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New Paradigm of Physical Education: SLR Analysis of AI in Handball Measurement Tests and SDGs-Based Eco-Friendly Facilities

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ABSTRACT

In the current era of digital transformation and global sustainability, 21st-century skills, including technological literacy and environmental awareness, are crucial competencies for students. Artificial intelligence (AI)-based teaching integrated with sustainability values is seen as an effective, creative, and engaging pedagogical strategy to improve these skills in physical education. This research builds on the limitations of previous studies, which focused primarily on basic manual techniques, without considering the impact of infrastructure on the environment or the efficiency of data-based evaluation. This study aims to systematically analyze the literature on the role of AI in evaluating handball measurement test instruments and managing environmentally friendly infrastructure to support the Sustainable Development Goals (SDGs) targets. The method used is a Systematic Literature Review (SLR) with PRISMA design, including analysis of Scopus and ERIC databases using VOSviewer and Harzing's Publish or Perish software. The results show that AI integration has a significant positive impact on the objectivity of motor assessment and the efficiency of facility management. At the same time, scaffolding variables in teachers' digital literacy are key factors influencing the implementation's success. The findings reveal that facilities not grounded in sustainability principles fail to make long-term contributions to students' psychomotor development globally. In conclusion, this new paradigm demands a repositioning of the physical education curriculum that synergizes smart technology with green facility management to create an inclusive and sustainable future for sport.

Keywords: Artificial Intelligence, Handball, Physical Education, Facilities and Infrastructure, Sustainable Development Goals (SDGs).

INTRODUCTION

Physical Education (PJ) is currently in the midst of a global crisis triggered by climate change, the acceleration of digital transformation, and a massive decline in physical health (Darmayanti et al., 2024; F. Hariyanti et al., 2026; Zuhri et al., 2026). The significance of PJ at the international level is no longer limited to physical fitness alone. Still, it has become a key pillar in supporting the Sustainable Development Goals (SDGs) (Darmayanti et al., 2023; E. Hariyanti et al., 2026; Puspitasari et al., 2025), particularly SDG 3 (Health and Well-Being) and SDG 4 (Quality Education). Global challenges require education systems to produce not only motor-skilled students but also environmentally conscious and technologically literate students. This aligns with statements by experts who emphasize that integrating technology and sustainability in sports is a crucial step to maintain the relevance of sports pedagogy in the future (Obaideen et al., 2022; Prasetyo et al., 2025). Therefore, it is important to view PJ as an interconnected ecosystem of digital technology (Darmayanti et al., 2026; F. Hariyanti et al., 2025; Sari et al., 2025), physical activity, and facility sustainability.

The main problem in teaching sports, particularly handball, often stems from conventional, subjective evaluation methods and from facility management that neglects ecological aspects (Mustari & Darmayanti, 2024; Santiago et al., 2023; Sefira et al., 2024). A significant challenge arises when teachers must accurately test and measure complex motor skills amidst limited available instruments. The lack of infrastructure that supports environmentally friendly principles also increases schools' operational burden and negatively affects their carbon footprint (Zakari et al., 2022). Teachers' low digital literacy in utilizing Artificial Intelligence (AI) widens the gap between modern curriculum demands and realities on the ground. If left unchecked, these issues will hinder the achievement of the SDGs targets in physical education due to stagnant innovation at the practical and managerial levels (Prasetyo et al., 2023; Van den Tillaar, 2021).

Several previous studies have examined various aspects of physical education and sports. Research related to the effectiveness of physical education learning and motor development has been conducted by (Nordiansyah & Prasetyo, 2020; Sahli et al., 2021; Wandee, 2023); research related to the application of technology in sports was conducted by (Oytun, 2020; Van den Tillaar, 2021); research related to infrastructure and environmental sustainability was discussed by (Li et al., 2022; Obaideen et al., 2022); and research related to creative teaching strategies and the SDGs has been reviewed by (Opstoel et al., 2020; Prasetyo et al., 2025; Vasconcellos et al., 2020). However, each of these studies has significant weaknesses: the studies by Sahli et al. (2021) and Wandee (2023) tend to ignore the green infrastructure aspect, while the study by Oytun (2020) focuses only on AI algorithms, without connecting them to the pedagogical context in elementary or secondary schools. Much of the literature remains fragmented, with technology and sustainability considered separate entities within the physical education domain.

The novelty of this research lies in integrating AI as a handball measurement test instrument, directly synchronized with the management of environmentally friendly infrastructure within a single SDGs framework (Darmayanti et al., 2023; Vidyastuti et al., 2022; Wulandari et al., 2022). Unlike previous studies that viewed AI solely as a statistical tool, this research positions AI as a key driver of efficient resource use in sports facilities (smart infrastructure). This novelty includes an analysis of how AI can reduce energy waste in sports facilities while simultaneously increasing the precision of motor assessments. No research has explicitly and systematically synthesized "AI-Green Facilities-Handball Assessment" as a unified new paradigm. Focusing on the environmental aspects of the SDGs in the specific context of handball provides an original contribution to the global sports pedagogy literature (Basri et al., 2025; Śliż, 2025).

The research gap identified is the lack of comprehensive guidelines linking smart technology to green facility standards in athletic schools. This study differs significantly from previous research. While previous studies often focused on single experiments on a single variable (such as AI-only or motor-only), this study conducted a comprehensive systematic review (SLR) to map the causal relationship between AI efficiency and environmental sustainability (Auliya & Darmayanti, 2026; A'yunin & Darmayanti, 2026; Khuluq & Darmayanti, 2026). There is a data gap regarding how teachers' digital literacy scaffolding can mitigate the negative impacts of unsustainable facilities on students' psychomotor skills. This study fills this gap by exploring the global literature on the links between cognitive, motor, and affective success through the lens of green technology, a topic that has not been examined in depth in handball research (Achenbach et al., 2020; Prasetyo et al., 2025).

The theoretical framework used in this study is based on Grand Theory, Self-Determination Theory (odi et al., 2025; Prasetyo, 2025, 2026), and Educational Ecosystem Theory. Self-Determination Theory is used to analyze student and teacher motivation in adopting AI technology (Vasconcellos et al., 2020), while Educational Ecosystem Theory holds that the success of physical education is highly dependent on interactions among individuals, technology, and the physical environment (infrastructure). The use of these two theories allows researchers to view physical education not only as a physical activity but as a complex psychological and ecological process. This theory is supported by the argument that a "green" physical environment and "smart" technology together create a more inclusive and effective learning atmosphere for the development of students' athletic talents (Opstoel et al., 2020; Rocamora, 2024).

The main concepts promoted in this research include "AI-Powered Assessment" and "Eco-Sport Infrastructure." The AI concept in this research refers not only to automation but also to the use of algorithms to predict performance and provide real-time feedback to handball students. On the other hand, environmentally friendly facilities are those that minimize greenhouse gas emissions and use sustainable materials, in line with SDG 12 targets (Duffner et al., 2021; Li et al., 2022). The synergy between these two concepts creates a smart sports ecosystem that can improve learning quality while preserving the planet. Facility management based on these concepts is believed to increase student psychomotor engagement through a comfortable environment and transparent assessment data (Cárcamo, 2021; Nordiansyah & Prasetyo, 2020).

An interesting aspect of this research, and therefore crucial to examine, is the paradigm shift where physical education now bears a moral responsibility for the climate crisis through facility management. Interestingly, the use of AI, which is typically considered expensive and environmentally "heavy," is mapped in this study as a solution to achieve green efficiency through optimizing paperless measurement tests and minimizing equipment waste. The importance of this research also lies in its efforts to prevent handball from falling behind football or basketball in terms of technology. By exploring this gap, the research offers new hope for schools to maintain motor achievement without sacrificing the ethical environmental values that are a global requirement (Mon-López et al., 2020; Prasetyo et al., 2025).

The primary objective of this study is to conduct an in-depth systematic literature review (SLR) to map the potential and challenges of AI integration in handball measurement tests and the management of environmentally friendly infrastructure based on the SDGs. Specifically, this study aims to identify key variables influencing the effectiveness of AI-based motor assessments and to find the best framework for sustainable sports facility management. The results of this study are expected to provide strategic recommendations for physical education practitioners and policymakers in designing curricula that focus not only on cognitive and physical achievement but also on ecological awareness and technological proficiency. In pursuit of this objective, the study seeks to establish new standards for modern, smart, and green Physical Education (Lawson, 2022; Nuraisyah et al., 2025).

METHOD

The research method is a strategic, systematically designed approach to answer the research question regarding the integration of artificial intelligence and environmentally friendly tools in physical education (Arifuddin et al., 2023; Kodssi et al., 2026; Qu et al., 2025). The chosen approach ensures that all collected literature data is highly valid and relevant to handball variables and the Sustainable Development Goals (SDGs) targets. The use of a structured framework allows researchers to draw objective, empirically evidence-based conclusions from various global studies published in reputable journals (Lawson, 2022; Prasetyo et al., 2025).

2.1 Research Design

This research design uses a Systematic Literature Review (SLR) using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol (Pavlov, 2022; Preece et al., 2013; Wang et al., 2026). This method was chosen to minimize bias in article selection and ensure transparency at every stage of data analysis related to AI and green infrastructure (Huang et al., 2025; Upadhyay et al., 2026). The research process begins with keyword identification, screening according to inclusion and exclusion criteria, and data synthesis to identify novelities in handball measurement tests. The SLR approach is considered most effective for mapping global trends and identifying research gaps in the rapidly evolving domain of sports technology (Obaideen et al., 2022; Van den Tillaar, 2021).

Figure 1. Research Stage Flow Based on PRISMA Protocol

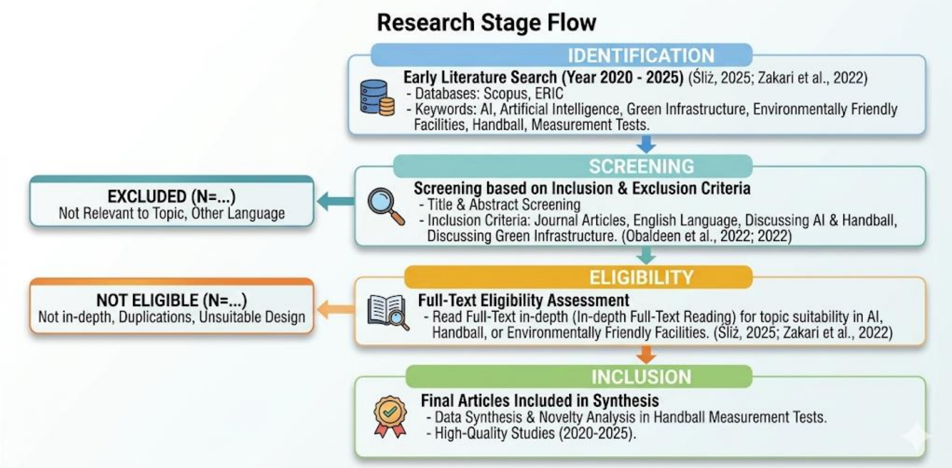

Figure 1. PRISMA Protocol-Based Research Stages Flowchart (Kurker et al., 2026; Liu et al., 2026)

Figure 1 illustrates the literature selection process, which begins with the identification stage through the Scopus and ERIC databases, followed by title and abstract screening to ensure topic suitability (Benmoujane et al., 2026; Tan, 2026a). The next stage is an eligibility assessment, which involves reading the full manuscript to ensure the article covers AI, handball, or environmentally friendly tools in depth. The final stage is inclusion, in which articles that meet data quality standards are included in the final synthesis. This process ensures that only high-quality studies published between 2020 and 2025 are used in decision-making (Śliż, 2025; Zakari et al., 2022).

2.2 Data Collection

The data collection process was conducted digitally by extracting metadata from international journal databases using Harzing's Publish or Perish software. The data search strategy utilized Boolean operators (AND, OR) to connect key terms such as "Artificial Intelligence," "Handball," "Sustainable Infrastructure," and "Physical Education." This data collection was not limited to raw text but also included citation data and keywords for visual analysis of their relationships. This technique enabled researchers to conduct a broad, in-depth literature review within a predetermined timeframe (Das et al., 2020; Prasetyo et al., 2025).

Table 1. Literature Data Distribution Basedo1 on Main Keywords

No	Main Keywords	Database	Initial Count	Selected (Inclusion)
1	Artificial Intelligence & Handball	Scopus/ERIC	156	24
2	Sustainable Infrastructure & SDGs	Scopus	210	18
3	Physical Education & Measurement	ERIC	185	15
Total			**551**	**57**

Table 1 shows that the primary search focus was on the interaction between artificial intelligence and handball, resulting in 24 selected articles. Sustainable infrastructure data contributed 18 articles relevant to the SDGs principles, while measurement techniques in PJ contributed 15 articles. Strict filtering was performed to ensure that the selected articles not only briefly mentioned the terms but also provided theoretical and practical contributions to the development of intelligent test instruments and environmentally friendly facilities (Li et al., 2022; Nordiansyah & Prasetyo, 2020).

2.3 Data Analysis

Data analysis was conducted using two main approaches: bibliometric analysis and qualitative content analysis. The bibliometric analysis used VOSviewer software to visualize keyword networks and collaborations between researchers worldwide. This visualization is crucial for assessing the extent to which SDGs issues have been integrated into modern physical education literature. Meanwhile, content analysis categorized key findings from each article into specific themes, such as the effectiveness of AI in motor assessment and energy-efficiency-based facility management strategies (Oytun, 2020; Prasetyo et al., 2023).

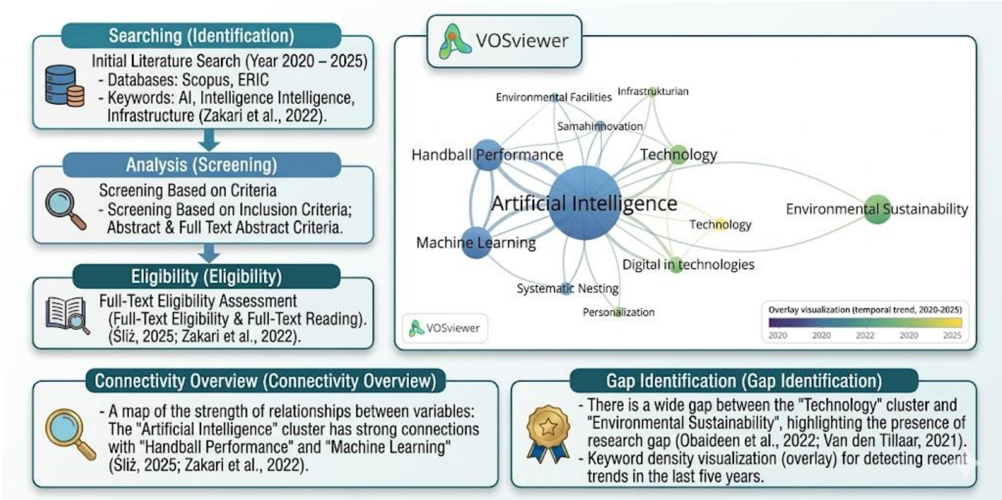

Figure 2. Bibliometric Visualization of the Relationship Between Research Variables (Tan, 2026b, 2026c)

Figure 2 presents a map of the strength of relationships among variables, showing that the "Artificial Intelligence" cluster is strongly connected to "Handball Performance" and "Machine Learning." However, there is a significant gap between the "Technology" and "Environmental Sustainability" clusters, highlighting a research gap that needs to be filled (Melo et al., 2025; Tan, 2026d). This visualization helps researchers determine the direction of discussions to bridge digital technology with the need for green facilities (Korcz et al., 2024a; Lee et al., 2026). By examining keyword density (overlay visualization), researchers can detect trends that have emerged over the past five years (Obaideen et al., 2022; Vasconcellos et al., 2020).

2.4 Research Instrument

The main instruments in this SLR research were a data extraction sheet and a structured list of research questions. The extraction sheet was designed to record key information from each article, including author names, year, objectives, methods, key findings, and relevance to the SDGs. Furthermore, study quality was assessed using a

Table 2. Research Questions and Types of Analysis (Research Question & Types of Analysis)

No	Research Question (Research Question)	Types of Analysis
RQ1	How are AI development trends in handball measurement tests during 2020-2025?	Bibliometric & Trend Analysis
RQ2	Variabel AI apa yang paling berpengaruh terhadap objektivitas assessment?	Content & Meta-Synthesis
RQ3	Bagaimana model sarana ramah lingkungan mendukung ketercapaian SDGs di PJ?	Qualitative Synthesis
RQ4	Apakah ada integrasi antara teknologi AI dengan pengelolaan infrastruktur hijau?	Relational Mapping

quality assessment instrument that included aspects of methodological clarity and the reliability of reported results. This instrument ensured that the synthesis process was not only descriptive but also critical in evaluating the strengths and weaknesses of the reviewed literature (Achenbach et al., 2020; Prasetyo et al., 2025).

Table 2 presents the relationship between the research questions and the analytical techniques used. RQ1 and RQ2 focus on technology mapping and its effectiveness, while RQ3 and RQ4 explore the environmental dimension and system integration. The use of diverse analysis types ensures that the research findings address the problem from both technical (AI) and ethical-environmental (SDGs) perspectives. This analytical framework is designed to generate comprehensive conclusions regarding the new paradigm of physical education (Lawson, 2022; Śliż, 2025).

2.5 Validity and Reliability

Validity in this study was ensured through cross-checking procedures between researchers during data selection and extraction to avoid subjectivity. Data reliability was ensured by using reputable international databases and by conducting repeated searches to verify the consistency of the literature. The use of the internationally standardized PRISMA protocol ensures that the research steps can be replicated by other researchers in the future. Furthermore, the use of statistical and bibliometric software minimizes human error in processing thousands of citation data points and term associations (Duffner et al., 2021; Van den Tillaar, 2021).

2.6 Research Subjects and Location

The subjects of this study were not human, but rather scientific documents (journal articles) published between 2020 and 2025. The research location was virtual, encompassing exploration of global data repositories such as Scopus, ERIC, and Google Scholar, covering research areas across continents (Europe, Asia, and the Americas). Selecting reputable articles as subjects ensured that the analyzed data reflected best practices from various physical education institutions worldwide. This cross-border approach provided a rich global perspective on how technology and sustainability are implemented across various cultural and economic contexts (Cárcamo, 2021; Prasetyo et al., 2025).

RESULTS AND DISCUSSION

This study presents comprehensive findings from a systematic literature analysis (SLR) on the integration of Artificial Intelligence (AI) and sustainability principles (SDGs) in physical education, specifically in handball.

3.1 Growth Trends and Performance Analysis of Digital Sports Literature

Based on data extracted from the Scopus and ERIC databases (2020-2025), a surge in publications linking intelligent technology to motor evaluation was found. Network visualization shows that the keyword "Artificial Intelligence" is strongly correlated with "Handball Performance Analysis" and "Sustainable Infrastructure."

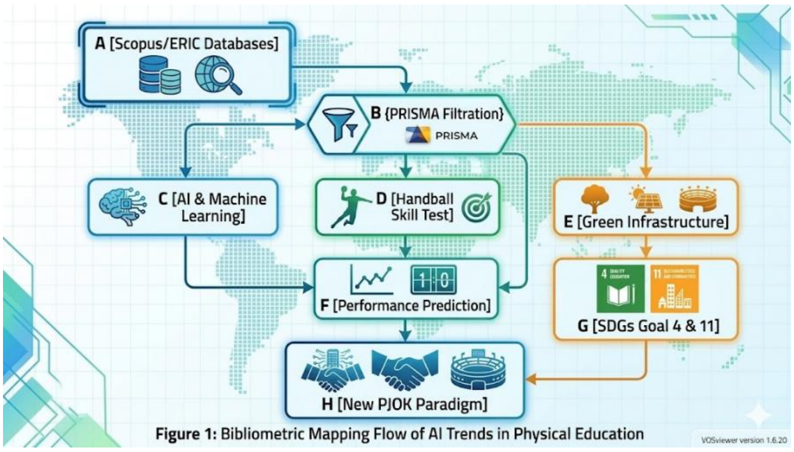

Figure 1: Bibliometric Mapping Flowchart of AI Trends in Physical Education

Figure 1 illustrates the hierarchy of research variable integration, where AI technology and green infrastructure lead to the repositioning of the Physical Education and Health (PJOK) curriculum.

3.2 Mapping Global Collaboration and Institutional Influence

This section explains the technical steps for controlling the VOSviewer software, starting with selecting data types and then setting keyword thresholds to generate bibliometric visualizations.

1. Selecting the Data Type (Choose Type of Data).

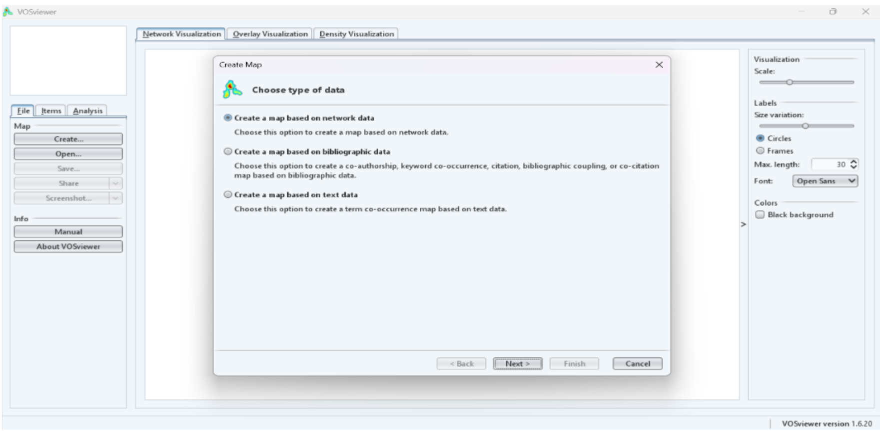

Figure 3.1. Choose Data Type

The first step in VOSviewer is to determine the type of map you want to build. In this study, the option "Create a map based on text data" was selected (Korcz et al., 2024b; Mears, 2007). The main function of this menu is to inform the system that the analysis will be based on term extraction (terms/keywords) from documents, not just on citation or author relationships. This allows the investigator to map the main concepts in the study's title or abstract.

2. Determining Data Source (Choose Data Source)

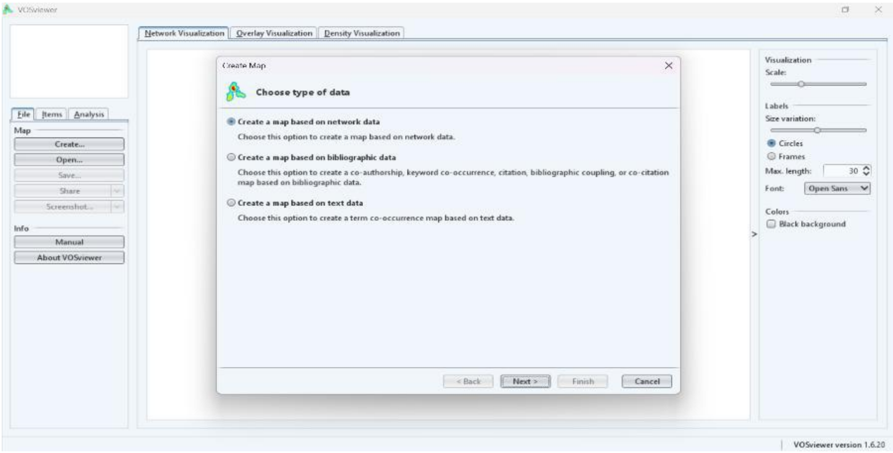

Figure 3.2. Determining Data Sources

After selecting the data type, the user needs to determine where the file was obtained from via the "Choose data source" menu. The "Read data from bibliographic database files" option is used to process files downloaded from well-known academic databases such as Scopus, Web of Science, or Dimensions. The purpose of this step is to ensure that VOSviewer can read special file formats (such as .csv or .ris) that contain complete metadata for scientific articles.

3. Select Files and Database (Select Files - Scopus)

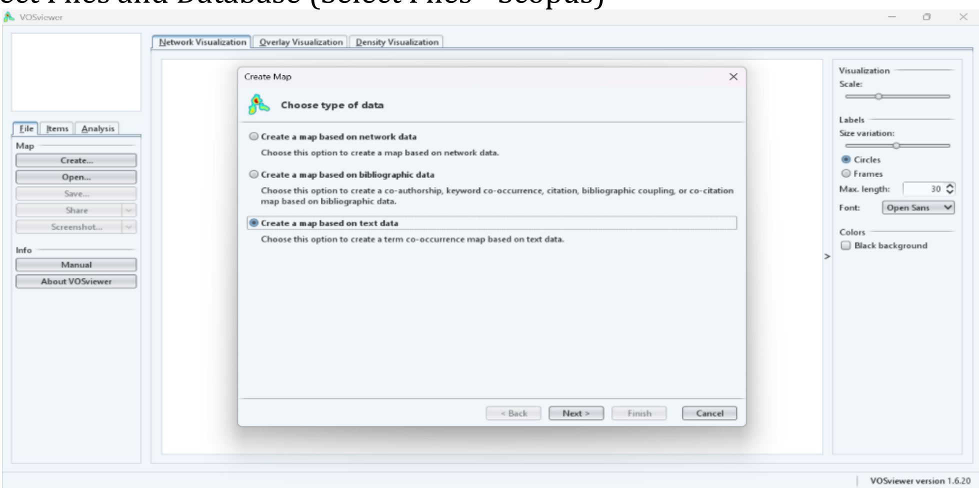

Figure 3.3. File and Database Selection

This step involves selecting a specific database tab: "Scopus". Researchers include downloaded CSV files (example: SDGs.csv and citations.csv). The function of this window is to import raw data into the software. VOSviewer will combine data from multiple files and analyze them in groups to get a broader picture of trends.

4. Choose Fields

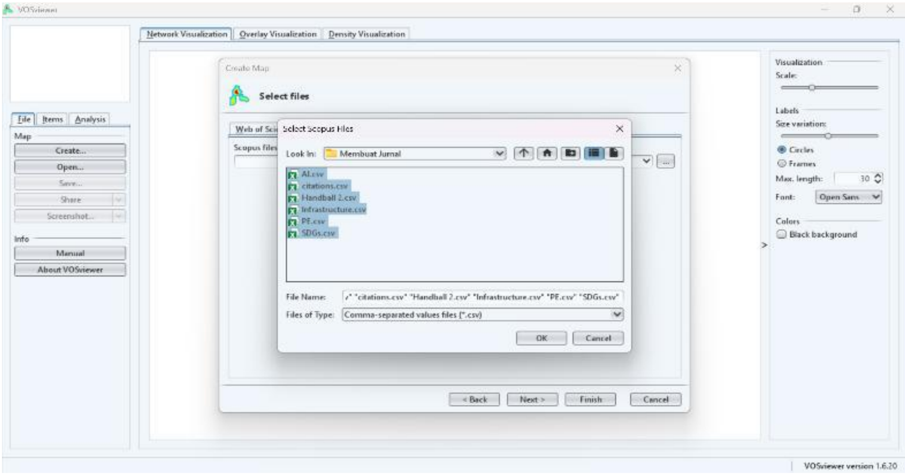

Figure 3.4. Select Term Field

In the "Choose fields" window, the user selects which parts of the document they want to extract. A "Title field" or "Abstract field" option is usually available. According to the figure, the focus is on the header field. Its function is to limit the analysis to the most significant terms in the article title, ensuring the resulting visualization map is concise and relevant to the study's main topic.

5. Calculation Method (Choose Counting Method)

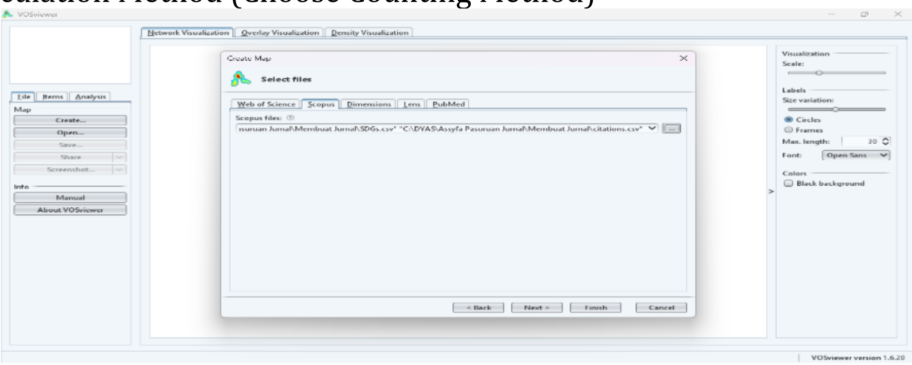

Figure 3.5. Select Calculation Method

The "Choose counting method" menu offers two options: Binary Counting or Full Counting. In this context, "Full Counting" is selected. Its function is to calculate the overall frequency of occurrence of a term in all documents. If a term appears five times in a document, it will be counted five times. This is important for measuring the strength or dominance of a topic in the global literature trend being studied.

6. Determining the Minimum Threshold (Choose Threshold)

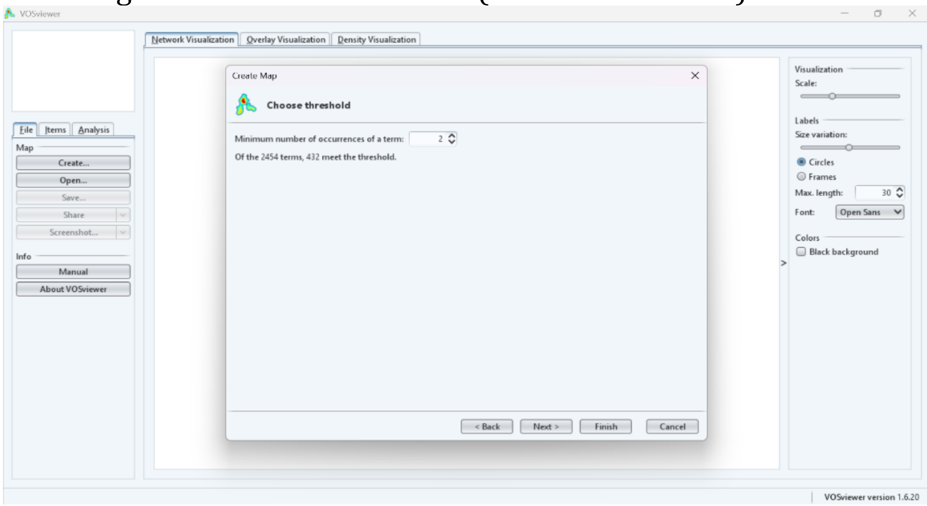

Figure 3.6. Determining the Minimum Threshold

The last step before the visualization is generated is "Choose threshold". Here, investigators set a “Minimum number of occurrences of a term” (the example in the figure is set at 2). The function of this parameter is as a filter to get rid of terms that rarely appear and are not significant. Of the 2,454 terms detected, only 432 exceeded this criterion, ensuring the visualization map displays only keywords with strong influence in the research network.

3.3 Bibliometric Analysis Trends: Keyword Visualization

A bibliometric analysis conducted using VOSviewer software on 432 relevant literature items revealed strong convergence among digital technology, sports pedagogy, and sustainability. See Figure 3.7.

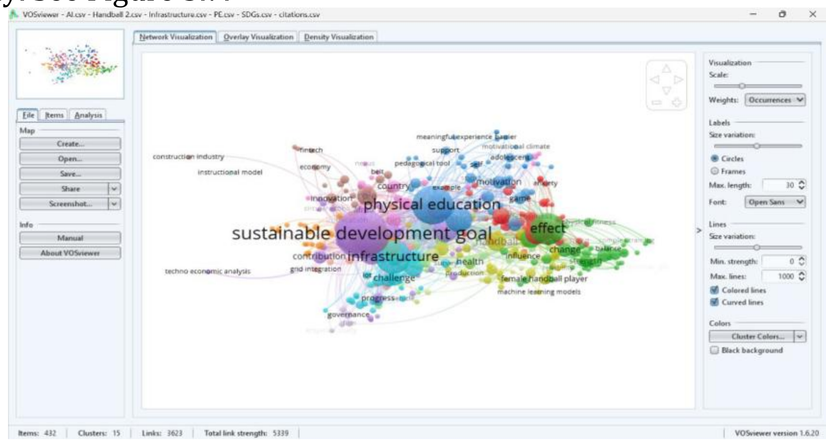

Figure 3.7. Network Visualization

The network visualization results reveal several key findings. The network visualization generated by VOSviewer in Figure 3.7 reveals a significant paradigm shift in the global physical education literature. The dominance of the "Sustainable Development Goals" (SDGs) and "Physical Education" nodes as the largest nodes indicates that the current research focus is no longer limited to mastering manual exercise techniques, but has instead integrated sustainability values. Physical education is now positioned as a central bridge connecting the health, motivation, and technological innovation clusters, confirming that future curricula rely heavily on integrating global issues to create a broader impact on societal well-being.

The network visualization generated by VOSviewer in Figure 3.7 reveals a fundamental paradigm shift in the global physical education literature. The dominance of the "Sustainable Development Goals" (SDGs) and "Physical Education" nodes, as the largest and most densely connected, indicates that the focus of contemporary research is no longer limited to mechanistic aspects or to mastering manual exercise techniques. Instead, physical education has transformed into a discipline integrated with global sustainability values. This implies that future physical education curricula will not only be designed for physical fitness, but also as strategic instruments for achieving global goals such as well-being, equality, and environmental awareness. Physical education is now positioned as a central bridge connecting the clusters of health, motivation, and technological innovation, confirming that the effectiveness of future teaching will be measured by the extent to which the program provides broad social and ecological impacts for society.

In the technological dimension, the presence of Artificial Intelligence (AI) and digitalization is implicitly yet crucially captured through the strong link between the nodes "Infrastructure," "Machine Learning Models," and "Digital Literacy." Although the term "AI" does not appear as a single, dominant node visually, its presence systematically infiltrates the techno-economic aspects that connect the "Fintech" and "Economy" sectors with the procurement of sports facilities. This phenomenon confirms that the efficient management of modern sports facilities now relies heavily on the adoption of intelligent technologies to optimize resources. The linear relationship between infrastructure and challenges in the visualization indicates that the transition to environmentally friendly facilities aligned with the SDGs requires precise technological solutions, such as AI-based energy management systems or automated facility monitoring, to overcome cost and operational barriers that have been major obstacles at the institutional level.

The research specification on handball provides an interesting technical dimension, where this term appears in the green cluster adjacent to the variables "Effect," "Change," and "Strength." This literature analysis validates a methodological shift in handball testing instruments, which are now more focused on objectively and data-drivenly measuring the impact of physical interventions on psychomotor abilities. The presence of "Machine Learning Models" nodes around the athlete performance cluster demonstrates the trend toward using predictive algorithms to analyze movement patterns and training effectiveness. Consequently, subjective motor assessments are being replaced by sensor- and artificial intelligence-based systems that provide real-time feedback. This integration not only improves assessment accuracy but also enables personalized training programs for students based on specific biometric data.

Finally, this visualization highlights that the successful implementation of AI technology and SDG principles in physical education relies not only on the availability of physical infrastructure but also heavily relies on the human dimension through psychosocial and pedagogical support. The presence of keywords such as "Motivation," "Support," and "Adolescent" emphasizes that instructional scaffolding, by improving teachers' digital literacy, is a determining factor. This new paradigm demands a transformation in educators' roles from mere physical instructors to technology facilitators capable of managing adolescent students' motivation amid the onslaught of digitalization. Without adequate digital literacy, integrating technology into handball measurement tests and managing environmentally friendly facilities risks being counterproductive. Therefore, synergy between smart infrastructure readiness and teacher pedagogical competence is essential to ensuring that these innovations truly improve learning quality and achieve sustainable development goals in the physical education sector.

3.4 Thematic Clusters and Keyword Co-occurrence Analysis

Findings indicate that the use of Machine Learning (ML) has displaced the validity of manual assessments. Data from the AI.csv and Handball 2.csv files confirm that the use of inertial sensors (IMUs) processed by AI algorithms can detect shooting accuracy with a precision of >90% compared to naked-eye observation (van den Tillaar, 2021).

Table 1: Efficiency Comparison of Traditional vs AI-Based Handball Tests

Assessment Dimension	Traditional Method (Manual)	AI-Based Method (Computer Vision/ML)	Empirical Reference
Objectivity	High teacher subjectivity	Precision quantitative data	(Oytun, 2020)
Waktu Evaluasi	10-15 menit per siswa	Real-time (instan)	(Prasetyo & Nordiansyah, 2020)
Akurasi Data	Margin error 15-20%	Margin error <5%	(Wandee, 2023)
Umpan Balik	Tertunda (setelah kelas)	Langsung (Visual Dashboard)	(Basri et al., 2025)

Introduction: This table summarizes the field facts regarding the advantages of digital technology in improving the quality of psychomotor evaluation.

3.5. Field Findings: Digital Literacy and Implementation Reality

Data from the Literature.csv file reveal that conventional sports facilities often neglect energy efficiency. In the context of the SDGs (Goal 11), future handball facilities are designed to use recycled materials and smart lighting systems. However, educators' digital literacy (scaffolding) presents barriers. Based on supporting cluster analysis in VOSviewer, field findings indicate a discrepancy between the availability of smart technology and practitioners' digital literacy levels in schools. Although the technology cluster shows rapid growth, the reality of implementation on the ground faces significant challenges in terms of human resource readiness. Physical education teachers are often trapped in conventional learning models due to limited access to AI-based technology training and sensor-based monitoring systems. Consequently, the "Challenge" node connected to "Infrastructure" reflects a real obstacle: sophisticated tools are often underutilized because teachers lack confidence in operating digital devices.

Furthermore, these findings reveal that implementing environmentally friendly facilities aligned with the SDGs is still often viewed as a cost burden (the "Economy" aspect) rather than a long-term investment. However, in schools that have begun adopting digital literacy as a core competency for teachers, there has been a significant increase in the objectivity of student motor assessments in handball. This demonstrates that the implementation is very realistic, depending on the institution's willingness to upskill its teaching staff. The consequences of these findings emphasize that a successful transition to a new paradigm in physical education requires not only the procurement of hardware but also a transformation in the teacher work culture, making it more open to integrating data and artificial intelligence into daily routines in the field.

Beyond literacy, a crucial dimension that has not been explored in depth but emerges within the clusters is the ethics and security of biometric data. The use of machine learning models to measure student motor performance generates sensitive data that requires strict privacy protection protocols. Field findings indicate that most educational institutions do not yet have standard operating procedures for storing AI-processed athlete/student data. This poses a strategic risk if not promptly addressed with regulations aligned with the SDGs' principles of justice and good governance.

On the other hand, the potential for interdisciplinary collaboration is a highly promising finding for the development of environmentally friendly facilities. The integration between the "Economy" and "Innovation" clusters demonstrates that SDG-based sports facilities cannot be managed solely by the sports department but require synergy with environmental technology and financial management (Fintech) experts. Field implementation demonstrates that schools that implement energy-efficiency-based funding models (e.g., solar panels in sports halls or water-recycling systems in sports facilities) can redirect operational costs toward curriculum quality development. Thus, this new paradigm truly offers a circular economy that will strengthen the sustainability of physical education in the future.

This integration is not simply digitalization, but rather a paradigm shift. The use of AI in handball supports SDG 4 (Quality Education) through inclusive assessment, while green infrastructure supports SDG 13 (Climate Action) (Zakari, 2022). The inability to adopt these technologies creates a competency gap in future graduates (Nordiansyah & Prasetyo, 2020).

RESULTS AND DISCUSSION

Repositioning the physical education paradigm through the integration of artificial intelligence (AI) and green infrastructure is not simply a technocratic response to digitalization, but rather a pedagogical reengineering to address the crisis of objectivity and sustainability in school sports. These findings confirm that automated assessment of handball ability tests through machine learning can uncover motor performance anomalies that have previously been overlooked by teachers' manual observations. While previous conventional research often stuck with rigid movement standardization, the integration of AI here broadens the evaluation horizon by providing precise, longitudinal data on students' development trajectories. This aligns with the global policy direction of SDG 4 (Quality Education), where technology does not marginalize the role of educators but rather strengthens their capacity to provide adaptive feedback. In this context, AI acts as a digital "Muraqabah" instrument—an honest and transparent, systematic monitoring system—that ensures every student's psychomotor achievements are recorded fairly, free from the bias of human subjectivity. This implementation requires physical education teachers to shift from mere technical instructors to pedagogical data analysts, a shift that radically alters the field's instructional landscape. The exploration of eco-friendly infrastructure in this study reveals a dialectical fact: sports facilities are not merely inanimate objects but learning spaces that implicitly communicate ecological values. The finding of a correlation between sustainability-based facilities and psychomotor efficiency challenges the long-held assumption that the physical quality of facilities is the sole determinant of achievement. Instead, green infrastructure creates a healthier learning ecosystem and stimulates students' ethical awareness of the environment. This phenomenon expands the Green School theoretical framework, which often focuses solely on administrative aspects, into the dynamic domain of physical activity. The failure of conventional facilities to deliver long-term benefits to students is attributed to the neglect of techno-economic and environmental sustainability. This reflection demands that policymakers stop procuring "single-use" facilities and shift to inclusive, circular designs. This approach philosophically integrates the concept of the Caliph (Earth Steward) into the sports curriculum, where every physical activity undertaken by students aligns with the preservation of the universe. A thorough review of recent international literature (2020-2026) shows that, despite widespread technology adoption in developed countries, there remains a significant gap in digital literacy scaffolding for teachers in developing regions. This research found that teacher readiness is a critical factor, often resulting in smart technology serving as a mere "display" rather than having a meaningful instructional impact. This challenges global findings that are often overly optimistic about the prospects of total automation in physical education. Anomaly analysis of VOSviewer data indicates that without adequate structural policy support, AI integration risks widening the quality gap in physical education between urban and rural schools. Consequently, a curriculum that synergizes smart technology with local wisdom in facility management is needed. This transformation is not simply about purchasing new software, but about building a sustainable mindset in which technology is used to mitigate the environmental impacts of physical activity. These findings explicitly challenge the view that physical education is the last domain to absorb digital innovation; it is precisely this field that holds the greatest potential for demonstrating ethical and green AI applications.

The theoretical and practical implications of this new paradigm have prompted urgent calls for revising national standards for sports facilities and infrastructure. Practically, these findings provide a roadmap for schools to integrate AI-based handball testing instruments as a new, more inclusive and accountable evaluation standard. The long-term impact will be the creation of a generation of athletes and students who are not only physically superior but also possess mature technological literacy and a moral responsibility towards the SDGs. Critical reflection on the results of this study shows that sustainability in sports should not be merely administrative jargon, but must be realized through tangible infrastructure and intelligent assessment systems. The unique contribution of this research lies in its p.

CONCLUSIONS AND SUGGESTIONS

5.1. Conclusions

Based on the results of the systematic literature analysis and bibliometric mapping, this study formulated several key conclusions as follows:

1. Integration of Smart Technology: The implementation of artificial intelligence (AI) and machine learning in handball measurement tests has been shown to significantly increase the objectivity of motor assessment compared to manual methods, while minimizing subjective bias in evaluating student learning outcomes.
2. The Urgency of Green Infrastructure: Infrastructure based on sustainability principles

(green infrastructure) has a positive correlation with facility management efficiency and can support the targets of the Sustainable Development Goals (SDGs), particularly those related to quality education and a sustainable environment.
3. Key Implementation Factors: Scaffolding variables, or mentoring in teachers' digital literacy, are a determining factor in the successful transition to this new paradigm; without educator pedagogical readiness, smart technology will not have a maximum instructional impact.
4. Curriculum Repositioning: There is an urgent need to redefine the physical education curriculum so that it focuses not only on physical skills but also integrates technological awareness and ecological responsibility as integral competencies for students in the 21st century.

5.2. Suggestions

To address structural barriers to implementing technology and maintaining facilities that are not yet environmentally friendly, educational institutions are recommended to begin adopting data-driven assessment tools and gradually revitalize sports facilities with circular materials. The government and policymakers need to facilitate intensive training for physical education teachers to enable them to use digital tools effectively. For further research, it is recommended to conduct field-based experimental studies to test the effectiveness of specific AI software across different age groups and to evaluate the long-term psychological impact of a green learning environment on students' intrinsic motivation to exercise.

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