Edutainment games combine education and entertainment to make learning enjoyable and engaging. By integrating educational content into interactive game formats, these games encourage active participation and deeper understanding. The phygital approach, which blends physical and digital interactions, further enhances learning by providing immersive and hands-on experiences [54]. As shown in Figure 7, various edutainment games including Poly-Universe, Hybrid Escape Room, Kid Space, GoNature Game, and Periodic Fable Discovery incorporate AR, VR, AI, sensor networks, and tangible materials to create meaningful learning environments [72].

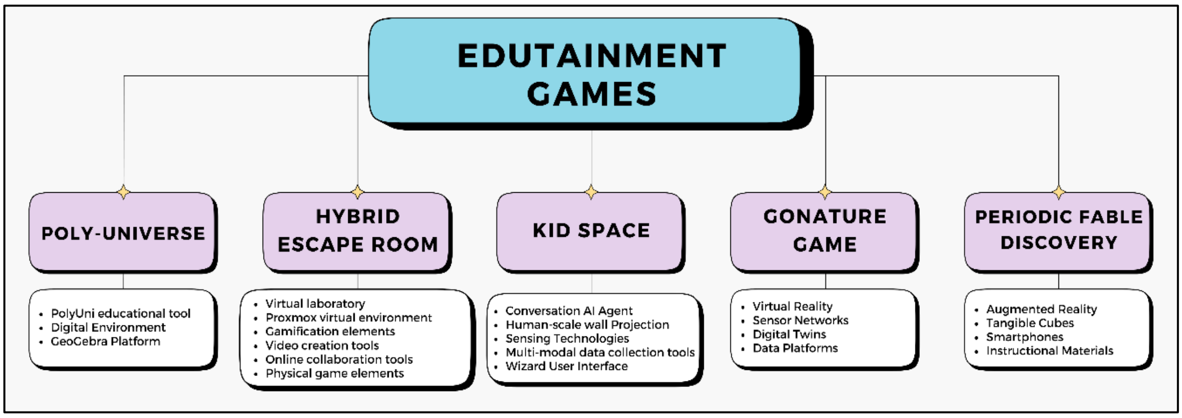

Figure 7. Phygital tools in edutainment games

Each of these games integrates different technologies to support education. Poly-Universe uses GeoGebra platforms and a digital environment to develop spatial and mathematical skills [73]. Hybrid Escape Room incorporates a virtual laboratory, gamification elements, video creation tools, and physical game elements, encouraging collaboration and problem-solving [74]. Kid Space features an AI conversation agent, human-scale wall projections, and sensing technologies, allowing students to interact with adaptive learning environments [75]. GoNature Game applies VR, sensor networks, and digital twins, enabling learners to explore environmental education in an immersive way [76]. Periodic Fable Discovery combines AR, tangible cubes, and smartphones to help children understand complex scientific concepts through hands-on engagement [54]. These games encourage experiential learning, where students actively participate in lessons, improving comprehension and retention [17].

Despite their many advantages, phygital edutainment games come with challenges. One concern is technological dependence, which may limit accessibility, especially in schools with limited resources [77]. Additionally, excessive exposure to digital stimuli may lead to cognitive overload, reducing learning effectiveness if not properly balanced with physical activities [78]. Another challenge is user adaptability, as these games must be designed to accommodate different learning styles and abilities to ensure inclusivity [79]. Ethical concerns regarding data privacy and security risks also arise when using AI and sensor networks in education, requiring careful implementation of safety measures [80].

3.4.4. Other types of games

Figure 8 highlights different types of games that improve user experience using phygital interfaces. These include playing with uncertainty (serious games) and HoloLens 2 (healthcare setting), both of which showcase the potential of phygital elements in decision-making, training, and user engagement. Playing with uncertainty integrates participatory modeling with physical-digital components to cultivate critical thinking and problem-solving skills in dynamic, unpredictable scenarios [81]. By merging physical and digital elements, these serious games create immersive learning environments that actively engage users, making them particularly effective for education and training. Similarly, HoloLens 2 in healthcare settings leverages mixed-reality technology, data extraction tools, and sentiment analysis techniques to enhance medical training, diagnostics, and therapy [23]. By enabling real-time visualization of complex medical data, MR improves clinical decision-making, accuracy, and efficiency in healthcare applications.

Despite their benefits, phygital games face challenges that hinder widespread adoption. High costs and technological complexity may limit accessibility, especially in resource-constrained settings. Additionally, user adaptability remains a concern, as not all individuals find mixed-reality interfaces intuitive or engaging. In healthcare, ethical issues such as data privacy and the accuracy of sentiment analysis require stringent safeguards to ensure compliance with medical regulations and protect user confidentiality [82].

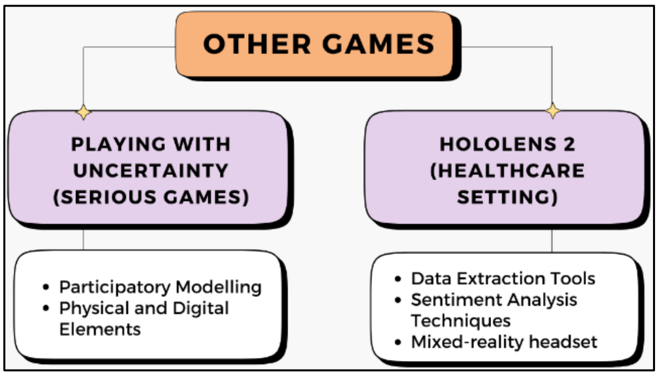

Figure 8. Phygital tools in other types of games

4. CONCLUSION

This systematic review identified 26 studies that examined the characteristics and user experiences of phygital interfaces. Seven key features were found, such as tangibility, hybridization, interactivity, personalization, multisensory input, contextual relevance, and technology integration. These contribute to immersive, playful, and socially connected experiences that surpass conventional digital interactions. However, limitations include the narrow database scope and focus primarily on user experience, suggesting future research should explore adoption challenges, broader regional applications, and insights from educators.

Phygital technologies show growing potential across various domains. In entertainment games, they enhance interactivity but require attention to ethical, economic, and accessibility issues. In education, they support personalized, multisensory learning but must address digital fatigue and inclusivity. Edutainment games can bridge learning and play, especially in low-resource settings, with a focus on adaptive and ethical design. Across all applications, future research should priorities usability, affordability, and scalability to ensure phygital solutions are inclusive, sustainable, and impactful.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors have no financial or personal relationships that could inappropriately influence or bias the content of this study.

DATA AVAILABILITY

The data supporting the findings of this study are accessible through databases indexed by Scopus, Web of Science, and IEEE Xplore. All data utilized in this research are presented within the article through tables, figures, and detailed discussions.

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