Journal of Learning Theory and Methodology
Журнал теорії та методології навчання

ISSN 2708-7581 (Online)
ISSN-L 2708-7573

Review Article

Augmented Reality in Secondary School Physical Education and Physical Literacy: Literature Review

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

DOI: 10.17309/jltm.2026.7.2.04

Abstract

Objectives. Although augmented reality (AR) is increasingly used in physical education, empirical evidence regarding its contribution to secondary school students' physical literacy remains scattered across different research designs, learning contexts, and outcomes. The purpose of this study was to synthesize empirical evidence regarding the use of AR in secondary school physical education and to map its contribution to outcomes conceptually related to physical literacy domains.

Materials and Methods. This study used a literature review design with reference to the PRISMA 2020 guidelines. Article searches were conducted in six databases, namely Scopus, Web of Science, ERIC, SPORTDiscus, PubMed, and Google Scholar. The search was limited to peer-reviewed journal articles published between 2015 and 2025. The keywords used combined terms related to augmented reality, physical education, secondary school, and outcomes related to physical literacy. A total of 1,061 articles were identified. After removing duplicate articles, screening titles and abstracts, assessing full texts, and evaluating eligibility, 7 articles met the inclusion criteria. Data were analyzed using narrative synthesis and thematic synthesis based on four domains of physical literacy: physical competence, motivation and confidence, knowledge and understanding, and physical activity engagement or participation. Methodological quality and risk of bias were assessed using the Mixed Methods Appraisal Tool (MMAT), and the strength of evidence was mapped using explicit coding criteria.

Results. The findings indicate that AR may support several outcomes conceptually related to physical literacy in secondary school physical education. AR-based learning can improve motor skills, sport-specific competencies, motivation, self-confidence, understanding of movement concepts, learning engagement, and physical activity participation. The strongest evidence was found in the domains of physical competence, motivation and self-confidence, and knowledge and understanding. Furthermore, AR-based game-based learning and AR-based outdoor activities also supported increased student engagement and physical activity. However, none of the included studies measured physical literacy as a complete multidimensional construct, so the results should be interpreted as evidence of physical literacy-related outcomes rather than direct evidence of overall physical literacy development.

Conclusions. AR has potential as a supportive pedagogical medium for promoting outcomes related to physical literacy in secondary school physical education. However, its effectiveness is highly dependent on the learning design, teacher preparedness, learning objectives, and the integration of AR with real-life physical activities. Future research is expected to develop more structured and long-term augmented reality interventions that explicitly measure students' physical literacy multidimensionally.

Keywords: augmented reality, physical education, physical literacy, secondary school, motor competence.

Introduction

Physical education plays a crucial role in supporting the development of secondary school students, particularly as adolescence is a transitional period marked by physical, psychological, social, and behavioral changes. In the school context, physical education serves not only to improve physical fitness but also serves as a pedagogical space for developing movement skills, cooperation, discipline, self-confidence, and active lifestyle habits (Prabowo et al., 2025). A study confirms that the provision of physical education, physical activity, and sport in schools has the potential to support adolescents' mental health, well-being, and physical activity experiences (Rocliffe et al., 2024). Therefore, physical

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education in secondary schools needs to be positioned as an important part of a holistic education that helps students build a foundation for participating in lifelong physical activity.

In modern physical education, physical literacy has become an important orientation because this concept views movement abilities more broadly than simply mastering motor skills. Physical literacy encompasses physical competence, motivation, self-confidence, knowledge, understanding, and engagement in meaningful physical activity. These domains indicate that physical literacy is not a single performance outcome, but a multidimensional construct that integrates physical, cognitive, affective, and behavioral aspects of participation in physical activity (Martínez-López et al., 2022). Scientific studies show that physical literacy has become a significant focus in school physical education and youth sports programs (Liu & Chen, 2021). However, its definition, measurement, and forms of intervention are still evolving, and school-based physical literacy promotion requires learning experiences that integrate movement competence, motivation, knowledge, confidence, and active engagement (Grauduszus et al., 2024; Nita Peranita et al., 2025; Nevitaningrum et al., 2026). Therefore, physical education that is oriented towards physical literacy needs to help students not only be able to perform movements, but also understand, appreciate, and be motivated to actively participate in physical activities.

However, despite its strategic role, its implementation in secondary schools still faces various challenges. Another problem is some students show low motivation, limited confidence, unequal movement competence, or insufficient engagement in movement-based learning. Scientific evidence shows that barriers to physical activity among secondary school and college students include lack of time, low motivation, and limited access to places or facilities that support physical activity (Silva et al., 2022; Alhroub et al., 2024). In addition, student involvement in physical education is greatly influenced by the quality of motivation, learning environment support, and learning strategies used by teachers (Cimenti et al., 2025; Terra et al., 2025). This condition shows that physical education learning requires a pedagogical approach that is more interesting, visual, interactive, and adaptive to the needs of secondary school students.

One approach that has the potential to address these challenges is the use of augmented reality in physical education learning. Augmented reality (AR) is a technology that combines virtual objects with real environments to provide more interactive, contextual, and immersive learning experiences. In education, studies in review articles and meta-analyses have shown that AR has a positive impact on various learning outcomes because it can provide more concrete visualization, interaction, and learning experiences (Chang et al., 2022; Yefremenko et al., 2025; Topalska & Rumenov, 2025). In physical education, AR may support learning through several mechanisms, including three-dimensional movement visualization, interactive exploration, embodied learning experiences, increased learner autonomy, and greater motivational engagement. Previous studies also indicate that virtual reality, augmented reality, and mixed reality technologies have begun to be used to support movement learning, motivation, and engagement in physical education contexts (K. E. Chang et al., 2020; Pérez-Muñoz et al., 2024; Omarov et al., 2024). With these characteristics, AR has the potential to help students understand movement techniques, visualize difficult concepts, increase motivation, and connect conceptual understanding with physical activity practice.

Numerous previous studies and reviews have addressed the use of digital technologies, augmented reality, virtual reality, and mixed reality in physical education. However, the available evidence remains scattered across contexts, educational levels, technology types, learning materials, research designs, and outcomes. This discrepancy suggests that AR studies in physical education still largely focus on instructional design and technology implementation options (Ariffin et al., 2022), while other, broader evidence still discusses and compares the use of virtual reality (VR), augmented reality (AR), and mixed reality (MR) in physical education (Pérez-Muñoz et al., 2024). On the other hand, physical literacy in physical education in schools still tends to focus on the motor skills aspect, while the application of a multidimensional physical literacy framework that includes motivation, self-confidence, knowledge, and long-term engagement is still limited (Ridha et al., 2025; Vieira et al., 2025). Moreover, many empirical AR studies in physical education do not directly measure physical literacy as a complete construct, but instead assess outcomes that are conceptually related to its domains, such as motor competence, motivation, confidence, knowledge, engagement, physical activity, and fitness. Therefore, a synthesis is still needed that specifically connects the use of AR in secondary school physical education with the realm of physical literacy.

Based on this gap, this study aims to conduct a literature review on the use of augmented reality (AR) in physical education at the secondary school level and its contribution to outcomes conceptually related to physical literacy. Specifically, this review aims to identify the forms of AR used, the context of the physical education materials developed, the results studied, and the contribution of AR to physical competence, motivation and self-confidence, knowledge and understanding, and engagement or participation in physical activity. This review does not assume that all included studies directly measured physical literacy as a multidimensional construct; rather, it maps and synthesizes AR-related evidence across domains that are theoretically aligned with physical literacy. This literature review is expected to provide a more comprehensive understanding of AR's position as a pedagogical medium in physical education. In addition, the results of this review are expected to be a basis for physical education teachers, researchers, and learning technology developers in designing AR-based learning that is not only technologically attractive but also meaningful for the development of physical literacy in secondary school students.

Materials and Methods

Research Design

This study employed a literature review design to identify, select, evaluate, and synthesize previous empirical studies on the use of augmented reality in secondary school

physical education. The review focused not only on studies that directly measured physical literacy, but also on studies that examined physical literacy-related outcomes, including physical competence, motor competence, motivation, confidence, knowledge and understanding, engagement, physical activity participation, and fitness. The reporting of this literature review refers to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines so that the process of searching, selecting, and synthesizing articles can be carried out transparently, systematically, and can be replicated (Page et al., 2021; Kurniawan et al., 2024).

This literature review was chosen because the available evidence on augmented reality in physical education is still distributed across different learning contexts, intervention designs, educational levels, and outcome measures. Therefore, the review aimed to map the forms of AR used in physical education, the types of learning materials involved, the outcomes measured, and the extent to which these outcomes were theoretically aligned with the domains of physical literacy. In this study, physical literacy is understood as a multidimensional construct that includes physical competence, motivation, self-confidence, knowledge, understanding, and engagement in physical activity. However, because most included studies did not assess physical literacy as a complete construct, the synthesis was framed around physical literacy-related domains rather than direct evidence of physical literacy as a whole.

The article selection process followed the main stages of the PRISMA 2020 flow: identification, screening, eligibility, and inclusion. The initial stage was the identification of articles from all predetermined databases. Next, duplicate articles were removed using a reference management tool. Articles were then screened based on their titles and abstracts to assess their initial relevance to the research topic. Articles deemed relevant were then read in full to ensure compliance with the inclusion and exclusion criteria. This process was conducted to ensure that only studies meeting the predefined criteria regarding AR use, secondary school context, physical education or school-based physical activity, and physical literacy-related outcomes were included in the final synthesis.

Article selection was conducted independently by two reviewers. Any differences in decisions during the selection process were resolved through discussion until consensus was reached. Articles meeting all inclusion criteria were then entered into the data extraction and synthesis phase. The identification, screening, eligibility, and inclusion process is presented in the form of a PRISMA flowchart. This procedure was applied to improve transparency, minimize selection bias, and strengthen the reproducibility of the review process.

Data Sources and Search Strategy

Article searches were conducted in six electronic databases: Scopus, Web of Science, ERIC, SPORTDiscus, PubMed, and Google Scholar. These databases were selected because they encompass multidisciplinary publications in education, physical education, sport science, health, physical activity, and learning technology. Google Scholar was used as a supplementary resource to identify relevant articles that may not be indexed in the primary databases. The article search was limited to publications published between 2015 and 2025. The search was restricted to peer-reviewed journal articles written in English and focused on studies involving secondary school students or adolescent populations within school-based physical education or physical activity contexts.

The search strategy was developed by combining four groups of keywords related to augmented reality, physical education, secondary school context, and physical literacy-related outcomes. The keywords used included: "augmented reality" OR "AR technology" OR "mobile augmented reality" OR "AR application" OR "AR-based learning"; "physical education" OR "school physical education" OR "PE class" OR "physical education learning"; "secondary school" OR "middle school" OR "junior high school" OR "senior high school" OR "high school" OR "adolescent students"; serta "physical literacy" OR "physical competence" OR "motor competence" OR "movement skills" OR "motivation" OR "confidence" OR "knowledge and understanding" OR "physical activity engagement" OR "fitness". The search strings were adapted to the syntax of each database, while maintaining the same conceptual structure across all searches. In Google Scholar, searches are more selective, reviewing the most relevant articles based on title, abstract, and compliance with research criteria. The last search was conducted on June 10, 2026.

Inclusion and Exclusion Criteria

Articles included in this systematic review must meet several inclusion criteria. First, the articles must have been published between 2015 and 2025. Second, the articles must be scientific publications in peer-reviewed journals. Third, the articles must be written in English. Fourth, the articles must discuss the use of augmented reality in the context of physical education or school-based physical activity. Fifth, the research subjects must be secondary school students, such as junior high, senior high, or high school students. Sixth, the articles must report either direct measures of physical literacy or outcomes conceptually related to physical literacy domains. In this review, physical literacy-related outcomes were operationally defined as outcomes associated with physical competence, motor competence, movement skills, motivation, confidence, knowledge and understanding, engagement, physical activity participation, or fitness. Seventh, the articles must be available in full-text or downloadable manuscript form.

The inclusion of physical literacy-related outcomes was necessary because many empirical studies on augmented reality in physical education do not measure physical literacy as a complete multidimensional construct. Therefore, studies were considered eligible when their outcomes could be theoretically mapped onto one or more physical literacy domains, namely physical competence, motivation and confidence, knowledge and understanding, and engagement or physical activity participation. This operational criterion was applied to avoid overclaiming while still allowing a structured synthesis of evidence relevant to physical literacy development.

Articles were excluded from the review if they met any of the following exclusion criteria: (1) did not use augmented reality; (2) only discussed virtual reality, mixed reality, instructional videos, or general digital applications without

augmented reality elements; (3) were not in the context of physical education or school-based physical activity; (4) the research subjects were not secondary school students or adolescent students in a school-based setting; (5) the article was in the form of an editorial, opinion piece, book chapter, thesis, dissertation, or conference abstract without full text; (6) did not report results relevant to physical literacy or physical literacy-related outcomes; (7) was a duplicate article; and (8) was not fully accessible.

Data Extraction

Data extraction was conducted systematically using a structured data extraction form developed by the authors. The extracted information included the author and year of publication, article title, study design, sample characteristics, educational level, form of augmented reality used, physical education or school-based physical activity context, intervention characteristics, comparison group, outcome variables, key findings, and relevance to physical literacy-related domains. The extraction process was conducted to ensure that the information obtained from each included study was comparable and relevant to the aims of the review.

The extracted outcomes were not limited to studies that directly measured physical literacy as a complete multidimensional construct. Because most included studies examined specific outcomes related to physical literacy, the extracted outcomes were categorized into four theoretically aligned domains: physical competence, motivation and confidence, knowledge and understanding, and engagement or physical activity participation. This approach was used to avoid overclaiming while still allowing a structured synthesis of how AR may contribute to outcomes conceptually related to physical literacy.

Data extraction was conducted independently by two reviewers. Any discrepancies in extracted data were discussed until consensus was reached. When necessary, the reviewers returned to the full-text articles to verify the accuracy of information related to the intervention, outcome measures, and main findings. The final extracted data were then organized in a synthesis table to support narrative and thematic analysis.

Quality Assessment and Risk of Bias

The methodological quality and risk of bias of the included studies were assessed using the Mixed Methods Appraisal Tool (MMAT) (Liao et al., 2021). MMAT was selected because the included studies used varied empirical designs, including quasi-experimental, comparative, pretest-posttest, and experimental approaches. The use of MMAT allowed the reviewers to evaluate the appropriateness of the study design, sample characteristics, data collection procedures, outcome measures, intervention implementation, and clarity of reported findings according to the methodological characteristics of each study.

The quality assessment was conducted independently by two reviewers. Each study was first assessed using the MMAT screening questions to determine whether the study had clear research questions and whether the collected data were appropriate to address those questions. After that, each article was appraised using the relevant MMAT criteria according to its research design. The appraisal focused on several aspects, including the clarity of participant selection, appropriateness of measurements, completeness of outcome data, clarity of intervention procedures, adequacy of comparison groups, and consistency between findings and conclusions.

The results of the quality assessment were not used to exclude studies from the review. Instead, they were used to support the interpretation of findings and to indicate the level of caution required when drawing conclusions. Studies with clearer intervention procedures, appropriate comparison groups, relevant outcome measures, and more complete reporting were given greater interpretive weight in the synthesis. Conversely, studies with methodological limitations, unclear reporting, or indirect relevance to physical literacy-related domains were interpreted more cautiously.

Coding Procedure for Physical Literacy-Related Domains

A coding procedure was developed to classify the contribution of each included study to the four physical literacy-related domains used in this review: physical competence, motivation and confidence, knowledge and understanding, and engagement or physical activity participation. This coding was necessary because most studies did not directly measure physical literacy as a complete construct, but instead reported specific outcomes that could be theoretically mapped onto one or more physical literacy domains.

Each included study was coded independently by two reviewers based on the outcomes reported, the relevance of those outcomes to the physical literacy-related domains, and the clarity of the study findings. The classification used four categories: strong, moderate, weak, and not reported. A domain was coded as strong when the study directly measured an outcome aligned with that domain and reported clear positive findings. A domain was coded as moderate when the study measured an outcome related to the domain but did not provide comprehensive evidence, or when the findings were positive but limited in scope. A domain was coded as weak when the relationship between the reported outcome and the domain was indirect, limited, or only briefly addressed. A domain was coded as not reported when the study did not include any outcome relevant to that domain.

The coding results were discussed until agreement was reached between reviewers. This procedure was used to make the classification in the evidence mapping table more transparent and reproducible. Therefore, the strong, moderate, and weak classifications in this review should not be interpreted as effect sizes or statistical strength, but as the degree of conceptual and empirical relevance between each included study and the physical literacy-related domains.

The research analysis process using the PRISMA guidelines is shown in Figure 1.

Based on Figure 1, the article selection process was conducted based on the PRISMA 2020 guidelines. In the identification stage, a search of articles through six databases—Scopus, Web of Science, ERIC, SPORTDiscus, PubMed, and Google Scholar—resulting in 1,061 articles. After all articles were collected, a duplication check was performed using a

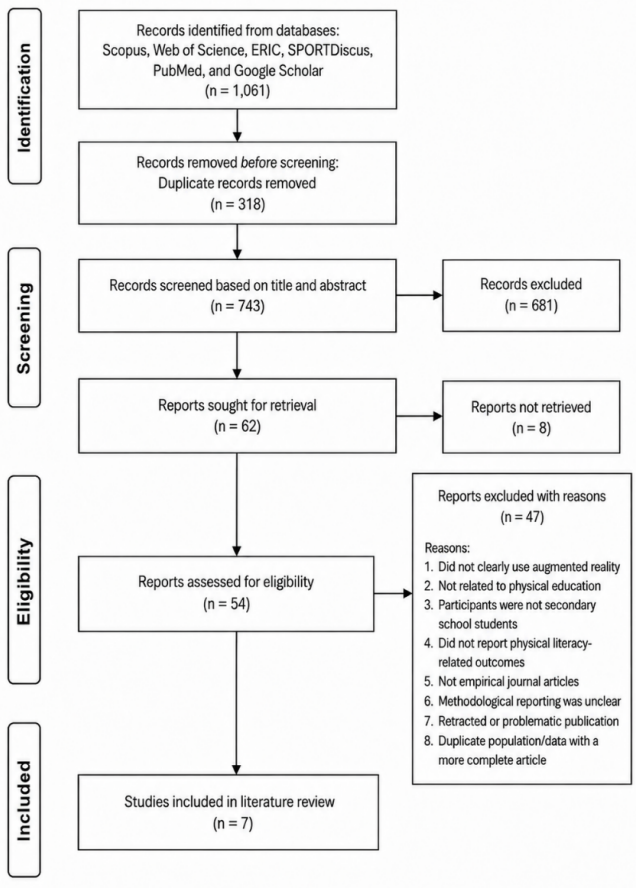

Fig. 1. Research framework based on the PRISMA method

reference management tool. A total of 318 duplicate articles were removed, leaving 743 articles for the screening stage.

In the screening stage, the titles and abstracts of the 743 articles were reviewed for relevance to the research focus, namely the use of augmented reality in physical education at the secondary school level and its relationship to physical literacy or outcomes relevant to physical literacy. From this process, 681 articles were excluded because they did not align with the research topic, did not use augmented reality, were not in the context of physical education, did not involve secondary school students, or did not report outcomes relevant to physical literacy. Therefore, 62 articles proceeded to the full-text search stage.

In the eligibility stage, 62 articles were searched and checked for full-text availability. Of these, 8 articles could not be retrieved in full text, resulting in a complete eligibility assessment of 54 articles. Full-text assessment was conducted based on established inclusion and exclusion criteria. Forty-seven articles were excluded for the following reasons: not explicitly using augmented reality, not in the context of physical education or school-based physical activity, not involving secondary school students, not reporting outcomes related to physical literacy, not being empirical articles, unclear research methods, having publication issues, or sharing data with other, more comprehensive articles.

Based on the entire selection process, seven articles met all inclusion criteria and were included in the final synthesis. These seven articles are Chang et al. (2020), Moreno-Guerrero et al. (2020), Orozco (2022), Kurniawan et al. (2025), Liang et al. (2023), Omarov et al. (2024), and Martínez-López et al. (2022). The identification, screening, eligibility, and inclusion process is presented in the PRISMA flowchart.

Results

Based on the article selection process using the PRISMA 2020 guidelines, seven articles met the inclusion criteria and were analyzed in this systematic literature review. These articles examined the use of augmented reality in secondary school physical education or school-based physical activity contexts and reported outcomes conceptually related to physical literacy. The characteristics of the included studies, forms of AR use, physical literacy-related outcomes, key findings, and synthesis meaning are presented in Table 1.

As shown in Table 1, the included studies varied in design, sample characteristics, AR implementation, learning context, and outcome measures. Most studies used quasi-experimental, comparative, or pretest-posttest designs, while the AR interventions included 3D movement models, mobile AR applications, AR-assisted sport skill learning, AR game-based environments, and outdoor AR activity. Importantly, none of the included studies measured physical literacy as a complete multidimensional construct. Therefore, the findings were interpreted as evidence related to physical literacy-related outcomes rather than direct evidence of overall physical literacy development.

The included studies most frequently reported outcomes related to physical competence, motor skills, learning motivation, knowledge and understanding, engagement, physical activity participation, and fitness. This pattern indicates that AR research in secondary school physical education is still more strongly focused on specific learning or behavioral outcomes than on comprehensive physical literacy assessment. Consequently, the synthesis in this review maps the evidence onto physical literacy-related domains to clarify how each study may contribute conceptually to physical literacy without overstating the findings.

To strengthen methodological transparency, all included studies were assessed for methodological quality and risk of bias. The appraisal focused on the clarity of research questions, appropriateness of collected data, participant selection, outcome measurement, completeness of outcome data, consideration of confounding factors, and clarity of intervention implementation. The results of the methodological quality and risk-of-bias assessment are presented in Table 2.

As shown in Table 2, all included studies had clear research questions and used data that were generally appropriate to address their stated objectives. However, several methodological concerns were identified, particularly related to non-randomized designs, limited reporting of participant allocation, incomplete control of confounding variables, and variation in intervention contexts. Most studies were therefore interpreted as having moderate methodological concerns. One study with a pretest-posttest design without a comparison group was interpreted with higher caution because causal inference was more limited. These appraisal results were not used to exclude studies, but they informed

Table 1. Characteristics of included studies and physical literacy-related outcomes

Title (author and year)	Design and Sample	AR Form	Outcome related to Physical Literacy	Key Findings	Meaning of Synthesis
Applying augmented reality in physical education on motor skills learning (K. E. Chang et al., 2020)	Quasi-experimental; Grade 7 students; comparing AR-assisted instruction with video-assisted instruction.	AR was used to teach movement skills through 3D models combined with books/ learning objects. The material included basic running movements and more complex Mark workout movements.	Physical competence, motor skills learning, learning motivation.	AR-assisted instruction is more effective than video-assisted instruction, especially for learning more difficult motor skills.	AR helps students understand movement in a more visual, interactive, and concrete way, contributing to improved movement competency.
Augmented reality as a resource for improving learning in the physical education classroom (Moreno-Guerrero et al., 2020)	Quasi-experimental post-test; 140 high school students in physical education.	AR used the Aurasma application to teach spatial orientation in physical education. The activities were conducted in two learning sessions.	Knowledge-understanding, motivation, autonomy, interaction, problem solving, spatial orientation.	AR-based learning is effective in physical education, particularly for mastering spatially oriented content. The largest difference was found in motivation.	AR not only enhances material comprehension but also strengthens student motivation, learning autonomy, and engagement in Physical Education learning.
Augmented Reality As A Teaching Strategy To Strengthen The Technical Fundamentals Of Volleyball (Orozco et al., 2022)	Comparative study with control and experimental groups; 44 Grade 9 students: 22 control and 22 experimental.	AR was used as a learning strategy for basic volleyball techniques, including overhand passing, underhand passing, serving, blocking, and spiking.	Knowledge-understanding, technical skill knowledge, motivation, sport-specific competence.	The AR group achieved higher post-test scores than the traditional group; the experimental average was 4.41 and the control average was 3.50, with a p-value of 0.001285.	AR strengthens students' understanding of sports technique concepts before they are internalized, thus supporting physical literacy in terms of movement knowledge and sports competency.
Augmented Reality (Ar)-Based Learning on Physical Education Learning Outcomes (Kurniawan et al.,2025)	Quantitative pretest–posttest; 32 junior high school students.	AR-assisted instruction was used in learning basic basketball movements.	Cognitive, affective, psychomotor outcomes, motivation, engagement, conceptual understanding.	There was a significant increase from pre-test to post-test; N-Gain was suggested to be effective. AR provides an immersive learning experience through 3D visualization and increases motivation, engagement, and conceptual understanding.	AR has the potential to enhance three domains of physical education learning outcomes: cognitive, affective, and psychomotor, which align with the concept of physical literacy.
The Effectiveness of Augmented Reality in Physical Sustainable Education on Learning Behaviour and Motivation (Liang et al., 2023)	Quasi-experimental pretest–posttest; two groups: 28 students in the video group and 28 students in the AR group.	AR was developed with Unity 3D and used as a teaching material for movement skills in health and physical education. The control group used video.	Motor skills, learning effect, learning motivation, confidence, satisfaction, learning behaviour.	The AR group demonstrated better motor learning outcomes, motivation, and motor skill performance than the video group.	AR is superior to video because students can manipulate 3D models, view movements from various angles, and learn more independently.
Applying an augmented reality game-based learning environment in physical education classes to enhance sports motivation (Omarov et al., 2024)	Experimental study; two groups of 30 students each; the intervention lasted for one semester.	AR game-based learning environment in physical education/ sports classes.	Motivation, physical activity level, engagement, participation.	The AR group demonstrated higher levels of physical activity and motivation than the traditional physical education group.	AR-based games strengthen motivation and active participation, thus supporting the affective and behavioral domains of physical literacy.

Table 1 (continued)

Title (author and year)	Design and Sample	AR Form	Outcome related to Physical Literacy	Key Findings	Meaning of Synthesis
Effects of the augmented reality game Pokémon GO on fitness and fatness in secondary school students (Martínez-López et al., 2022)	Comparative design; 78 students in the Pokémon GO group and 86 students in the control group; students aged 12–15.	Use of the AR Pokémon GO game for 8 weeks in school and family contexts to increase physical activity.	Physical activity, cardiorespiratory fitness, speed/agility, muscular strength, BMI, body fat.	Pokémon GO players walked a total of 52 km over 8 weeks and played for an average of 40 minutes per day. There was an increase in CRF and a decrease in BMI; inactive students experienced a 22.2% increase in CRF and an 11.3% decrease in body fat.	AR-based outdoor activities can increase physical activity and fitness, but its position as a stronger supporter of the active engagement domain is stronger than formal physical education learning.

Table 2. Methodological quality and risk-of-bias assessment of included studies

Study	Study design	S1	S2	QN1	QN2	QN3	QN4	QN5	Main methodological concerns	Overall appraisal
Chang et al. (2020)	Quasi-experimental	Yes	Yes	Yes	Yes	Yes	Partial	Yes	Non-randomized design; potential confounding was only partly controlled.	Moderate concerns
Moreno-Guerrero et al. (2020)	Quasi-experimental post-test	Yes	Yes	Yes	Yes	Partial	Partial	Yes	Post-test design limits baseline comparison; potential confounding may remain.	Moderate concerns
Orozco et al. (2022)	Comparative study	Yes	Yes	Partial	Yes	Yes	Partial	Yes	Small sample size and limited information on participant allocation.	Moderate concerns
Kurniawan et al. (2025)	Pretest–posttest quantitative study	Yes	Yes	Partial	Yes	Yes	No	Partial	Absence of a comparison group limits causal interpretation.	Higher concerns
Liang et al. (2023)	Quasi-experimental pretest–posttest	Yes	Yes	Yes	Yes	Yes	Partial	Yes	Non-randomized design; some concerns regarding control of confounding variables.	Moderate concerns
Omarov et al. (2024)	Experimental study	Yes	Yes	Partial	Yes	Yes	Partial	Yes	Limited clarity on allocation and control of possible confounders.	Moderate concerns
Martínez-López et al. (2022)	Comparative design	Yes	Yes	Yes	Yes	Yes	Partial	Yes	Outdoor AR activity context may introduce uncontrolled behavioral and environmental factors.	Moderate concerns

Note. S1 = clarity of research questions; S2 = appropriateness of collected data to address the research questions; QN1 = appropriateness of participant selection; QN2 = appropriateness of measurements; QN3 = completeness of outcome data; QN4 = consideration of confounding factors; QN5 = whether the intervention or exposure was implemented as intended. "Yes" indicates that the criterion was sufficiently met, "Partial" indicates that the criterion was partly met or insufficiently reported, and "No" indicates that the criterion was not met. The overall appraisal indicates the level of caution required when interpreting each study and should not be treated as a numerical quality score.

the interpretation of the synthesis and the level of caution applied when drawing conclusions.

The extracted outcomes were then mapped onto four physical literacy-related domains: physical competence, motivation and confidence, knowledge and understanding, and engagement or physical activity participation. Because the included studies did not all directly measure physical literacy, this mapping was used to identify the degree of conceptual and empirical relevance between the outcomes reported in each study and the physical literacy-related domains. The evidence mapping is presented in Table 3.

Table 3 shows that the strongest evidence was concentrated in three domains: physical competence, motivation and confidence, and knowledge and understanding. In the physical competence domain, Chang et al. (2020), Kurniawan et al. (2025), and Liang et al. (2023) provided the strongest evidence because they directly reported motor skill, psychomotor, or movement learning outcomes. These studies suggest that AR may support movement learning by making movement sequences, body positions, and technical information more visible and easier to understand.

In the motivation and confidence domain, Moreno-Guerrero et al. (2020), Kurniawan et al. (2025), Liang et al. (2023), and Omarov et al. (2024) provided strong evidence. These studies reported outcomes such as motivation, confidence, satisfaction, autonomy, and learning behavior. The findings suggest that AR may enhance affective engagement because it provides interactive, novel, and learner-centered experiences that differ from traditional instruction or video-based learning.

Table 3. Evidence mapping of included studies across physical literacy-related domains

Artikel	Physical Competence	Motivation & Confidence	Knowledge & Understanding	Engagement / Physical Activity	Posisi dalam Review
Applying augmented reality in physical education on motor skills learning (K. E. Chang et al., 2020)	Strong	Moderate	Moderate	Moderate	A core article explaining the impact of AR on motor skill learning.
Augmented reality as a resource for improving learning in the physical education classroom (Moreno-Guerrero et al., 2020)	Moderate	Strong	Strong	Moderate	A core article explaining the impact of AR on motivation, autonomy, and spatial orientation understanding.
Augmented Reality As A Teaching Strategy To Strengthen The Technical Fundamentals of Volleyball (Orozco et al., 2022)	Moderate	Moderate	Strong	Moderate	A key article explaining AR in learning specific sport techniques, namely volleyball.
Augmented Reality (Ar)-Based Learning on Physical Education Learning Outcomes (Kurniawan et al.,2025)	Strong	Strong	Strong	Moderate	A key article covering the cognitive, affective, and psychomotor domains.
The Effectiveness of Augmented Reality in Physical Sustainable Education on Learning Behaviour and Motivation (Liang et al., 2023)	Strong	Strong	Medium	Moderate	A core article comparing the effectiveness of AR with video-based learning.
Applying an augmented reality game-based learning environment in physical education classes to enhance sports motivation (Omarov et al., 2024)	Moderate	Strong	Moderate	Strong	A core article explaining AR game-based learning on motivation and physical activity.
Effects of the augmented reality game Pokémon GO on fitness and fatness in secondary school students (Martínez-López et al., 2022)	Moderate	Moderate	Weak	Strong	A supporting article explaining the contribution of AR to students' physical activity and fitness.

Note. Strong = the study directly measured an outcome aligned with the domain and reported clear positive findings. Moderate = the study measured an outcome related to the domain but provided limited, partial, or indirect evidence. Weak = the study only indirectly addressed the domain or provided limited evidence. Not reported = the study did not report outcomes relevant to the domain. These classifications indicate the degree of conceptual and empirical relevance to physical literacy-related domains and should not be interpreted as statistical effect sizes.

In the knowledge and understanding domain, Moreno-Guerrero et al. (2020), Orozco et al. (2022), and Kurniawan et al. (2025) showed strong relevance. These studies indicate that AR can support conceptual understanding in physical education, including spatial orientation, sport technique knowledge, and cognitive learning outcomes. This evidence suggests that AR may function as a bridge between conceptual explanation and movement practice by making abstract or technical content more concrete.

In the engagement or physical activity domain, Omarov et al. (2024) and Martínez-López et al. (2022) provided the strongest evidence. Omarov et al. (2024) showed that AR game-based learning was associated with higher motivation and physical activity levels in physical education classes. Martínez-López et al. (2022) showed that Pokémon GO encouraged physical activity and improved selected fitness-related outcomes. However, this evidence should be interpreted carefully because AR-based outdoor activity does not always represent formal physical education learning with explicit pedagogical objectives.

Overall, the results indicate that AR may support several outcomes conceptually aligned with physical literacy, especially when AR is used to visualize movement, increase motivation, strengthen conceptual understanding, and promote active engagement. Nevertheless, the evidence remains limited because the included studies mostly measured domain-specific outcomes rather than physical literacy as a complete multidimensional construct. Therefore, the findings should be interpreted as evidence of AR's contribution to physical literacy-related outcomes, not as direct evidence that AR improves physical literacy as a whole.

Discussion

The results of this literature review indicate that the use of augmented reality in physical education at the secondary school level has the potential to positively contribute to students' physical literacy-related outcomes. However, the findings should not be interpreted as direct evidence that AR improves physical literacy as a complete multidimensional construct, because most included studies measured specific outcomes related to physical literacy rather than physical literacy itself. This contribution is seen in four main domains: physical competence, motivation and confidence, knowledge and understanding, and engagement or physical activity. These findings suggest that augmented reality functions not

only as a technological medium but also as a pedagogical approach that can enrich the movement learning experience. Through visualization, interaction, embodied learning, and learner-centered exploration, AR may create conditions that support outcomes conceptually aligned with physical literacy. These results align with the development of research on immersive technologies in physical education, which shows that AR, VR, and MR are beginning to be used to support student learning, motivation, engagement, and physical activity (Pérez-Muñoz et al., 2024; Jantanukul, 2024).

In the realm of physical competence, review results indicate that AR can help students understand and master movement skills more effectively. Studies by Chang et al. (2020), Liang et al. (2023), Kurniawan et al. (2025), and Orozco (2022) show that the use of AR can support learning in motor skills, sports skills, and psychomotor domains. The advantage of AR lies in its ability to display objects or movement models visually, interactively, and observably from various angles. This mechanism may help students observe movement sequences, recognize body positions, compare correct and incorrect techniques, and internalize technical information before engaging in direct movement practice. This helps students understand movement sequences, body positions, and sports techniques before practicing them directly (Antonopoulos, 2024). Therefore, AR can be a supporting media that is relevant to physical education materials that require movement control, coordination, and mastery of motor skills. Nevertheless, the evidence should be interpreted cautiously because several studies used non-randomized or quasi-experimental designs, meaning that improvements in motor-related outcomes cannot be attributed solely to AR without considering the role of teacher instruction, practice time, and initial student ability.

In the motivation and self-confidence domain, review results indicate that AR can increase student motivation, learning interest, self-confidence, and satisfaction in physical education learning. Findings by Moreno-Guerrero et al. (2020), Liang et al. (2023), Omarov et al. (2024), and Kurniawan et al. (2025) indicate that students who learn using AR tend to have better affective engagement compared to traditional or video-based learning. This may occur because AR provides a more novel, interactive, and enjoyable learning experience. From a pedagogical perspective, AR may influence motivation through several mechanisms, including novelty effects, autonomy in exploring learning materials, immediate visual interaction, game-based challenges, and opportunities to learn at an individual pace. In the context of physical literacy, motivation and self-confidence are important aspects because students not only need to be able to move but also need to have an internal drive to engage in physical activity continuously (Martín-Rodríguez & Madrigal-Cerezo, 2025; Prabowo et al., 2025). Therefore, AR can be a relevant strategy to overcome low student motivation in learning Physical Education, although its motivational benefits may depend on how well the AR activity is integrated with meaningful physical tasks rather than being used merely as a technological attraction.

In the realm of knowledge and understanding, AR plays a role in strengthening students' understanding of movement concepts, sports techniques, spatial orientation, and the relationship between theoretical knowledge and physical practice. A study by Moreno-Guerrero et al. (2020) showed that AR is effective for learning spatial orientation, while Orozco (2022) showed that AR helps students understand basic volleyball techniques. Kurniawan et al. (2025) also showed that 3D visualization in basketball learning can improve students' conceptual understanding. These findings align with the characteristics of AR, which can make abstract concepts more concrete by combining virtual objects with real environments (H. Y. Chang et al., 2022). In this way, AR may serve as a cognitive bridge between verbal explanation, visual representation, and physical execution, allowing students to connect what they see, understand, and perform in movement learning. However, the use of AR still needs to be designed carefully because visualizations that are too complex or unfocused can distract students from the main learning objectives (Chamola et al., 2025; Albishri & Blackmore, 2025). Thus, AR-based learning should include clear instructional cues, simple visual displays, and teacher-guided reflection to prevent unnecessary cognitive load.

In the domain of engagement and physical activity, AR has the potential to increase student engagement in physical activity, especially when developed in the form of game-based learning or outdoor activities. A study by Omarov et al. (2024) showed that AR game-based learning environments can increase students' motivation and physical activity levels compared to traditional physical education. Meanwhile, Martínez-López et al. (2022) showed that using Pokémon GO can encourage students to be more physically active, improve cardiorespiratory fitness, and reduce certain body composition indicators. These findings are important because one of the challenges of physical education in secondary schools is how to keep students active, engaged, and enjoying physical activity (Cimenti et al., 2025; Prabowo et al., 2025). However, the use of outdoor game-based AR needs to be distinguished from formal physical education learning, because not all AR activities automatically have a structured pedagogical goal. Therefore, evidence from outdoor AR games should be interpreted as supporting engagement or physical activity participation rather than as direct evidence of formal physical education learning or complete physical literacy development.

Importantly, the results of this review demonstrate that the effectiveness of AR in physical education is determined not only by technological sophistication but also by the quality of pedagogical design. AR is most effective when used to support clear learning objectives, appropriate movement materials, targeted teacher instruction, and adequate opportunities for physical practice (Ariffin et al., 2022; Antonopoulos, 2024; Ridwan et al., 2025). On the other hand, AR can be less effective if it is only used as an additional medium without strong integration with motor learning (Yudiernawati et al., 2025). The methodological quality assessment also indicates that most included studies had moderate methodological concerns, particularly related to non-randomized designs, limited reporting of participant allocation, and incomplete control of confounding variables. One study with a pretest-posttest design without a comparison group required higher caution because causal inference was more limited. Previous literature also shows that technology integration in education can address challenges such as device access gaps, limited teacher training, digital content quality, cognitive load, and school readiness (Martín-Rodríguez & Madrigal-Cerezo, 2025). Therefore, AR should not be positioned as a substitute for teachers or a

substitute for movement practice, but rather as a pedagogical medium to strengthen physical education learning.

The implications of this literature review indicate that physical education teachers can utilize AR to clarify reflection techniques, strengthen understanding of movement concepts, increase motivation, and encourage student engagement in physical activity. For schools, the use of AR requires device support, networking, teacher training, and integration with the physical education curriculum. For learning technology developers, the results of this review emphasize the importance of designing AR applications that are simple, easy to use, appropriate to the characteristics of secondary school students, and support real-life physical activity. For researchers, these findings open up opportunities to develop AR interventions that explicitly measure physical literacy multidimensionally, not just motor learning outcomes or motivation. Thus, AR can be developed as a learning medium that is not only technologically engaging but also relevant to the goals of modern physical education.

This study has several limitations. First, only seven articles met the inclusion criteria, so generalization of the findings should be done with caution. Second, most articles did not measure physical literacy as a whole, but instead used outcomes related to physical literacy, such as motor competence, motivation, knowledge, engagement, physical activity, and fitness. Third, study designs, types of AR, intervention duration, physical education materials, and measurement instruments varied significantly across articles, necessitating a meta-analysis. Fourth, some articles focused more on school-based or outdoor physical activity than on formal learning. Future research is expected to develop more structured and long-term augmented reality interventions that explicitly measure students' physical literacy across multiple dimensions.

Conclusion

This review indicates that augmented reality (AR) has the potential to support outcomes conceptually related to physical literacy in secondary school physical education. Across the seven included studies, AR was associated with improvements in physical competence, motivation and confidence, knowledge and understanding, and engagement or physical activity participation. However, the evidence should be interpreted cautiously because most studies did not directly measure physical literacy as a complete multidimensional construct. Instead, they reported domain-specific outcomes such as motor skills, conceptual understanding, motivation, physical activity, and fitness. The findings suggest that AR may be useful when it is integrated with clear pedagogical objectives, teacher guidance, appropriate movement tasks, and opportunities for real physical practice. Therefore, AR should be positioned as a supportive pedagogical tool rather than a substitute for teachers or direct movement experiences. Future studies should use stronger designs and multidimensional physical literacy measures.

Ethics Approval

Ethical approval was not required because this study was a literature review based exclusively on previously published studies and did not involve the collection of primary data from human participants.

Informed Consent

Informed consent was not applicable because this study did not involve the recruitment of human participants or the collection of primary data.

Data Availability Statement

No new primary data were generated or collected in this study. All data analyzed in this review were derived from the published studies included in the literature review and are reported within the article.

AI Transparency Statement

Generative artificial intelligence tools were used solely for language editing and improving the readability of the manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest.

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Доповнена реальність у фізичному вихованні та фізичній грамотності учнів середньої школи: огляд літератури

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 13 с., 3 табл., 1 рис., 36 джерел.

Мета. Незважаючи на зростання використання технологій доповненої реальності (AR) у фізичному вихованні, результати емпіричних досліджень щодо їх застосування серед учнів середньої школи є неоднорідними за дизайном досліджень, освітнім контекстом і досліджуваними показниками. Метою дослідження було систематизувати та узагальнити емпіричні дані щодо застосування AR у фізичному вихованні учнів середньої школи та визначити її зв'язок із показниками, що характеризують основні компоненти фізичної грамотності.

Матеріали та методи. У дослідженні використано дизайн огляду літератури з урахуванням рекомендацій PRISMA 2020. Пошук статей проводили в шести базах даних: Scopus, Web of Science, ERIC, SPORTDiscus, PubMed та Google Scholar. Пошук було обмежено рецензованими журнальними статтями, опублікованими в період з 2015 по 2025 рік. Використані ключові слова поєднували терміни, пов'язані з доповненою реальністю, фізичним вихованням, середньою школою та результатами, пов'язаними з фізичною грамотністю. Загалом було виявлено 1061 статтю. Після видалення дублікатів, скринінгу назв і анотацій, оцінювання повних текстів та перевірки відповідності критеріям включення до огляду було включено 7 статей. Дані аналізували за допомогою наративного та тематичного синтезу на основі чотирьох доменів фізичної грамотності: фізична компетентність, мотивація та впевненість, знання та розуміння, а також залученість до фізичної активності або участь у ній. Методологічну якість і ризик упередженості оцінювали за допомогою Mixed Methods Appraisal Tool (MMAT), а силу доказів визначали з використанням чітких критеріїв кодування.

Результати. Результати свідчать, що AR може сприяти покращенню низки показників, концептуально пов'язаних із фізичною грамотністю, у фізичному вихованні учнів середньої школи. Навчання на основі AR може покращувати рухові навички, специфічні для окремих видів спорту компетентності, мотивацію, упевненість у собі, розуміння концепцій руху, залученість до навчання та участь у фізичній активності. Найпереконливіші докази було виявлено в доменах фізичної компетентності, мотивації та впевненості в собі, а також знань і розуміння. Крім того, ігрове навчання та заняття на відкритому повітрі на основі AR також сприяли підвищенню залученості учнів і рівня фізичної активності. Однак у жодному з включених досліджень фізичну грамотність не вимірювали як цілісний багатовимірний конструкт, тому отримані результати слід інтерпретувати як докази щодо показників, пов'язаних із фізичною грамотністю, а не як прямі докази розвитку фізичної грамотності загалом.

Висновки. AR має потенціал як допоміжний педагогічний засіб для сприяння результатам, пов'язаним із фізичною грамотністю, у фізичному вихованні учнів середньої школи. Однак її ефективність значною мірою залежить від дизайну навчання, підготовленості вчителя, навчальних цілей та інтеграції AR із реальною руховою активністю. У майбутніх дослідженнях доцільно розробляти більш структуровані й довготривалі втручання із застосуванням доповненої реальності, які передбачатимуть безпосереднє багатовимірне оцінювання фізичної грамотності учнів.

Ключові слова: доповнена реальність, фізичне виховання, фізична грамотність, середня школа, рухова компетентність.

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Cite this article as: Prabowo, T. A., Afifah, M., Indarto, A. V., Pahlavi, Z. Y. D., & Cahyo, F. D. (2026). Augmented Reality in Secondary School Physical Education and Physical Literacy: Literature Review. *Journal of Learning Theory and Methodology, 7*(2), 91-103. https://doi.org/10.17309/jltm.2026.7.2.04

Received: 18.06.2026. Accepted: 21.07.2026. Published: 15.08.2026