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# Issues and Perspectives in Business and Social Sciences

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## Integrating knowledge and action: a review of sustainability education and energy literacy strategies

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### Abstract

This systematic literature review (SLR) investigates the impact of cognitive, emotional, and behavioural aspects in sustainability and energy literacy education. Focusing on recent research published from 2020 to 2024, the study employs the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology to select, evaluate, and synthesise pertinent literature. The results reveal that whilst cognitive comprehension of sustainability is extensively covered, there remain deficiencies in nurturing emotional engagement and encouraging behavioural modifications amongst students. The analysis underscores the significance of cross-disciplinary methods, including project-based learning (PBL) and arts-integrated sustainability education, in effectively addressing these shortcomings. Moreover, the review identifies obstacles such as limited resources, inadequate teacher training, and difficulties in curriculum integration as impediments to successful implementation. The study concludes by outlining effective practices and approaches for enhancing energy literacy and sustainability education across various educational contexts.

### Keywords:

Energy literacy;  
Interdisciplinary approaches;  
Sustainability education;  
Teacher preparedness;  
Project-based learning.

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## 1. Introduction

The importance of education in sustainability and energy literacy is gaining recognition as a crucial element in tackling environmental issues worldwide (Pillan et al., 2023). As society grapples with problems such as climate change, energy use, and resource scarcity, it has become imperative to provide future generations with the necessary understanding, emotional connections, and practical abilities to actively contribute to sustainable solutions (Pillan et al., 2023). Educational establishments have a pivotal function in this process, nurturing not only intellectual comprehension, but also emotional engagement and behavioral shifts, thereby cultivating well-rounded individuals who are both cognizant of sustainability concerns and driven to take action (Martins et al., 2020).

Contemporary studies have highlighted the importance of adopting a multifaceted strategy in sustainability education (Xiao et al., 2024). Findings indicate that while many learners can

comprehend the theoretical principles of sustainability, there often exists a disparity between understanding and implementing these ideas in practice (Stylos et al., 2023). Experiential learning, such as practical projects involving sustainable energy systems and refuse management, has been demonstrated to improve students' intellectual grasp of the subject while also cultivating emotional bonds and behavioral dedication to sustainability (Altassan, 2023). Nevertheless, substantial obstacles, including constrained resources, inadequate teacher preparation, and the integration of sustainability education into current curriculum structures, continue to be prevalent in numerous educational frameworks (Avelar & Farina, 2022).

Notwithstanding these obstacles, the potential advantages of combining the cognitive, emotional, and behavioral aspects of sustainability education are considerable. A holistic, cross-disciplinary strategy can cultivate stronger emotional ties with environmental concerns and motivate learners to embrace sustainable practices. Nevertheless, further investigation is required to gain a better understanding of how these aspects can be efficiently incorporated into educational frameworks to produce enduring behavioral shifts (Agueda Gras-Velazquez & Verdiana Fronza, 2020). The main aims of this study were: (i) to systematically review and synthesize existing research on sustainability and energy literacy education, with a focus on the integration of cognitive, affective, and behavioral dimensions in teaching practices; (ii) to explore how these dimensions can be utilized to foster environmental awareness and promote sustainable behavior among students; and (iii) to identify effective strategies, best practices, and challenges in implementing sustainability education, particularly in the context of energy literacy. These goals seek to enhance our understanding of how sustainability education can transcend mere knowledge transfer to cultivate emotional bonds and behavioral shifts, thereby enabling students to actively participate in worldwide sustainability initiatives.

## 2. Method

Based on the PRISMA framework, this SLR focuses on three main processes: identification, screening, eligibility, data abstraction, and analysis (Page, McKenzie, et al., 2021). A discussion of this procedure is provided in subsections 2.1, 2.2, 2.3, and 2.4.

### 2.1 Identification

The systematic review process consisted of three basic phases that were used to select the relevant papers for this study. The first phase entails the identification of keywords and the search for associated related terms using thesaurus, dictionaries, encyclopedias, and prior research. Following the selection of all pertinent terms, search strings for the Scopus and Web of Science (WoS) (see Table 1) were developed. The current research endeavors effectively obtained 1,215 papers from both databases during the first stage of the systematic review process.

**Table 1: Search string for database**

Scopus	TITLE-ABS-KEY ( ( "energy literacy" OR "energy education" OR "sustainability education" OR "environmental literacy" ) AND ( "primary school" OR "elementary school" OR "students" OR "school children" ) AND ( "cognitive" OR "knowledge" OR "affective" OR "attitudes" OR "behavior" OR "actions" ) AND ( "sustainability" OR "SDG" OR "sustainable development" OR "environmental awareness" ) )
WoS	("energy literacy" OR "energy education" OR "sustainability education" OR "environmental literacy") AND ("primary school" OR "elementary school" OR "students" OR "school children") AND ("cognitive" OR "knowledge" OR "affective" OR "attitudes" OR "behavior" OR "actions") AND ("sustainability" OR "SDG" OR "sustainable development" OR "environmental awareness") (Topic)

## 2.2 Screening

The authors applied the inclusion and exclusion criteria to eliminate 895 papers in the initial screening phase, prioritizing research articles as the primary source of knowledge. Systematic reviews, meta-analyses, book series, books, chapters, and conference proceedings were also excluded. The review focused on 320 English-language, open-access studies on energy literacy, sustainability, and education published between 2020 and December 2024 ( Table 2). The selection of this period was justified by the completion of the article production cycle by the end of 2024. Consequently, the researcher opted to focus on finalized data, establishing the cutoff point in the first quarter of 2025, which still represents an early phase of the year. In addition, before articles were considered eligible, 101 duplicates were identified, which then underwent a cleaning process to ensure that unique articles were considered for the next stage.

**Table 2: Selection criteria**

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline / Years	2020 (December, 2024)	< 2020
Literature type	Journal (Article)	Conference, Book, Review
Publication Stage	Final	In Press
Availability	Open Access	No open retrieval

## 2.3 Eligibility

In the third step, eligibility, a total of 223 articles has been prepared. All article titles and key content were thoroughly reviewed at this stage to ensure that the inclusion requirements were fulfilled and fit the present study with the current research aims. A total of 211 articles were omitted because they were not related to energy or sustainability education (n=105), did not mention cognitive, affective, or behavioral dimensions (n=38), were not aligned with sustainability or SDG goals (n=36), and did not focus on primary school/elementary school/secondary school students (n=31). Finally, 13 articles were included in this review.

## 2.4 Data abstraction and analysis

Integrative analysis was employed to examine and synthesize various research designs (quantitative, qualitative, and mixed methods) to identify relevant topics and subtopics. Data collection-initiated theme development. Figure 1 illustrates the meticulous analysis of the 13 publications on materials pertinent to the study's topics. The authors then evaluated significant studies on energy literacy, sustainability, and education for their classification, methodologies, and outcomes.

Collaboration among co-authors helped develop themes based on evidence. A log was maintained to record the analyses, viewpoints, and thoughts related to data interpretation. The results were compared to identify inconsistencies in the theme design, with the authors discussing any disagreements. The final themes were then refined to ensure consistency. Two experts, one in Education for Sustainability and the other in Educational Curriculum for Sustainability, reviewed the analysis to validate the issues, ensuring the clarity, importance, and suitability of each subtheme.

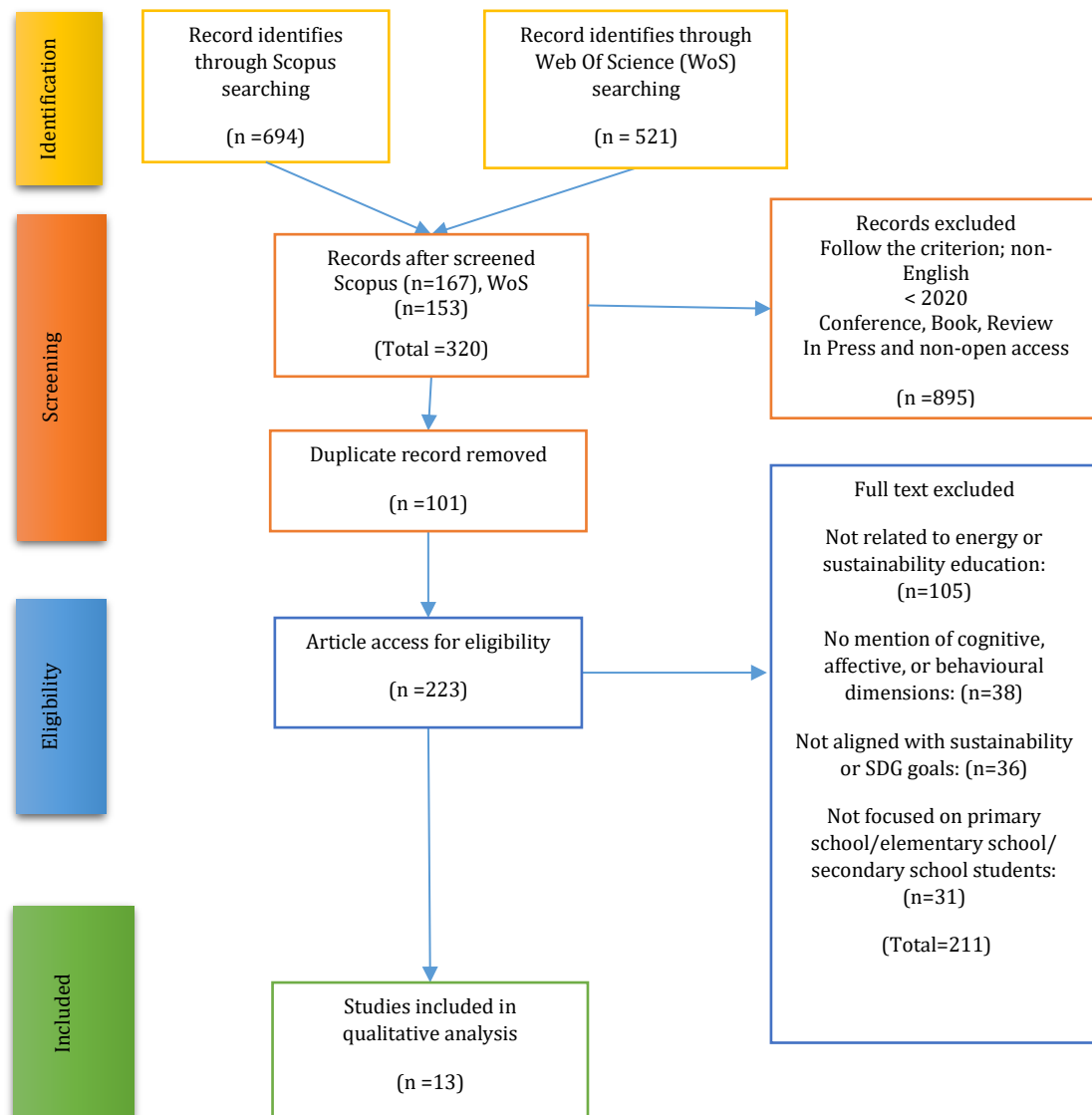


Figure 1: Flow diagram of the proposed searching study (Page, Moher, et al., 2021)

### 3. Results and discussion

Based on the 13 articles included, three interrelated themes emerged as particularly salient: (1) cognitive, affective, and behavioral dimensions; (2) energy literacy; and (3) sustainability education. The findings are presented and discussed in Sections 3.1, 3.2, and 3.3.

#### 3.1 Theme 1: Cognitive/affective/behavioral dimensions

Within sustainability education, the cognitive, affective, and behavioral lenses are useful because they prevent the review from equating “knowing” with “acting.” In primary contexts, cognitive gains (facts, concepts, systems understanding) are necessary, but rarely sufficient; affective

engagement (values, care, sense of place, identity) often functions as a catalyst that makes behavioral commitments (habits, choices, participation) developmentally plausible. From an instructional perspective, this triadic framing remains pedagogically defensible, particularly for younger learners, whose dispositions towards sustainability are still forming. This study transcends the mere search for a complementary framework to integrate the three elements within the context of energy sustainability. Across the included studies, the strongest pedagogical designs are those that intentionally link these dimensions through authentic contexts place, community, real problems, and tangible outputs rather than treating attitudes and action as “optional” add-ons to content delivery (Hernandez Gonzalez, 2023).

Qu et al. (2024) demonstrated how learning can move beyond cognition by using place-rooted and arts-based experiences to deepen meaning making and attachment. For primary learners, this approach is particularly defensible because artistic production and sensory engagement are age-appropriate routes for building affective connections, an essential precursor to sustained pro-environmental dispositions. Within primary education contexts, arts- and place-based approaches support the internalization of abstract sustainability concepts by providing aesthetic and embodied learning experiences, rather than serving solely as enrichment activities. Critically, however, the behavioral dimension in such designs is commonly inferred from participation and expressed intentions; it is rarely verified through long-term observations. This reveals a critical vulnerability, while interventions may be highly engaging, and evidence regarding their post-activity behavioral durability remains indirect or short-lived (Qu et al., 2024). Consequently, further research is essential to ensure that emerging approaches and pedagogies transcend immediate engagement. They must offer a sustainable framework that secures both the continuity of activities and meaningful long-term student behavioral changes.

In contrast, Jäggle et al. (2024) operationalized the behavioral dimension more explicitly through a structured PBL sequence that culminates in concrete tasks (e.g., working with e-waste, planning solutions, and prototyping). For primary education, the contribution is not that the exact tasks must be replicated but that the instructional architecture is transferable; problem framing, investigation, design, and implementation provide a coherent link between learning and doing. That said, the behavioral claims remain constrained by common measurement limits (self-report surveys and immediate post-activity perceptions), and the authors themselves flag scalability constraints (resources, teacher preparation, and curricular support). These challenges are particularly pronounced in primary school settings, where generalist teachers often face wide instructional responsibilities and limited access to specialist tools and support, rendering complex sustainability interventions difficult to sustain (Jäggle et al., 2024).

Crucially, Hernandez Gonzalez (2023) strengthens the synthesis by arguing through multiple case study analyses that place-based education can support holistic outcomes across the three dimensions. For a primary-focused review, the value here is conceptual; it provides a defensible explanation for why place or community contact and learner agency are repeatedly associated with stronger socio-emotional engagement and more plausible action competence. This shifts the analysis from describing programs to identifying a mechanism: sustainability education becomes behaviorally meaningful when learners experience relevance, belonging, and the opportunity to act not merely to acquire content. The emphasis on context and learner involvement aligns with the findings from the other two studies, supporting the conclusion that sustainable behavioral learning in primary education is most effective when cognitive, affective, and behavioral elements are intentionally designed as mutually reinforcing (Hernandez Gonzalez, 2023).

Across the reviewed studies, we recognize the pedagogical significance of deliberately sequencing cognitive, affective, and behavioral elements in ways that align with the developmental profile of primary learners. While cognitive understanding provides the necessary conceptual foundation, the affective dimension shaped through place-based immersion, creative expression, and relational contexts appears essential for making sustainability content personally meaningful. Our collective interpretation is that behavioral intentions are unlikely to emerge in the absence of emotional engagement and perceived agency. Therefore, sustainability learning in primary education must not rely on content transmission alone. Rather, it must be designed to inculcate ownership, relevance, and participation. Such an approach demands an integrated pedagogy that positions the learner as an active meaning-maker within real and situated contexts rather than as a passive recipient of prescribed values or actions.

Taken together, under the primary education umbrella, the synthesis indicates that effective sustainability education tends to (i) secure cognitive clarity with age-appropriate concepts, (ii) activate affective commitment through place/identity/creative meaning-making, and (iii) structural behavior through feasible, guided actions and routines. The most significant cross-study limitation and key point reviewers often demand is that behavioral outcomes are frequently asserted more strongly than the underlying evidence warrants. Therefore, the review should frame behavioral claims cautiously and recommend stronger behavioral verification in future primary focused studies (e.g., follow-up measures, triangulation with observed routines, family/community corroboration) rather than implying that engagement automatically equals behavior change. All articles in Theme 1 are summarized in a matrix, as shown in Table 3.

**Table 3. Cognitive/affective/behavioral dimension**

Author (Year)	Methodology	Key findings	Insights
Qu et al. (2024)	Qualitative, participatory/action-oriented; arts- and place-based learning.	Strong cognitive understanding and socio-emotional connection to local sustainability issues.	Behavioural impact mainly inferred (engagement/intent); transferability depends on context and facilitation capacity.
Jäggle et al. (2024)	PBL intervention; survey + open-response coding.	Reported gains in sustainability/e-waste knowledge and action-oriented engagement.	Evidence largely self-reported and short-term; scaling requires teacher readiness and resources (critical for primary).
Hernandez Gonzalez (2023)	Multiple case-study synthesis of PBE cases.	PBE supports cognitive, socio-emotional, and behavioural outcomes; cognition alone may not shift behaviour.	Provides mechanism-based justification; behavioural outcomes vary across cases and are not uniformly measured.

### 3.2 Theme 2: Energy literacy

In educational contexts, the notion of energy literacy highlights a growing need for holistic teaching methods that go beyond mere cognitive understanding of sustainability, encompassing emotional engagement and behavioral changes. The research indicates that while various approaches, from professional development initiatives to immersive technological solutions, have successfully enhanced energy literacy, a significant hurdle remains in seamlessly integrating these elements into traditional educational frameworks. The main challenge in sustainability education is the lack of teacher preparedness.

According to Ogunyemi et al. (2022), although many educators possess a basic understanding of sustainability concepts, there is a notable deficiency in their ability to effectively impart this knowledge in the classroom. The research revealed that 73% of trainee teachers were cognizant of sustainability issues, yet struggled to incorporate this understanding into practical teaching methods. This observation indicates that current teacher training programs are falling short of

adequately preparing educators to teach energy literacy, particularly when it comes to integrating cognitive, emotional, and behavioral aspects. The crux of the matter lies in the necessity for more comprehensive, cross-disciplinary teacher training that not only provides educators with the requisite knowledge, but also equips them with practical strategies to effectively engage pupils in meaningful sustainability education.

There are four potential ways to enhance energy literacy based on SLR. First, the implementation of teachers' professional development (PD) initiatives is a potential solution to the lack of teachers' preparedness. Bruno et al. (2024) demonstrated that practical, community-oriented PD programs can enhance educators' self-assurance and capacity to teach environmental literacy, subsequently improving student involvement. Nevertheless, while PD programs are advantageous, their impact is often constrained to teachers who can take part. It is challenging to expand these programs to ensure widespread access to high-quality PD in energy literacy for all educators, not just a few. In the absence of a comprehensive approach to teacher training, the broader influence of such initiatives remains limited.

The second approach was to use an eco-reflective teaching model, as proposed by Herranen et al. (2021). The authors proved that sustainability education can be successfully incorporated into fundamental subjects such as chemistry. Their eco-reflexive teaching model revealed that integrating sustainability concepts into existing coursework enhances students' comprehension of environmental processes. This method is particularly effective, as it merges cognitive learning with ethical contemplation, nurturing both intellectual grasp and emotional engagement with sustainability issues. Nevertheless, the widespread implementation of this model across various academic disciplines and educational frameworks remains a challenge. There is a notable gap in curriculum development that enables the smooth incorporation of sustainability principles into a wide array of subjects, extending beyond scientific fields.

The third approach involves the application of extended reality (XR) technologies. Mulders and Träg (2023) examined the application of extended reality (XR) technologies in sustainability education. This approach has been shown to markedly enhance student engagement, leading to improved cognitive and emotional outcomes through the creation of immersive educational environments. XR's capacity to deliver immediate, hands-on learning experiences is vital for narrowing the divide between knowledge acquisition and practical application, as it enables students to observe the environmental consequences of their actions. Nevertheless, despite XR's considerable potential, the availability and expense of such technology presents a substantial obstacle. Educational institutions in underprivileged or isolated areas may lack the resources necessary to implement these advanced technologies, potentially exacerbating the disparity between students who have access to these sophisticated learning tools and those who do not.

The fourth method incorporated cultural and spiritual viewpoints into sustainability education, as proposed by Muhamad et al. (2021). Their findings suggest that including religious principles in the curriculum can enhance students' moral and ethical dedication to sustainability, thereby providing a comprehensive framework for engaging with energy literacy. Nevertheless, this strategy may not be universally suitable, particularly in secular or culturally diverse learning environments. There is a need to contextualize these frameworks to ensure that sustainability education remains inclusive and pertinent to all students, irrespective of their cultural or religious backgrounds.

Despite advances in innovative approaches to energy literacy education, several critical gaps remain, including persistent teacher training deficiencies, where many educators lack the pedagogical skills to teach sustainability effectively and therefore require more comprehensive, interdisciplinary preparation; limited access to professional development, as promising PD

initiatives are not widely available and need broader, systemic implementation; insufficient curriculum integration, with sustainability concepts still concentrated in science or environmental subjects rather than embedded across disciplines; technological barriers, since advanced tools such as XR can enhance learning but are constrained by cost and accessibility, particularly in underfunded schools; and challenges of cultural relevance, where spiritual or value-based frameworks may strengthen engagement but must be applied sensitively to remain inclusive and avoid alienating learners from diverse backgrounds.

The reviewed research provides significant insights into diverse approaches to incorporating energy literacy into educational frameworks. Nevertheless, to optimize the effectiveness of these programmes, future endeavors must address the identified shortcomings. Through improved teacher education, expanded opportunities for professional growth, and the comprehensive integration of sustainability principles across the syllabus, educators can successfully cultivate the necessary cognitive, emotional, and behavioral changes for students to become engaged contributors to global sustainability efforts. Consequently, the outcomes of the initial theme can be condensed as shown in Table 4.

**Table 4. Energy literacy**

Author	Methodology	Key Findings	Insights
Ogunyemi et al., (2022)	Mixed-method descriptive survey with questionnaires and focus group discussions with 200 final-year undergraduate teachers.	73% of participants were aware of sustainability concepts but lacked pedagogical skills for teaching sustainability effectively.	Sustainability education must be more robustly infused into teacher training curricula, emphasizing pedagogical methods.
Bruno et al., (2024)	Case studies of four teacher professional development programs focused on environmental literacy and sustainability education.	The four programs improved teachers' confidence in incorporating environmental literacy into their classrooms, leading to better student engagement.	Teacher PD programs are crucial for enhancing environmental literacy and maximizing sustainability education's reach.
Herranen et al., (2021)	Development of an eco-reflexive didactic model integrating sustainability education into chemistry curricula.	The model improved students' understanding of chemical processes in environmental contexts, increasing both cognitive and affective engagement.	Integrating sustainability into core subjects enhances scientific knowledge and deepens students' ethical connections to environmental issues.
Mulders & Träg, (2023)	Experimental study using extended reality (XR) technologies to teach sustainability.	XR-based learning significantly enhanced student engagement and improved cognitive and affective learning outcomes in sustainability education.	XR offers new avenues for engaging students by providing immersive experiences that foster deep understanding and emotional connection.
Muhamad et al., (2021)	Qualitative case study integrating religious and spiritual perspectives into sustainability education.	Incorporating spiritual and religious values enhances moral connections to sustainability among students.	Religious frameworks provide a holistic approach to engaging students in sustainable behaviors, connecting their beliefs with sustainable practices.

### 3.3 Theme 3: Sustainability education

In recent years, the field of sustainability education has garnered considerable interest, with scholars and instructors exploring various techniques to improve students' cognitive comprehension and behavioral modifications. Five pivotal studies shed light on novel methodologies, including augmented reality (AR), cross-disciplinary frameworks, location-specific learning, and practical energy education. While these approaches show promise, significant obstacles remain in terms of accessibility, instructor preparation, and availability of resources, which impede their widespread implementation. The SLR shows that sustainability education uses various methods and incorporates the available technologies and frameworks.

Two studies examined technology factors in sustainability education. Ardyansyah and Rahayu (2023) investigated the effectiveness of augmented reality (AR) card games in teaching students carbon compounds, focusing on environmental literacy. The research revealed that AR substantially enhanced students' comprehension of intricate subjects, including chemical structures, while also boosting their enthusiasm for subject matter. The interactive nature of AR transforms abstract concepts into concrete ideas, making it a highly efficient method for student engagement. Nevertheless, a major obstacle to the widespread adoption of AR is unequal access

to technology. Numerous educational institutions, especially those in disadvantaged regions, lack the infrastructure necessary to support AR technology. This disparity in access creates an educational gap that must be addressed to facilitate the broad implementation of AR in education.

Chien et al. (2021) examined the effectiveness of practical energy education using dye-sensitized solar cells was examined. Their project-oriented methodology enabled students to bridge the gap between theoretical energy system knowledge and real-world applications, resulting in enhanced cognitive comprehension and behavioral modifications. The study found that students who engaged in solar cell projects were more inclined to embrace energy-efficient practices and investigate renewable energy technologies in their everyday lives. Nevertheless, the expense of scientific apparatus poses a significant obstacle to the broad adoption of such practical learning experiences. Educational institutions with constrained budgets may lack the means to involve students in experiential learning initiatives, underscoring the need for a more equitable distribution of educational resources.

Researchers have introduced new frameworks for sustainability education. Okada and Gray (2023) developed the CARE-KNOW-DO framework, an interdisciplinary model aimed at promoting cognitive, affective, and behavioral learning outcomes in sustainability education. The framework emphasizes that students should not only gain knowledge (KNOW) but also cultivate a sense of responsibility (CARE) and undertake meaningful action (DO). The framework has demonstrated its effectiveness in motivating students to engage more profoundly with sustainability issues and adopt practical measures towards environmental stewardship. Nevertheless, the model's efficacy is constrained by insufficient teacher training in interdisciplinary methodologies. Educators may find it challenging to implement the framework successfully without proper preparation, highlighting the deficiency in professional development opportunities for sustainability education.

Hernandez Gonzalez (2023) examined the impact of place-based education on students' socio-emotional and behavioral outcomes. This research revealed that learners who actively participated in local environmental initiatives not only enhanced their comprehension of sustainability, but also implemented sustainable practices, including waste minimization and recycling. The study highlighted that emotional bonds developed through place-based learning are crucial for enduring behavioral modifications. Nevertheless, the widespread application of this educational approach faces considerable obstacles, particularly for educational institutions in urban settings and those with limited access to natural environments. A potential solution to this challenge could be the use of virtual simulations, which may provide students with engaging learning experiences when direct environmental interaction is not possible.

A recent investigation by Alkaher et al. (2024) examined the role of educators as catalysts for policy-driven changes in their educational institutions by integrating sustainability into their teaching programs. With backing from an Israeli environmental education center, these teachers spearheaded influential projects that had a significant impact on their school communities. This study highlights the crucial role of institutional backing in enabling teachers to champion sustainability. Nevertheless, a discrepancy remains between policy aspirations and classroom implementation. Teachers' endeavors often fall short of their full potential because of insufficient resources, lack of administrative support, and time constraints. This indicates the necessity for comprehensive policy reforms that prioritize sustainability education and provide teachers with the necessary resources for enduring success.

Taken together, the evidence indicates that combining technology-enhanced learning, interdisciplinary frameworks, place-based approaches, and hands-on energy projects can significantly advance sustainability education by strengthening engagement and creating pathways from understanding to action. The more consequential pattern, however, is that equity and implementation capacity consistently shape whether these innovations become routine practices or remain isolated examples. A practical reading of the findings suggests that sustainability education is most likely to endure when interventions are designed with realistic delivery conditions in mind: flexible options that work with and without advanced technology;

professional learning that equips teachers to run interdisciplinary and action-oriented sequences with confidence; and school-level support that protects time and resources for sustained implementation. It also follows that future studies would benefit from sharper behavioral verification clearer definitions of “behaviour change” and follow-up evidence beyond immediate post-intervention measures so that claims about action become as robust as the cognitive gains that are already well documented as Table 5 summarizes the third theme:

**Table 5: Sustainability education**

Author	Methodology	Key Findings	Insights
Ardyansyah & Rahayu, (2023)	Augmented reality (AR) card games to teach environmental sustainability.	AR-based learning enhanced students' cognitive understanding of environmental issues and emotional engagement.	AR can effectively improve environmental literacy, but technology accessibility remains a barrier.
Hernandez Gonzalez (2023)	Place-based experiential learning with local environmental engagement.	Place-based learning led to stronger emotional and behavioral connections to sustainability through local interaction.	Place-based learning is effective but difficult to implement in urban or resource-limited areas, highlighting scalability issues.
Okada & Gray, (2023)	CARE-KNOW-DO framework for interdisciplinary sustainability education.	The CARE-KNOW-DO framework improved cognitive, affective, and behavioral learning outcomes, but teacher training is needed.	Interdisciplinary frameworks like CARE-KNOW-DO require robust teacher training for effective implementation.
Chien et al., (2021)	Hands-on, project-based learning using dye-sensitized solar cells for energy education.	Students developed both knowledge and practical skills in renewable energy systems through hands-on solar cell projects.	Hands-on energy projects foster both learning and behavioral change, but access to advanced equipment is a challenge.
Alkahrer et al., (2024)	Policy-driven sustainability initiatives with teachers as agents of change in an Israeli education center.	Teachers empowered as change agents successfully integrated sustainability into schools, but institutional support was inconsistent.	Policy-driven education empowers teachers but requires consistent institutional support for long-term success.

#### 4. Conclusion

This systematic review synthesized 13 studies on sustainability and energy literacy education through a cognitive–affective–behavioral lens. Evidence indicates that cognitive outcomes are comparatively well developed, while affective and behavioral dimensions remain underrepresented and are often assessed indirectly through short-term self-reports or participation rather than verified, sustained action. Promising approaches such as project-based learning, place-based learning, and arts-based pedagogy can strengthen emotional engagement and agency, thereby making behavior change more plausible. However, implementation is frequently constrained by teacher readiness, curriculum time, and resource availability, limiting scalability, particularly in underfunded contexts.

Our findings have two important implications. Theoretically, they support conceptualizing energy literacy and sustainability learning as a multi-dimensional competence rather than a cognitive achievement, and they challenge linear “knowledge to behavior” assumptions by positioning affect (values, relevance, identity, and agency) as a critical mechanism linking understanding to action. Practically, the review suggests that effective programs should be intentionally sequenced to build conceptual clarity, cultivate affective connections, and scaffold feasible, repeatable actions supported by professional development and assessment systems that capture all three domains. Future research should prioritize longitudinal, multi-site designs and stronger behavioral verification, alongside scalable, cost-sensitive models and policy support that enable equitable implementation.

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**Author contributions:** Mohd Yahya Fadzli Jusoh led the study design, data collection and curation, analysis, and drafting. Nor Asniza Ishak supported the methodology and validation, and revised the manuscript. Rendi Restiana Sukardi supervised the work, provided a critical review, and approved the final version of the manuscript.

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