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Integrating Electric Vehicles into Higher Education: A Systematic Literature Review of Learning Pathways, Campus Living Laboratory, and Sustainable Energy Literacy

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Abstract: The integration of electric vehicles (EVs) into higher education represents an emerging research area connecting mobility transition, energy systems, sustainability-oriented learning, and sustainable energy literacy. This systematic literature review examines how EV integration can support sustainable energy literacy through learning pathways, campus living laboratory approaches, and technology-based educational activities. Following the PRISMA 2020 guidelines, this review analyzed 51 Scopus-indexed journal articles published between 2020 and 2026 using descriptive mapping, bibliometric analysis with VOSviewer, thematic synthesis, and evidence classification. The findings reveal that EV integration research in higher education has expanded across diverse geographical regions, although the evidence base remains fragmented. Bibliometric analysis identifies three interconnected research domains, including educational applications, sustainable energy systems, and EV operational technologies. However, research attention remains concentrated on technical-operational aspects, particularly charging infrastructure, vehicle-to-grid systems, energy management, and data analytics, while educational evaluation remains comparatively limited. The synthesis demonstrates that EV integration can support sustainable energy literacy through three dimensions, namely knowledge, attitude, and practical experience. EV-related curricula, projects, laboratories, campus mobility services, and operational data provide pathways for developing students' knowledge, sustainability attitudes, and practical experience. Nevertheless, a persistent gap remains between technological integration and educational assessment. Future research should strengthen multidimensional assessment approaches, longitudinal evaluations, integration of campus operational data into learning, and comparative studies across institutional settings.

Keywords: Electric vehicles, Sustainable energy literacy, Campus living laboratory, Systematic literature review

Introduction

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The transition toward low-carbon mobility has positioned electric vehicles (EVs) as integral components of broader energy transition systems rather than solely as transportation technologies. EV development is increasingly linked with renewable energy integration, charging infrastructure, energy management, and the transformation of mobility systems toward sustainability (Patil et al., 2024; Santillán & Cedano, 2023). Recent studies have also highlighted that EV adoption involves social acceptance, user readiness, and interactions between energy systems and mobility behavior (Rimpas et al., 2025; Udendhran et al., 2025). These developments position EVs as interconnected technological systems that support mobility transformation while creating opportunities for sustainability-oriented learning.

Higher education institutions (HEIs) represent strategic environments for examining the educational implications of EV integration because universities combine teaching, research, innovation, and sustainability initiatives (Ankareddy et al., 2025; Hyytinen et al., 2026; Y. Wang & Vasques, 2026). Through curriculum development, laboratory activities, applied projects, and campus initiatives, EV-related activities can connect technological knowledge with practical learning experiences. Within this context, sustainable energy literacy represents an important competency that enables students to understand energy systems, evaluate energy-related decisions, develop attitudes toward low-carbon technologies, and engage in sustainability practices (Wu et al., 2020). Previous studies have examined EV integration in higher education through curriculum development, experiential learning, renewable energy applications, and project-based approaches (Ariza & Aiyedun, 2023; Curiel-ramirez et al., 2022; Forbes & Lord, 2023; Lavado-anguera et al., 2024; X. Wang & Guo, 2021). These studies indicate that EV-related activities can support learning associated with energy storage, propulsion systems, renewable energy integration, and sustainability challenges. However, existing findings remain distributed across different educational approaches and technological applications, limiting a comprehensive understanding of how EV integration contributes to sustainable energy literacy development.

Although EV literature has developed rapidly, existing studies remain dominated by technical and operational dimensions, including battery systems, charging infrastructure, grid integration, ownership considerations, and adoption behavior (Burra et al., 2024; Fernandez et al., 2023). Meanwhile, sustainability education literature has rarely conceptualized EVs as integrated learning resources that connect technological systems, campus operations, and student competencies. Previous studies have emphasized the need to strengthen the relationship between EV technology development and educational implementation by considering technical, social, and educational dimensions simultaneously (Chau et al., 2025; Gutierrez-Bucheli et al., 2022). Therefore, the relationship between EV integration pathways, campus living laboratory approaches, and sustainable energy literacy requires further systematic synthesis. To guide this review, Figure 1 presents the conceptual framework of EV integration in higher education. The framework illustrates the relationship between EV integration drivers, educational implementation approaches, and sustainable energy literacy outcomes. The drivers include energy transition, transport decarbonization, and EV technology development. These drivers influence EV-related learning through curriculum development, active learning activities, and exposure to EV technologies. These educational processes contribute to three dimensions of sustainable energy literacy, namely knowledge, attitude, and practical experience.

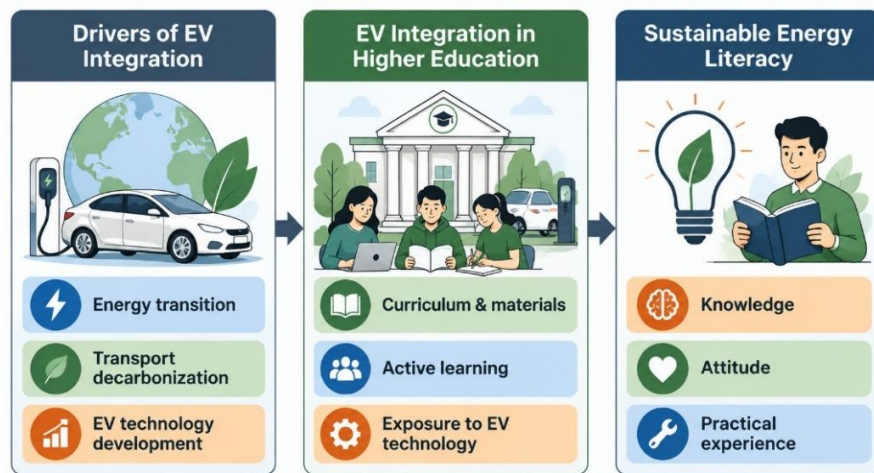


Figure 1. Conceptual framework of EV integration in higher education

In this review, a campus living laboratory refers to a university environment where EV technologies, energy systems, mobility services, and educational activities are integrated to provide authentic learning experiences.

This approach enables students to engage with real-world sustainability challenges through observation, experimentation, problem-solving, and applied learning activities. Based on the identified research gap, this systematic literature review addresses the following research questions:

- RQ1:** How are studies on EV integration in higher education geographically distributed?
RQ2: What thematic trends and keyword clusters emerge in the literature on EV integration, sustainable energy, and higher education?
RQ3: How does EV integration in higher education support students' sustainable energy literacy across knowledge, attitude, and practical experience dimensions?
RQ4: What methodological limitations, educational implications, and future research directions are identified in existing studies on EV integration in higher education?

This review contributes to the literature by synthesizing fragmented evidence on EV integration in higher education and establishing an evidence-based perspective that connects EV technologies, campus living laboratory approaches, and sustainable energy literacy dimensions. By integrating bibliometric analysis, thematic synthesis, and tiered evidence classification, this review advances the understanding of how EV integration can function as an educational pathway through knowledge development, sustainability-oriented attitudes, and practical learning experiences. Furthermore, this review identifies the persistent gap between technological implementation and educational assessment, providing a future research agenda for developing measurable, scalable, and institutionally adaptable EV-based sustainability education.

Method

Research Design and Review Procedure

This systematic literature review (SLR) was conducted to identify, evaluate, and synthesize empirical studies on electric vehicle (EV) integration in higher education. The review followed the PRISMA 2020 guidelines to structure the identification, screening, eligibility assessment, and inclusion processes (Page et al., 2021). The analytical approach combined descriptive mapping, bibliometric analysis using VOSviewer, and thematic synthesis to address the research questions. Descriptive mapping examined geographical distribution, bibliometric analysis identified research trends and keyword relationships, and thematic synthesis examined how EV integration contributes to sustainable energy literacy across knowledge, attitude, and practical experience dimensions.

Data Sources and Search Strategy

The literature search was conducted using Scopus as the sole database due to its multidisciplinary coverage, standardized bibliographic metadata, and suitability for systematic literature reviews and bibliometric analysis (Gusenbauer & Gauster, 2025; Mohd & Abang, 2026). The use of a single database ensured consistency in metadata extraction and screening procedures. Full-text availability was assessed during the eligibility stage to ensure that selected articles provided sufficient information for evidence extraction and synthesis. The search strategy consisted of three components, namely electric vehicles, higher education, and sustainable energy learning. The search configuration was designed to identify studies connecting EV technologies with educational activities, sustainability, renewable energy, and campus practices. The complete search configuration is presented in Table 1.

Table 1. Database search configuration for the systematic review	
Search Component	Description
Database	Scopus
Search string	TITLE-ABS-KEY (("electric vehicle*" OR "electric mobility" OR "electric transportation" OR electromobility OR "e-mobility") AND ("higher education" OR universit* OR college* OR campus OR "engineering education" OR "technical education") AND (sustainab* OR "energy literacy" OR "renewable energy" OR curriculum OR education OR learning OR teaching OR "project-based learning" OR "green campus"))
Main search focus	EV integration, higher education, sustainable energy, learning, curriculum, campus infrastructure, and green campus practices

Inclusion and Exclusion Criteria

The inclusion and exclusion criteria were established to identify studies that directly addressed the research objectives and research questions. The criteria considered document type, publication period, study context, EV-related focus, and availability of relevant empirical findings. The criteria applied during the selection process are summarized in Table 2.

Table 2. Inclusion and exclusion criteria for study selection

Criterion	Inclusion	Exclusion
Document type	Peer-reviewed journal articles reporting empirical findings related to EV integration within higher education contexts	Non-empirical studies, non-journal publications, reviews, conceptual papers, editorials, theses, reports, proceedings, book chapters, or in-press publications
Language and year	English-language journal articles published from 2020 to 2026	Non-English articles or articles outside the selected period
Study context	Higher education institutions, universities, colleges, engineering education, or campus-based learning environments	Studies outside higher education settings
Research focus	Studies addressing EV technologies, electric mobility, EV-related learning activities, campus transportation, charging infrastructure, renewable energy integration, or campus energy systems	Studies without clear relevance to EV integration or electric mobility
Data relevance	Full-text articles providing empirical findings relevant to EV integration pathways, educational activities, campus systems, or sustainable energy literacy dimensions	Articles without accessible full text, empirical findings, or extractable information

Study Selection Process

The study selection process followed the PRISMA 2020 framework. Records identified through Scopus were screened using the predefined inclusion and exclusion criteria. Potentially eligible articles were assessed through full-text review to determine their relevance to EV integration in higher education and the availability of extractable empirical findings. The final selection resulted in 51 articles included in the synthesis. Figure 2 presents the study selection process from identification to final inclusion.

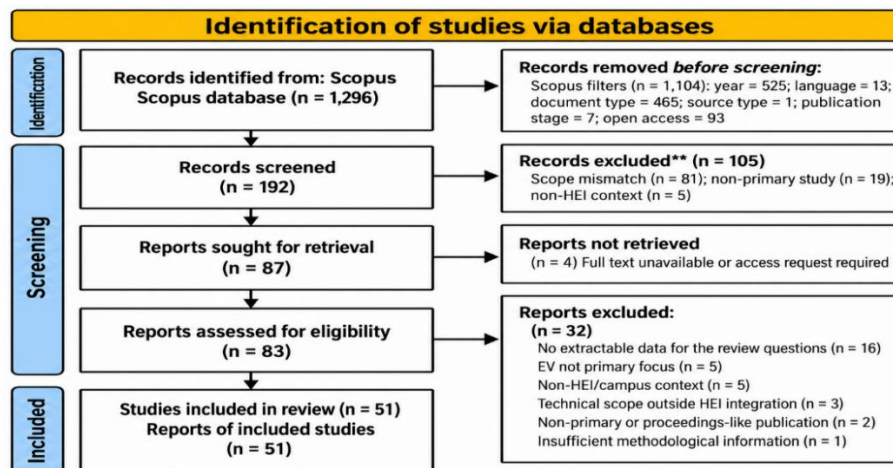


Figure 2. PRISMA 2020 flow diagram for study selection

Data Extraction and Evidence Classification

Data extraction was conducted through full-text analysis of the 51 included articles using a structured worksheet. The extracted information included article characteristics, EV integration approaches, research methods, findings, contributions to sustainable energy literacy, limitations, implications, and future research directions. The

extraction process was used to organize evidence and support systematic synthesis across the included studies (Afifi et al., 2023; Nelson et al., 2025).

All included articles were analyzed as a single evidence base to address the research questions through integrated descriptive, bibliometric, and thematic analyses. The studies were classified according to their contribution to sustainable energy literacy based on the extent to which they reported learning outcomes, behavioral responses, or contextual conditions related to EV integration. Three evidence categories were established, namely direct evidence, partial direct evidence, and contextual evidence. Direct evidence represented studies that explicitly examined learning-related outcomes, while partial direct evidence represented studies providing indirect insights into attitudes, behaviors, or mobility experiences. Contextual evidence represented studies examining technological and operational environments that support EV-based learning activities. The classification framework is presented in Table 3.

Table 3. Evidence classification criteria for literature synthesis

Evidence Type	Classification Criteria	Function in the Synthesis
Direct evidence	Articles reporting explicit evidence of student learning, curriculum implementation, projects, attitudes, intentions, behaviors, competencies, or practical experiences related to EVs	Provides primary evidence for interpreting EV contributions to sustainable energy literacy
Partial direct evidence	Articles examining campus communities, user behavior, or electric mobility experiences that provide indirect evidence related to energy literacy dimensions	Supports interpretation of attitude, behavioral response, and practical experience dimensions
Contextual evidence	Articles examining EV infrastructure, charging stations, photovoltaic systems, microgrids, vehicle-to-grid systems, smart charging, campus transport, or energy systems that provide contextual conditions for EV-based learning	Explains technological and institutional environments that support EV integration as a learning resource

Data Analysis

The included articles were analyzed using descriptive mapping, bibliometric analysis, and thematic synthesis. Descriptive mapping was used to examine the geographical distribution of the included studies. Bibliometric analysis was conducted using VOSviewer based on metadata from the included articles to examine keyword co-occurrence, thematic clusters, topic density, and temporal patterns. Thematic synthesis was used to examine how EV integration relates to sustainable energy literacy across knowledge, attitude, and practical experience dimensions. The evidence classification was incorporated into this synthesis to distinguish direct evidence, partial direct evidence, and contextual evidence. A cross-study thematic synthesis was also conducted to identify recurring methodological limitations, educational implications, and future research directions. The analytical strategy applied to each research question is summarized in Table 4.

Table 4. Data analysis strategy by research question

Research Question	Analytical Focus	Analytical Technique	Main Output
RQ1	Geographical distribution of EV integration studies in higher education	Descriptive mapping based on country or region	Geographical distribution and article counts
RQ2	Keyword relationships, thematic clusters, topic density, and temporal patterns	Bibliometric analysis using VOSviewer	Network, overlay, and density visualizations
RQ3	Contribution of EV integration to sustainable energy literacy	Thematic synthesis informed by evidence classification and knowledge, attitude, and practical experience dimensions	EV integration pathway synthesis
RQ4	Recurring limitations, educational implications, and future research directions	Cross-study thematic synthesis	Research gaps and future research agenda

Results and Discussion

Research Landscape and Geographical Distribution

The geographical distribution of the 51 included articles was analyzed using articles as the unit of analysis. The multi-country study involving Ecuador, Peru, and Colombia was treated as one country or region record because the analysis focused on article-level distribution rather than individual country counts.

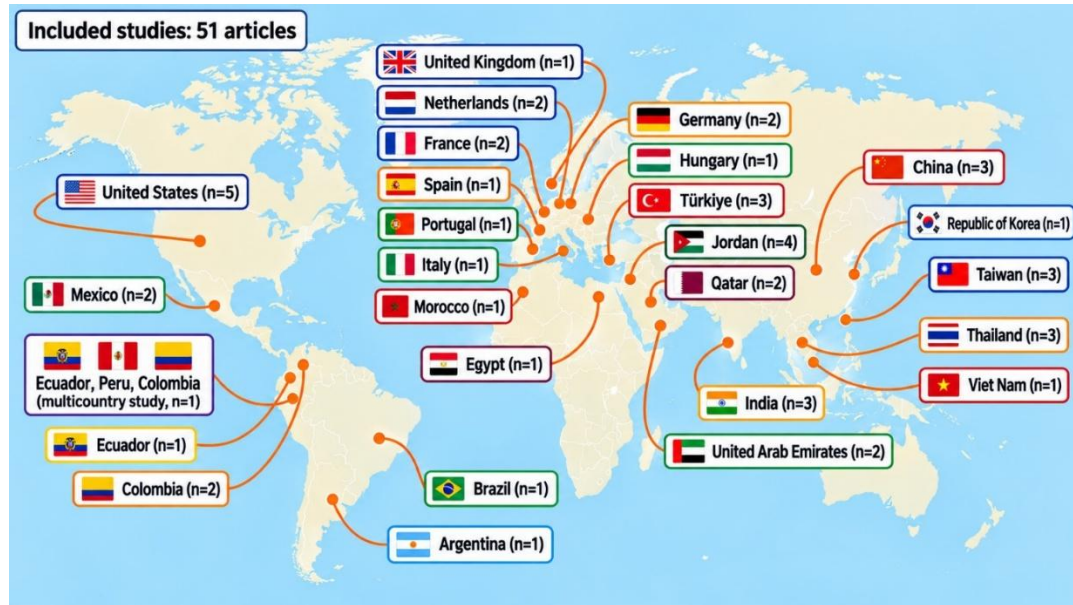


Figure 3. Geographical distribution of EV integration studies

The geographical mapping identified 27 countries, or region records across North America, Europe, Asia, the Middle East, Latin America, and Africa. The United States contributed the highest number of articles with five records, followed by Jordan with four records. China, India, Taiwan, Thailand, and Türkiye each contributed three records, while most remaining locations were represented by one or two records. The distribution pattern indicates that EV integration research in higher education has emerged across diverse geographical settings but remains fragmented across regional contexts. This pattern suggests that the field has developed through multiple research settings rather than following a unified geographical trajectory.

In response to RQ1, the findings demonstrate that EV integration in higher education represents a developing interdisciplinary research area with contributions from diverse geographical regions. However, the fragmented distribution highlights the need for comparative studies examining how institutional characteristics and regional factors influence EV-based educational implementation.

Thematic Development and Research Trends

The bibliometric analysis was conducted using VOSviewer to examine keyword co-occurrence, thematic clusters, topic density, and temporal development across the 51 included articles. The analysis generated network visualization, overlay visualization, and density visualization to identify dominant research themes and emerging directions in EV integration within higher education. The network visualization shows that EV-related keywords occupy a central position within the research landscape. The dominant keywords, including electric vehicle, electric vehicles, charging batteries, electric vehicle charging, energy management, solar energy, energy efficiency, vehicle-to-grid, state of charge, students, and higher education, reflect the connection between EV technologies, sustainable energy systems, and educational applications. The keyword structure revealed three interconnected thematic areas. The first area relates to educational integration, represented by higher education, students, and engineering education. The second area focuses on sustainable energy systems, represented by sustainability, solar energy, alternative energy, energy efficiency, and energy management. The third area concerns EV technical operation, represented by charging systems, battery technologies, state of charge estimation, and vehicle-to-grid applications. The dominance of technical-operational keywords indicates that EV

integration research has been primarily oriented toward technological systems, particularly charging infrastructure, energy management, battery performance, and vehicle-to-grid applications (Abdullah et al., 2022; Ahmad et al., 2024; Haffaf et al., 2022; Kassem et al., 2025). These studies connect EV research in higher education with renewable energy integration, smart charging, and campus energy management.

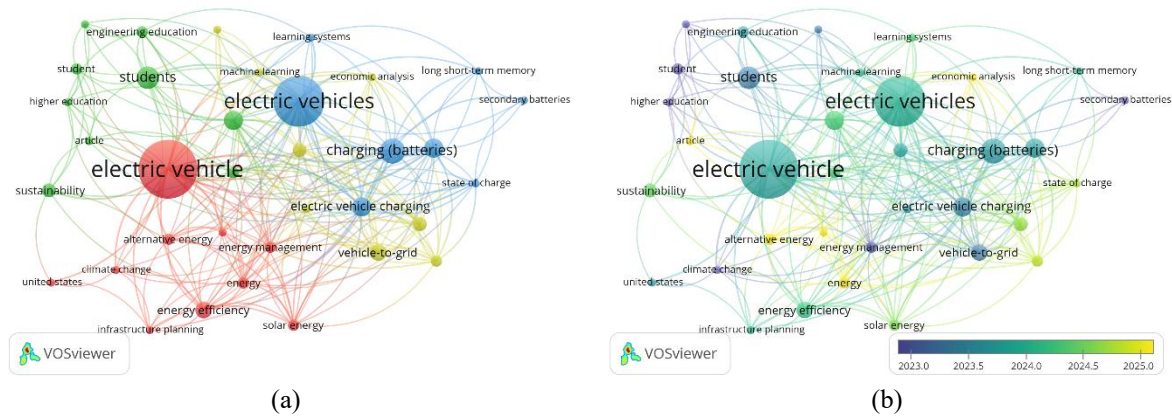


Figure 4. (a) Network and (b) overlay visualizations of EV research

The emergence of keywords related to machine learning, learning systems, and long short-term memory networks reflects the growing attention toward data-driven approaches in EV research. Recent studies have applied predictive and optimization methods for charging demand forecasting, state of charge estimation, battery performance analysis, and EV operational management (Gandhi et al., 2026; Joh et al., 2026; Klungsida et al., 2024; Nawakiattikorn et al., 2023; Polat et al., 2025; D. Zhou et al., 2022). However, the stronger concentration of technical-operational themes compared with educational themes indicates an imbalance in the current literature. Although EV integration has been implemented through curricula, training programs, laboratories, and student projects, systematic evaluation of learning outcomes and sustainable energy literacy remains limited (Bonnema et al., 2025; Curiel-ramirez et al., 2022; Saleet et al., 2023). This finding suggests that EV technological development has progressed faster than the evaluation of educational contributions generated through integration activities.

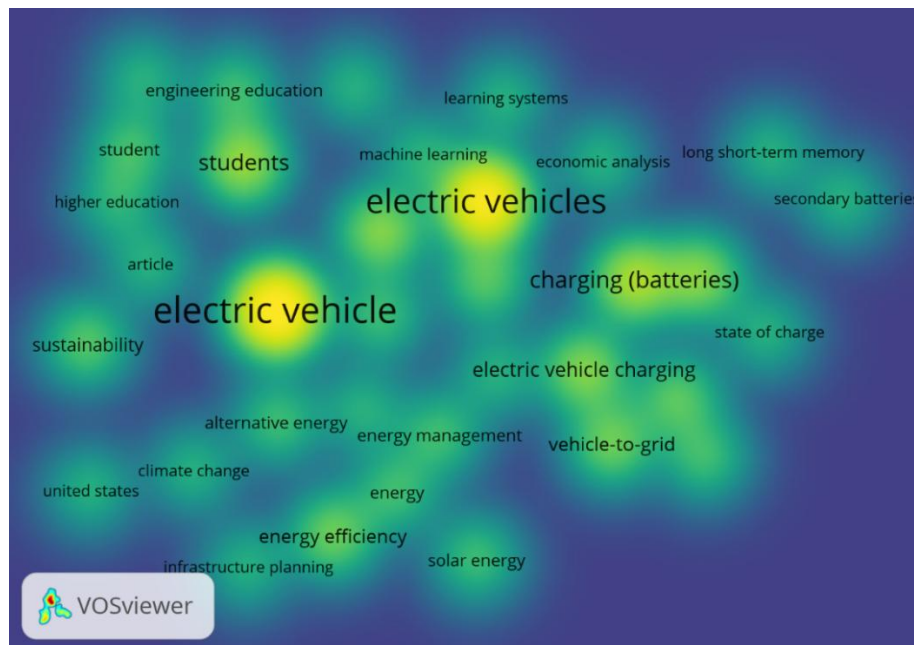


Figure 5. Density visualization of keyword occurrence

The overlay visualization demonstrates a temporal shift in research emphasis. Earlier studies were more closely associated with higher education, students, engineering education, and climate change. Recent studies increasingly emphasize solar energy, vehicle-to-grid systems, EV charging, state of charge, economic analysis, and data analytics. This transition indicates that EV integration research has increasingly incorporated integrated energy

system analysis and operational optimization alongside educational and sustainability-oriented discussions. The density visualization confirms that electric vehicle charging batteries, electric vehicle charging, vehicle-to-grid, energy management, and students represent the most concentrated research areas. In contrast, higher education, engineering education, sustainability, infrastructure planning, and climate change demonstrate lower density, indicating that educational evaluation receives comparatively less research attention than technical and operational aspects.

In response to RQ2, the bibliometric findings demonstrate that EV integration research in higher education develops through three interconnected domains: educational applications, sustainable energy systems, and EV operational technologies. Nevertheless, the dominance of technical-operational themes reveals a persistent gap between EV technological development and educational assessment, particularly in measuring contributions to students' sustainable energy literacy.

Contributions of EV Integration to Sustainable Energy Literacy

The contribution of EV integration to students' sustainable energy literacy was synthesized by mapping the 51 included articles across three dimensions, namely knowledge, attitude, and practical experience. Based on the evidence classification, 21 articles were categorized as direct evidence, 5 articles as partial direct evidence, and 25 articles as contextual evidence. This classification was applied to distinguish evidence strength and function rather than article relevance. Direct evidence provided the primary basis for interpreting learning-related outcomes, partial direct evidence supported the interpretation of attitudes and mobility experiences, while contextual evidence described infrastructure and operational conditions that can support EV-based learning environments. The evidence distribution indicates that EV-based learning is primarily supported by structured educational interventions and experiential activities rather than infrastructure-oriented studies alone. Direct evidence primarily emerged from curricula, training programs, projects, laboratories, and prototype development, providing stronger indications of links between EV integration and student learning activities.

The knowledge dimension is developed through exposure to EV technologies and energy systems. Studies involving curricula, course design, training programs, and project-based learning connect EV concepts with battery technologies, energy storage, renewable energy integration, propulsion systems, and energy management (Bonnema et al., 2025; Curiel-ramirez et al., 2022; Kesler et al., 2022; López et al., 2021; Saleet et al., 2023). These approaches support students' understanding of EV systems as interconnected components within sustainable energy systems. The practical experience dimension is strengthened through project-based learning, laboratory activities, simulations, prototypes, and engineering experiments. These approaches allow students to apply theoretical knowledge through design, testing, optimization, and system evaluation activities (Anitha & Marudhachalam, 2026; Ariza & Aiyedun, 2023; Franco et al., 2020; Rosas-Cervantes & Fernández-Ramos, 2025). Such activities provide opportunities for students to engage with EV technologies through problem-solving and technical decision-making. The attitude dimension is supported by studies examining EV acceptance, intention, readiness, perceived benefits, risk perception, and user preferences. These studies indicate that responses toward electric mobility are influenced by technological understanding, environmental concern, perceived usefulness, social influence, and trust in EV technologies (Bridi & Hosani, 2020; Chotisarn et al., 2026; Cordero et al., 2026; R. Jou et al., 2022; R. C. Jou et al., 2023; Kovacs & Wolf, 2025). Although these studies do not always directly measure sustainable energy literacy, they provide evidence of how students and university-age groups perceive and respond to EV adoption.

Table 5. EV pathways for sustainable energy literacy

EV integration pathway	Included studies	Evidence base	Knowledge dimension	Attitude dimension	Practical experience dimension
EV curriculum, course design, and training programs	(Bonnema et al., 2025; Curiel-ramirez et al., 2022; Saleet et al., 2023)	Direct evidence	EV systems, battery technology, e-mobility, energy storage, and energy management	EV competency readiness and industry relevance	Training programs, workshops, and course activities
Project-based, problem-	(Anitha & Marudhachalam, 2026;	Direct evidence	EV design, renewable	Attitudinal development,	Projects, laboratories,

EV integration pathway	Included studies	Evidence base	Knowledge dimension	Attitude dimension	Practical experience dimension
based, laboratory, and prototype-based EV learning	Ariza & Aiyedun, 2023; Fösel & Wilhelm, 2022; Franco et al., 2020; Hadraoui et al., 2022; Kesler et al., 2022; López et al., 2021; Rosas-Cervantes & Fernández-Ramos, 2025; Yang & Kuo, 2021)		energy integration, battery systems, simulation, and optimization	collaboration, problem-solving, and sustainability awareness	simulations, prototypes, and experiments
Student attitudes toward EV adoption, intention, acceptance, and sustainability perception	(Bridi & Hosani, 2020; Chotisarn et al., 2026; Cordero et al., 2026; R. Jou et al., 2022; R. C. Jou et al., 2023; Kovacs & Wolf, 2025)	Direct evidence and partial direct evidence	Adoption factors, perceived usefulness, risk, trust, and environmental concern	Perceived usefulness, trust, risk perception, environmental concern, and behavioral readiness	Surveys and behavioral assessments
Campus electric mobility experience and user response	(Borne et al., 2025; Buehler et al., 2021; Chen et al., 2025; Decker et al., 2023; Kazemzadeh et al., 2026; Mohammad et al., 2022; Ochoa-correa et al., 2025; Ton & Duives, 2021; Trrad, 2025)	Partial direct evidence and contextual evidence	Electric mobility services, travel behavior, safety, and low-carbon transportation	Satisfaction, willingness to use, perceived benefits, and behavioral response	E-bike, e-scooter, electric bus, shared mobility, and campus mobility services
Campus EVCS, PV, microgrid, V2G, and energy infrastructure	(Abdullah et al., 2022, 2026; Ahmad et al., 2024; Ahmed et al., 2026; Alhendi & Ayadi, 2026; Awada et al., 2024; Cecchini et al., 2024; Comi & Elnour, 2025; Do et al., 2026; Haces-fernandez, 2024; Haffaf et al., 2022; Juang et al., 2024; Kassem et al., 2025; Movlyanov & Selçuklu, 2025; Salazar & Gómez, 2024; Scott et al., 2021; Tiwari et al., 2026; Wu et al., 2020)	Contextual evidence	Charging infrastructure, PV-EV integration, storage, microgrid, V2G, smart charging, and energy management	Awareness of clean energy systems and low-carbon technologies	Infrastructure analysis, modeling, optimization, and energy scenarios
Data-driven EV operation, forecasting, range estimation, and optimization	(Gandhi et al., 2026; Joh et al., 2026; Klungsida et al., 2024; Nawakiattikorn et al., 2023; Polat et al., 2025; D. Zhou et al., 2022)	Contextual evidence	Forecasting, range estimation, SOC prediction, machine learning, and EV optimization	Understanding of reliability, efficiency, and operational performance	Data analytics, prediction models, optimization, and operational planning

Infrastructure-oriented studies involving campus EV charging stations, PV systems, microgrids, vehicle-to-grid systems, and smart charging provide additional learning resources through operational data and real-world systems. However, these studies mainly represent contextual evidence because they rarely evaluate student learning outcomes directly. Therefore, their contribution should be interpreted as supporting conditions for EV-based learning rather than direct evidence of literacy development (Abdullah et al., 2022; Ahmad et al., 2024; Haffaf et al., 2022; Kassem et al., 2025). Data-driven EV studies involving forecasting, range estimation, state of charge prediction, and optimization extend sustainable energy learning through analytical approaches. These studies provide operational datasets and computational methods that can support understanding of EV performance, energy management, and system optimization (Gandhi et al., 2026; Joh et al., 2026; Klungsida et al., 2024; Nawakiattikorn et al., 2023; Polat et al., 2025; Y. Zhou & Smith, 2022). Through these approaches, EV integration connects technical analysis with data-driven sustainable energy decision-making.

In response to RQ3, the synthesis demonstrates that EV integration can contribute to sustainable energy literacy through three interconnected dimensions. The knowledge dimension develops through structured learning activities and exposure to EV technologies and energy systems. The attitude dimension emerges through perceptions, acceptance, and responses toward electric mobility. The practical experience dimension is supported through projects, laboratories, prototypes, campus mobility services, and data-driven system analysis. Overall, EV integration provides multiple educational pathways through which vehicles, infrastructure, operational data, and learning activities contribute to the development of sustainable energy literacy.

Limitations, Implications, and Future Research Directions

The synthesis of the 51 included articles identified recurring limitations that shape the current development of EV integration research in higher education. These limitations reflect broader research gaps rather than isolated weaknesses of individual studies, namely the imbalance between technological integration and educational evaluation, the limited availability of standardized assessment approaches for sustainable energy literacy, and limited evidence regarding scalability and institutional implementation conditions. The identified limitations, educational implications, and future research directions are summarized in Table 6.

The first major gap concerns the relationship between EV technological integration and educational evaluation. A substantial proportion of studies focuses on EV charging infrastructure, renewable energy integration, microgrids, vehicle-to-grid systems, smart charging, forecasting, and energy management. These studies provide important insights into EV technologies and campus energy operations, but their connection with student learning outcomes remains limited. Consequently, future research should examine how EV infrastructure, operational data, and campus mobility systems can be transformed into learning resources through curricula, project-based learning activities, laboratory experiments, and data-driven assessment.

The second gap relates to the measurement of sustainable energy literacy. Existing studies frequently evaluate EV acceptance, adoption intention, perceived benefits, technical competence, or project experiences, but sustainable energy literacy is not consistently measured as a multidimensional construct. This limitation creates challenges in evaluating whether EV integration contributes to students' knowledge, attitude, practical experience, systems thinking, and sustainability competence. Future research should therefore develop and validate multidimensional assessment instruments through longitudinal studies, intervention-based designs, and comparative evaluations across different learning environments.

The third gap concerns scalability and institutional implementation conditions. Many studies examine single campuses, specific mobility services, individual infrastructure systems, or limited educational interventions. Although these studies provide valuable insights, their findings remain difficult to generalize across different institutional settings. Future research should investigate how institutional characteristics, resource availability, energy conditions, and educational capacity influence the implementation and transferability of EV-based learning approaches across different universities and regions.

Beyond these three major gaps, the literature also indicates the need for greater conceptual clarity and consistency in defining EV-related educational objects. The reviewed studies include diverse elements, such as EVs, electric mobility services, e-bikes, e-scooters, electric buses, mobility-as-a-service, charging infrastructure, vehicle-to-grid systems, and campus energy systems. These elements represent different educational functions and should not be treated as equivalent. Clearer distinctions among EV technologies, mobility services, charging infrastructure, and energy systems are required to improve research design and educational evaluation.

Table 6. Limitations, implications, and future research directions

Research limitation	Educational implication	Future research direction
EV research remains dominated by technical-operational studies on charging infrastructure, renewable energy integration, microgrids, vehicle-to-grid systems, smart charging, forecasting, and energy management, while links to student learning outcomes remain limited.	EV infrastructure should be connected with curricula, project-based learning activities, laboratories, and assessment approaches rather than treated only as technical facilities.	Examine how EV infrastructure and operational data can be integrated into learning activities and evaluated through measurable student outcomes.
Sustainable energy literacy is not consistently measured and is often represented through attitudes, intentions, acceptance, technical competence, or project experiences.	EV education requires assessment approaches covering knowledge, attitude, practical experience, systems thinking, and sustainability competence.	Develop and validate multidimensional instruments for measuring EV-based sustainable energy literacy.
Technical EV integration and educational evaluation remain separated, limiting the use of operational data as learning resources.	Campus EV systems, charging data, renewable energy systems, and mobility services should be integrated into teaching and assessment activities.	Investigate data-driven learning approaches, project-based assessment, and evidence-based evaluation using EV operational data.
Many studies focus on single campuses, specific mobility services, infrastructure systems, or limited educational interventions.	EV integration should consider institutional characteristics, educational capacity, resource availability, and local energy conditions.	Conduct multi-campus, cross-country, and comparative studies to examine transferability across different institutional environments.
Research designs frequently rely on cross-sectional studies, simulations, and predictive models, limiting evidence of learning development over time.	Evaluation should capture changes in students' knowledge, attitudes, and practical experiences.	Apply longitudinal designs, pre-post intervention studies, and learning experiments to evaluate educational development.
The literature includes diverse objects such as EVs, electric mobility services, e-bikes, e-scooters, electric buses, MaaS, charging infrastructure, vehicle-to-grid systems, and campus energy systems.	Educational research requires clearer distinctions among EV technologies, mobility services, charging infrastructure, and energy systems.	Develop clearer taxonomies defining the educational role of different EV-related technologies and systems.
Competency indicators and learning outcomes for EV education remain inconsistent across studies.	EV programs require assessment approaches that distinguish technical competence, energy literacy, sustainability attitudes, and practical experience.	Develop interdisciplinary assessment approaches for EV learning in curricula, projects, laboratories, and campus learning environments.
Institutional conditions, resource availability, and implementation challenges remain insufficiently examined.	EV implementation should consider infrastructure readiness, lecturer capacity, industry collaboration, student access, and long-term operational support.	Investigate scalable implementation strategies, university-industry partnerships, shared facilities, and approaches suitable for institutions with different resource conditions.

In addition, competency indicators and learning outcomes related to EV education remain inconsistent across studies. Although many studies demonstrate technical learning activities, assessment approaches that distinguish technical competence, sustainable energy literacy, sustainability attitudes, and practical experience are not yet standardized. Future research should establish interdisciplinary assessment approaches that can be applied across curricula, projects, laboratories, and campus-based learning environments. Institutional implementation conditions also require further investigation because EV integration depends on infrastructure availability, financial resources, lecturer capacity, industry collaboration, student accessibility, and long-term operational support. These factors may create different implementation challenges among institutions with varying capacities. Future research should therefore examine scalable implementation strategies, university-industry partnerships, shared facilities, and approaches suitable for institutions with different resource conditions.

In response to RQ4, the literature indicates that future EV integration research in higher education should extend beyond technological implementation toward measurable educational evaluation. Future studies should establish stronger connections among EV technologies, campus infrastructure, operational data, learning activities, assessment instruments, and institutional conditions to evaluate EV integration as an educational pathway supported by technological systems.

Conclusion

This systematic literature review synthesized 51 Scopus-indexed articles published between 2020 and 2026 to examine EV integration in higher education through learning pathways, campus living laboratory approaches, and sustainable energy literacy. The review followed PRISMA 2020 and combined descriptive mapping, bibliometric mapping, thematic synthesis, and tiered evidence classification. The findings demonstrate that EVs can be understood not only as low-carbon transport technologies but also as learning resources that connect educational activities, campus infrastructure, electric mobility experiences, operational data, and sustainable energy systems.

In relation to RQ1, the findings show that EV integration research in higher education has emerged across diverse geographical regions but remains fragmented. The corpus included studies from 27 countries or regions, with no single country or region demonstrating dominant research concentration. This distribution indicates broad international interest in EV integration, while comparative understanding of how institutional characteristics and regional conditions influence implementation remains limited.

In relation to RQ2, bibliometric analysis identifies three interconnected research domains, including educational applications, sustainable energy systems, and EV operational technologies. The literature shows strong concentration around technical-operational themes, particularly charging infrastructure, vehicle-to-grid systems, energy management, and data analytics. Although educational applications appear within the research landscape, thematic development remains more strongly oriented toward technological systems than educational evaluation. This pattern reveals a persistent gap between EV technological development and evaluation of its contribution to sustainable energy literacy.

In relation to RQ3, EV integration has the potential to support sustainable energy literacy across knowledge, attitude, and practical experience dimensions. The knowledge dimension is supported through students' understanding of EV systems, battery technologies, energy infrastructure, and operational data. The attitude dimension is reflected through acceptance, intention, readiness, preferences, and responses toward EVs and electric mobility. The practical experience dimension is supported through projects, laboratories, simulations, prototypes, campus mobility services, and data-driven system analysis. However, the strength of evidence varies, with direct evidence providing stronger support for learning-related outcomes compared with partial direct evidence and contextual evidence.

In relation to RQ4, the review identifies several research gaps related to educational assessment, measurement approaches, scalability, and institutional implementation. Existing studies predominantly examine EV technologies, infrastructure systems, mobility services, or user responses, but fewer studies systematically evaluate changes in students' sustainable energy literacy. Future research should prioritize multidimensional assessment instruments, longitudinal and pre-post intervention studies, multi-campus comparisons, integration of campus operational data into learning processes, clearer conceptual taxonomies, and evaluation of institutional readiness. Overall, EV integration represents an emerging educational pathway that connects sustainable mobility, energy systems, and higher education learning environments. Its contribution to sustainable energy literacy is strengthened when infrastructure, operational data, learning design, and measurable educational outcomes are integrated within educational practices.

Recommendations

Based on the findings of this review, several recommendations are proposed to strengthen EV integration as an educational pathway for sustainable energy literacy in higher education. First, higher education institutions should integrate EV technologies, campus energy systems, and mobility services into structured learning frameworks rather than treating them solely as operational infrastructure. EV charging systems, renewable energy integration, and operational datasets should be connected with curricula, laboratories, project-based learning, and assessment activities to support experiential and systems-oriented learning. Second, institutions should develop

multidimensional assessment frameworks to evaluate EV-based sustainable energy literacy. Future evaluations should consider knowledge, attitudes, practical experience, systems thinking, and sustainability competencies rather than relying only on technical skills, adoption intentions, or user perceptions. Third, universities should strengthen campus living laboratories through interdisciplinary collaboration among academic programs, industry partners, and campus management. Such collaboration can support the use of real EV systems and operational data as learning resources while improving the scalability and practical relevance of EV-based education. Fourth, future research should prioritize longitudinal, comparative, and evidence-based studies to evaluate how EV integration influences students' learning outcomes across different institutional settings. Developing standardized assessment instruments and implementation models will be essential for advancing EV-based sustainability education.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPESS Journal belongs to the authors.

* The authors declare that this article was conducted in accordance with scientific research principles and ethical standards. This study is a systematic literature review based on publicly available academic publications and did not involve human participants, personal data collection, or experimental procedures requiring ethical committee approval. The authors assume full scientific and legal responsibility for the content of this article.

Conflict of Interest

* The authors declare that they have no conflicts of interest related to the publication of this article.

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