Low-Cost, Community-Driven Pedagogy and Canadian SSI Education: A Cross-Cultural Analysis

Norris Erhabor, *University of Ottawa, University of Benin*

Giuliano Reis, *University of Ottawa*

Authors' Note

Norris Erhabor https://orcid.org/0000-0001-6470-9498

Giuliano Reis https://orcid.org/0000-0003-4831-5485

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Correspondence concerning this article should be addressed to Norris Erhabor at norris.erhabor@uniben.edu

Abstract

Socioscientific issues (SSI) in education help develop citizens capable of engaging with complex science-society challenges; yet from literature reviewed by the researchers, some Canadian teachers face persistent barriers in implementing SSI education in underserved settings. This paper examines how a low-cost, community-driven approach to teaching waste recycling to Nigerian pre-service teachers that was developed by the authors, might inform SSI pedagogy in Canadian rural, francophone, and Indigenous contexts. Our argument is built upon a review of selected Canadian SSI education literature (2010-2024) and a cross-cultural case analysis to discuss the transferability of the approach and its implications for advancing equity in selected education contexts in Canada.

Keywords: socioscientific issues, community-driven pedagogy, teacher education, Canadian science education, equity in education

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The integration of socioscientific issues (SSI) into education has emerged as a crucial pedagogical approach for preparing citizens to engage with complex interdisciplinary challenges at the intersection of science, technology, and society (Viehmann et al., 2024). SSI in education are often open-ended and unresolved (Sadler, 2011). Climate change, public health crises, biotechnology ethics, and technological justice represent archetypal SSI that require citizens capable of critical thinking, ethical reasoning, and evidence-based decision-making (Herman, 2018).

SSI in education shares roots with the Science, Technology, Society, and Environment (STSE) movement and other sociocultural movements (Chowdhury, 2016). However, the distinction is that SSI place an explicit focus on developing moral intelligence (integrity and moral decision) and social responsibility, without bifurcating science into process and moral imperatives (Bencze et al., 2020). Scientific literacy is described as the ability to understand, interpret, and apply scientific concepts and processes (Tyler, 2024), and SSI education is a key aspect of scientific literacy because it equips learners to apply scientific knowledge to complex ethical, environmental, and societal issues.

One of the key outcomes of SSI in education is to engage students in social action, thus "enabling young people to be part of the solution to society's problems rather than contributing to them" (Hodson, 2014, p. 68). Despite these benefits, emerging research reveals that many science teachers, both pre-service and in-service, struggle to navigate the pedagogical complexities of integrating SSI in their teaching (Chen & Xiao, 2021). Moving towards embedding action in teaching is complex and difficult for teachers as it is a radical change (Hodson, 2020). Action-focused SSI in education puts new demands on teachers, challenging deep-rooted assumptions and beliefs that school is traditionally founded on, such as the view of knowledge as fixed, the teacher as the sole authority, and learning as the passive absorption of information rather than active engagement with real-world problems (Chowdhury, 2016).

Studies have shown that while SSI in science education is promoted for its potential to connect science learning with real-world, ethical, and societal concerns, many teachers feel ill-equipped to implement such pedagogies effectively (Zhang & Hsu, 2025). For instance, Pedretti et al. (2008) noted that 64 secondary pre-service teachers at a large Canadian university lacked a clear understanding of how to integrate issue-based STSE teaching, a challenge related to SSI education, in classroom practice especially when dealing with interdisciplinary content. In-service teachers, while aware of the value of SSI, cite the lack of time, assessment frameworks, and confidence in addressing contentious or value-laden topics as key barriers (Chen & Xiao, 2021). The implementation of SSI pedagogy tends to be inconsistent and context-dependent, with few systemic supports for professional development (PD) and/or curriculum reform in British Columbia (BC) (Jellema, 2024).

Recent pedagogical approaches for SSI in education in other educational contexts, such as the study by Erhabor and Reis (2026) on low-cost, community-based participatory research using discarded or waste materials to foster recycling behaviours among university student teachers in Nigeria, offer promising models for localized, resource-sensitive approaches to SSI in education. Against this backdrop, this paper draws on a review of Canadian-related literature to (i) identify existing barriers to implementing SSI in education programs across the country, and (ii) examine how the approach of Erhabor and Reis (2026) might inform SSI in education in Canadian rural,

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francophone, and Indigenous contexts. In the next section, we will describe key aspects of this approach.

Community-Driven, Low-Cost SSI in Education Approach of Erhabor and Reis (2026)

Erhabor and Reis (2026) propose a community-driven, low-cost pedagogical approach to SSI education. The study was conducted at a federal university in Nigeria. Developed in a resource-constrained educational context, this approach demonstrates how SSI-aligned competencies can be cultivated by engaging pre-service teachers in low-cost, community-based problem-solving. It emphasizes the use of locally available materials, contextualized learning, and active student engagement in addressing real-world environmental and social challenges because the institution where this study was conducted faces resource constraints that limit access to specialized environmental laboratory equipment and dedicated recycling facilities for practical instruction (Erhabor & Reis, 2026). Although recycling is increasingly recognized as an important component of environmental sustainability and environmental education, opportunities for students to engage in practical recycling activities may remain limited in Nigerian institutions. For example, Ifegbesan (2010) found that 77.3% of school students surveyed in Ogun State reported having no opportunity to reuse or recycle items in their schools, indicating limited practical engagement with recycling. These contextual challenges made this specific university an appropriate setting for evaluating whether low-cost, locally sourced instructional materials could provide an affordable and practical alternative for improving students' recycling knowledge and supporting sustainability education.

Erhabor and Reis (2026) employed a quasi-experimental pre-test–post-test control-group design using two purposively selected first-year B.Ed. classes of pre-service teachers from the Faculty of Education during the 2022–2023 academic session. One intact class served as the experimental group while the other served as the control group. Participation was voluntary and only pre-service teachers who provided informed consent and completed both the pre-test and post-test were included in the final sample, resulting in 25 participants in each group (n = 50).

The experimental group consisted of pre-service teachers in Health Education, while the control group consisted of pre-service teachers in Human Kinetics. Both groups received instruction on the same recycling concepts and were assessed using identical pre-test and post-test instruments. The principal difference between the groups was the instructional approach. The experimental group received instruction through hands-on, participatory activities using low-cost and locally available discarded or waste materials, whereas the control group received the same recycling content through conventional lecture-based instruction.

The use of pre-testing enabled the assessment of participants' baseline knowledge and attitudes before the instructional intervention and helped to account for pre-existing differences between the groups. Both groups participated in the study within the same institutional setting and academic period and were exposed to the intervention over the same study period. However, because the groups were intact classes drawn from different academic areas, differences in disciplinary background, previous experiences, and student engagement could not be completely eliminated. These potential confounding factors are inherent limitations of the quasi-experimental design and should be considered when interpreting the findings.

In this Nigerian university context, the pre-service teachers in the experimental group used recycled materials to create learning aids that encouraged practical engagement with recycling behaviours (Erhabor & Reis, 2026). This participatory and action-oriented approach reflects the

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goals of SSI education and demonstrates a potentially useful approach for educational programs, particularly in underserved or resource-constrained contexts. The findings suggest that creativity, active participation, and local relevance can support meaningful engagement with SSI without requiring expensive infrastructure.

This approach of Erhabor and Reis (2026) is explicitly grounded in Vygotsky's (1978) sociocultural theory, which asserts that cognitive development is influenced by cultural and social factors and occurs through interaction with cultural tools and more knowledgeable others. Vygotsky emphasizes the role of social interaction in the development of mental abilities, e.g., speech and reasoning in children (McLeod, 2025). Informed by Vygotsky's (1978) theory, in the approach used by Erhabor and Reis (2026), recycled materials, recycling processes, and waste management practices function as cultural tools that mediate student learning; they are not merely objects, but artifacts imbued with cultural meanings and practical purposes. Final-year students served as peer mentors, scaffolding learning of first-year students by breaking down complex activities, offering timely feedback, and progressively reducing assistance as learners developed confidence and competence. They also encouraged the use of bilingual language especially with the use of visual aids with minimal text to bridge language gaps. Thus, first-year students were able to participate in tasks within their zone of proximal development that were slightly beyond their independent capabilities but achievable with peer guidance.

Hence, in this approach, knowledge is socially constructed through collaborative problem-solving, group work, and peer teaching, emphasizing co-construction rather than individual discovery. It reflects constructivist learning principles. Students actively constructed understanding by manipulating materials, testing hypotheses (e.g., determining optimal pulp-to-water ratios), and addressing problems such as waste management. Inquiry-based learning is central, as activities provoked questions such as "Why does aluminum compress more easily than plastic?" or "What happens to waste that isn't recycled?" and drove further investigation. This approach also employs scaffolded complexity, moving learners from concrete tasks, such as hands-on recycling, to more abstract analyses of waste flow systems, thereby, progressively deepening conceptual understanding. Majority of the materials used in this study were waste and recycled materials received from the community.

The use of this SSI in education approach by Erhabor and Reis (2026) demonstrated notable gains in the pre-service teachers' knowledge and practical capacities regarding environmental sustainability. Quantitatively, the experimental group exhibited a pre-intervention mean score of 6.0 out of 10, which increased to 8.84 post-intervention, representing a 47% improvement. The control group showed a smaller increase, from 5.96 to 8.36 (40%). Analysis of covariance (ANCOVA) confirmed the statistical significance of these gains, with $F = 4.171$ and $p = 0.047$ at the $\alpha = 0.05$ level. These results indicate that the use of community-based participatory approach of SSI education significantly enhanced knowledge of recycling processes, waste categorization, environmental impacts, and sustainable management strategies.

In this paper, we use the above-mentioned SSI in education approach of Erhabor and Reis (2026) as a conceptual lens for examining how SSI education is implemented in Canadian contexts, particularly in rural, Indigenous, and under-resourced settings where similar constraints and opportunities may exist. To enhance analytical clarity, this approach is operationalized through four interrelated components: contextual relevance, low-cost resource utilization, participatory learning, and community integration, which are described below.

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Contextual Relevance

This component emphasizes the alignment of SSI instruction with learners' immediate environmental, social, and cultural realities. Rather than relying on abstract or distant examples, teaching is grounded in locally meaningful issues. In this present study, it was used to examine how Canadian SSI education literature reflects rural environmental concerns, localized socioscientific challenges, and regional diversity across provinces. Erhabor and Reis's (2026) approach closely aligns with core SSI pedagogy principles. The intervention fosters interdisciplinary integration, blending chemistry (paper pulping), physics (mechanical advantage in can crushers), biology (decomposition processes), economics (analyzing recycling business models), and ethics (environmental responsibility). Students engage in scientific argumentation and reasoning as they justify design choices, evaluate trade-offs between recycling methods, and debate priorities in waste management. Moral and ethical dimensions are central, as activities prompt reflection on equity in pollution burdens, intergenerational resource responsibility, and consumption choices. Furthermore, the approach emphasizes action competence, explicitly moving students from knowledge acquisition to values-driven behaviors, exemplified through campus campaigns and peer-led initiatives for sustainability.

Low-Cost Resource Utilization

This component focuses on the use of affordable, accessible, and locally available materials to support teaching and learning of SSI, reducing dependence on expensive or standardized resources. Using this component as a conceptual lens helped assess the resource disparities across Canadian schools and feasibility of SSI implementation in under-resourced or remote areas, as evident in the SSI literature reviewed (Sadler, 2011; Rivard & Gueye, 2016). A major principle of effective SSI education is that it does not depend on expensive laboratory equipment or commercial teaching aids. Rather, materials that would otherwise be discarded can be transformed into powerful pedagogical tools, providing students with meaningful, hands-on learning experiences. For example, in Erhabor and Reis's (2026) study, student teachers creatively repurposed readily available items from their environment: old newspapers and wastepaper were transformed into recycled paper products; wooden scraps, nails, and discarded plastic tubing were used to construct can crushers; empty buckets, gloves, and weighing scales facilitated waste auditing exercises; and natural colorants alongside absorbent cloths served as processing materials. The pedagogical rationale for this approach lies in the direct engagement with 'waste-as-resource,' allowing learners to experience the circular economy concept in a tangible way rather than abstractly. From an SSI perspective, repurposing materials encourages students to grapple with socioscientific dimensions of sustainability. They negotiate competing values such as economic viability versus environmental responsibility, evaluate trade-offs between convenience and ecological impact, and develop systems thinking by tracing material flows within society. This approach not only fosters practical skills but also cultivates critical reflection on sustainable practices and decision-making.

Participatory and Inquiry-Based Learning

Environmental literacy develops most effectively through embodied experiences that involve doing, making, observing, and reflecting rather than learning through textbook instruction alone. In the workshops organized during Erhabor and Reis's (2026) study, pre-service teachers engaged in three core hands-on activities that included paper recycling, can crushing and waste watching exercise. During the Paper Recycling session, they shredded paper, prepared pulp, spread it on

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mesh screens, pressed excess water, and dried new sheets, navigating challenges of pulp consistency, coordinating production steps collaboratively, and engaging their senses to appreciate the labour intensity of recycling processes. In the Can Crusher Construction session, students designed and built simple mechanical devices from scrap materials, applying physics concepts such as leverage and compression to real-world environmental problems while quantifying space-saving impacts. The Waste Watcher exercise involved collecting, weighing, categorizing, and analyzing personal waste over several days, with data visualization making abstract concepts like waste generation rates tangible and prompting critical reflection on personal consumption patterns. These experiential learning cycles encompassing concrete experience, reflective observation, abstract conceptualization, and active experimentation (Kolb, 1984), enhance understanding, retention, and emotional engagement beyond what lectures alone can achieve. This hands-on approach aligns with SSI pedagogy, which emphasizes personally meaningful problems requiring dialogue, discussion, and critical engagement (Macalalag et al., 2024), transforming waste management from an abstract issue into a lived reality that students can actively influence. This component promotes active student engagement through dialogue, investigation, and collaborative problem-solving around real-world SSI. We used this component to analyze the extent of student-centered approaches in Canadian classrooms and opportunities for critical thinking and decision-making as reflected in the Canadian SSI literature.

Community Integration

This component highlights the inclusion of community knowledge systems, including Indigenous and local perspectives, in the teaching and learning of SSI. It is particularly relevant for examining how and in what ways Canadian SSI education literature illustrates Indigenous education contexts, cultural responsiveness and integration of local and traditional knowledge systems. In Erhabor and Reis's (2026) study, pre-service teachers led campus-wide aluminum-can collection campaigns, conducted peer-led recycling demonstrations, performed waste audits of their own consumption, and collaborated on designing local solutions to identified waste challenges.

Thus, the above four components collectively served as an analytical conceptual lens for examining the Canadian literature to analyze the implementation of SSI education in Canada. They guided the identification of key challenges and opportunities across diverse contexts, including rural, Indigenous, francophone, and under-resourced educational settings that were reflected in the literature reviewed. This conceptual lens also supports the exploration of how adaptable, community-driven approaches can enhance the relevance and effectiveness of SSI pedagogy. Table 1 below summarizes these components and their application to Canadian SSI education contexts.

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Table 1

Conceptual Lens Based on Erhabor and Reis's (2026) SSI in Education Approach

Component	Description	Application to Canadian SSI Contexts	Expected Outcomes
Contextual Relevance	Learning is grounded in real-life, local socioscientific issues.	Supports learning in rural and Indigenous communities where local realities shape education.	Improved relevance of SSI content and deeper student engagement.
Low-Cost Resource Utilization	Emphasizes the use of locally available and affordable materials for teaching SSI.	Addresses resource limitations in under-resourced and remote schools across Canadian provinces and territories.	Increased accessibility and feasibility of implementation of SSI education.
Participatory and Inquiry-Based Learning	Encourages active student involvement in discussion, investigation, and decision-making with regards to SSI.	Enhances student-centered learning across diverse classrooms, including francophone and multicultural settings.	Development of critical thinking and problem-solving skills.
Community Integration	Incorporates community knowledge, including Indigenous and local perspectives into SSI learning.	Aligns with Indigenous education principles and promotes culturally responsive pedagogy	Strengthened cultural relevance and socially responsible decision-making.

Methodology

This study adopts an integrative review methodology (Torraco, 2016) to critically synthesize empirical, theoretical, and policy literature on the implementation of SSI education in Canada. An integrative review methodology is a comprehensive research approach that systematically synthesizes literature from diverse sources and methodologies to create new knowledge and frameworks of understanding about a particular phenomenon (Whittemore & Knafl, 2005). An integrative review is well suited for examining complex educational phenomena, as it allows for the inclusion of diverse research designs, including quantitative, qualitative, mixed-methods, and conceptual frameworks (Torraco, 2016; Whittemore & Knafl, 2005).

A comprehensive literature search was conducted across the following electronic databases and supplementary sources:

- Scopus
- Web of Science
- ERIC
- ProQuest Dissertations & Theses Global
- Google Scholar
- Government and institutional policy repositories

The search included peer-reviewed journal articles and dissertations published in English between 2010 and 2024. The search terms used were combinations of keywords such as:

- socio-scientific issues OR socioscientific issues
- science education OR science pedagogy
- teacher education OR pre-service teachers OR in-service teachers OR teacher preparation

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- Canada OR Canadian education
- curriculum OR instruction OR implementation OR pedagogical practices

Boolean operators (AND/OR) were used to ensure inclusivity and relevance of results. The inclusion criteria were:

- Population: Pre-service and in-service teachers in Canadian K-12 education (all K–12 levels were included).
- Concept: Socioscientific issues (SSI), science literacy, teacher education, curriculum design, instructional strategies.
- Context: Canada; studies conducted within Canadian provinces and territories.
- Types of Sources: Peer-reviewed articles, reports, policy and curriculum documents, theses (English-language sources only due to translation constraints).
- Time Frame: Publications between 2010 and 2024.

Although the review focuses on Canadian literature, selected international studies related to SSI and low-cost educational materials were included to provide comparative insights, broaden inclusion criteria and illustrate transferable pedagogical strategies relevant to SSI implementation across diverse contexts. Teacher education was deliberately included in this review because the capacity of teachers to implement SSI pedagogy is shaped during pre-service and in-service training. Understanding barriers in teacher preparation is therefore essential to explaining classroom-level implementation challenges.

The exclusion criteria were:

- Studies conducted outside Canada unless they provided comparative insights relevant to the Canadian context.
- Literature not explicitly addressing SSI.
- Articles that lacked full text or were inaccessible after attempts to retrieve them.

The data collected were recorded based on the following aspects:

- Author(s), year of publication
- Study location and context
- Type of study (empirical, theoretical, policy)
- Focus of the study (e.g., teacher training, classroom implementation)
- Key findings related to SSI pedagogy
- Identified challenges, supports, and recommendations

The data collected were organized into a summary table by using Critical Appraisal Skills Programme (CASP, 2024) to evaluate each study's aim, methodology, key findings, strengths, limitations, and relevance to SSI teaching. The CASP is a structured tool used to assess the quality, rigour, and relevance of research studies. In this study, CASP was used to assess the quality and rigour of the included studies as indicated in Table 2 below. The four-component conceptual lens based on Erhabor and Reis's (2026) approach guided the analysis of each study's contribution to SSI teaching.

Thematic Analysis

Each study was appraised for methodological rigour (sample size, study design, and data collection and analysis), relevance (applicability to SSI pedagogy and teacher preparation in Canada), and credibility (peer-reviewed status, citation impact, or policy significance). This review found

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studies in provinces such as Ontario, Saskatchewan, Nova Scotia, BC and Alberta, with limited or no empirical studies identified for other Canadian provinces and territories.

A thematic synthesis (Thomas & Harden, 2008) was applied to identify patterns, concepts, and insights across studies. This thematic synthesis was conducted manually following a systematic process of familiarization, line-by-line open coding, and iterative grouping of similar codes into descriptive and analytical themes. Codes were developed from key findings across studies and refined through constant comparison to ensure coherence and alignment with this study's objectives. In view of the above, the themes derived were from the conceptual lens through four interrelated components of Erhabor and Reis (2026), namely, contextual relevance, low-cost resource utilization, participatory learning, and community integration.

Table 2

CASP Table for Selected SSI Studies

Study	Aim	Methodology	Key Findings	Strengths	Limitations	Relevance to SSI Teaching
Aikenhead & Elliott (2010)	To explore the emergence of decolonizing and cross-cultural science education in Canada, particularly Saskatchewan	Qualitative, documentary case study drawing on curriculum documents, previous research, stakeholder consultations, community collaboration and curriculum implementation	Integrating Indigenous and Eurocentric ways of knowing can reduce alienation, strengthen cultural identity, improve engagement and achievement, and promote scientific literacy	Community-centered, theoretically grounded, and provides a practical curriculum model	Mainly descriptive; Saskatchewan-focused; limited experimental evidence	Supports SSI teaching through culturally responsive, place-based, dialogic learning that incorporates Indigenous knowledge, multiple perspectives, sustainability, social and ecological justice
Bartlett et al. (2012)	To explore co-learning journeys between Indigenous and Western science	Narrative & reflective; based on program development	"Two-Eyed Seeing" essential for co-learning; advisory councils sustain efforts	Deep cultural insight; long-term reflection	Not generalizable; lacks empirical measurement	Critical for integrating Indigenous knowledge in SSI contexts
Bayram-Jacobs et al. (2019)	To examine science teachers' Pedagogical Content Knowledge (PCK) development through SSI	Mixed methods; data from lesson prep, reflection forms, observation tables; PCK model-based analysis	Teachers developed stronger PCK components for SSI; single module can improve PCK	Multinational sample; robust PCK framework	Short-term study; self-reported data	Strong insight into effective teacher professionali-zation in SSI teaching

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	curriculum enactment					
Bencze (2010)	To investigate pre-service teachers' engagement with student-led science/tech projects	Qualitative case analysis during methods course	Design projects encouraged core pedagogical practices; helped overcome teaching anxiety	Practical, innovative entry into pedagogy	Focused on teacher candidates; no long-term follow-up	Relevant for SSI through empowerment and inquiry-based methods
Bossér et al. (2015)	To explore challenges in implementing SSI in classroom practices	Qualitative; video-recorded discussions with teachers; year-long study	Teachers became more student-centered but struggled to align with learning goals	Longitudinal design; in-depth teacher reflections	Small sample; limited generalizability	Highlights pedagogical tensions in SSI implementation
Boucher (2015)	To discuss French-language school equity	Policy report	Highlights linguistic challenges and strengths	Focused on minority language rights	Not empirical study	Supports inclusive SSI delivery in minority language contexts
Bryant & Walker (2024)	To explore how principals support middle leader learning	Qualitative case studies across 12 schools	Principal-designed structures foster leadership learning	Context-sensitive models; supports job-embedded learning	Qualitative scope	Offers structural insights for building SSI leadership capacity
Burek & Zeidler (2015)	To explore conservation through SSI in informal learning	Descriptive and conceptual analysis	SSI can motivate conservation and activism among learners	Connection to real-world issues	Not empirical; conceptual in nature	Supports SSI's transformative potential for environmental literacy
Chen & Xiao (2021)	To review perceptions and challenges in SSI teaching	Systematic review of 25 studies (2004-2019)	Teachers lack clear SSI strategies; need systemic support	Comprehensive synthesis; practical recommendations	Broad range of study quality	Identifies system-wide enablers for effective SSI integration
Corbett (2014)	To argue for geography of rural education in Canada	Theoretical & conceptual	Rural schools undervalued but resilient	Advocates spatial understanding in policy	Canada-specific; theoretical	Spatial perspectives important for localizing SSI in rural settings

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Forbes & Davis (2010)	To understand how pre-service teachers adapt curriculum for inquiry-based science	Quantitative methods; curriculum design analysis	Pre-service teachers can adapt materials; inquiry-orientation influenced by existing materials	Focus on curriculum use/adaptation	Pre-service focus; may not translate to in-service settings	Shows how curriculum adaptation can support SSI-like inquiry learning
Jellema (2024)	To investigate how a Learning Study approach supports teacher professional learning for SSI pedagogy in secondary science classrooms	Qualitative case study using iterative lesson design, video analysis, and teacher reflection within a Learning Study framework	Teachers' understanding of SSI deepened, particularly in linking content to values-based reasoning; iterative design enhanced pedagogical confidence	Rich qualitative data; longitudinal engagement with teachers; strong practitioner collaboration	Small sample size; limited to one provincial context	Demonstrates how sustained, collaborative lesson study can strengthen teachers' capacity to implement SSI in practice
Kim et al. (2017)	To critique use of Traditional Ecological Knowledge (TEK) in science education	Critical literature review	TEK often misrepresented as Indigenous knowledge; calls for distinction	Sharp conceptual analysis	May be contentious; lacks field data	Key to decolonizing SSI teaching frameworks
Lyon et al. (2022)	To validate a scale measuring School Implementation Leaderships (SILS)	Quantitative; survey of 441 teachers; factor analysis	SILS validated with 21-item scale across 7 factors	Psychometrically sound; wide sample	Focused on leadership, not SSI per se	Provides tools for measuring support systems in SSI implementation
Rivard & Gueye (2016)	To investigate literacy-enhanced science instruction via PD program	Mixed methods over 3 years; teachers & students	PD improved teacher beliefs/ practices; boosted student literacy	Longitudinal; mixed methods	Context-specific; high teacher mobility	Emphasizes PD in supporting SSI-aligned literacy strategies
Sadler (2011)	To introduce SSI as contexts for promoting key science learning outcomes	Conceptual chapter drawing on empirical studies	SSI promotes content understanding, epistemic insight, and socioscientific reasoning; requires explicit	Clear articulation of SSI learning outcomes; widely cited foundational work	No direct empirical data; general recommendations	Provides theoretical underpinning for SSI integration into science education programs

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			pedagogical design			
Sullivan et al. (2018)	To compare rural disadvantages in science education across 3 countries	Secondary data analysis (PISA)	Rural students face greater challenges, especially in Australia	Strong international comparison	Does not focus on SSI directly	Provides context for implementing SSI in underserved rural areas
Therrien et al. (2022)	To examine place-based learning in postgraduate resource courses	Reflective survey & analysis	Place-based methods are enriching but sometimes lack critical depth	Innovative in linking place and extraction	Narrow postgrad focus	Inform SSI through localized real-world engagement
Viehmann et al. (2024)	To map and synthesize research on SSI use in science education	Scoping review; 106 articles from 2013-2023	SSI focuses on environmental/ genetic issues; methods are mainly qualitative	Broad synthesis; covers pedagogy & tech tools	Some studies lack depth; review-level	Useful map of current SSI teaching practices

Findings

A cross-cultural comparative lens was applied by using Erhabor and Reis's (2026) low-cost, community-driven SSI approach that they used in Nigeria. The four components as discussed in Table 1, provided a critical conceptual lens to analyze studies and examine principles of resource use, community engagement, and action-based SSI learning in Canadian teacher education; and exploring scalability of SSI education for rural, francophone, and underserved schools. Key themes around SSI education in Canada included the following:

1. Pedagogical knowledge gaps and PD needs among teachers;
2. Resource inequities and curriculum integration challenges;
3. Assessment and evaluation practices;
4. Community engagement, cultural responsiveness, and sociocultural dynamics.

Pedagogical Knowledge Gaps and PD Needs Among Teachers

The literature reviewed reveals significant gaps in teachers' understanding of SSI pedagogy in selected Canadian provinces (Ontario and BC). Shakkouri's (2017) study of Ontario secondary science teachers found that teachers' experiences informed understandings of SSI in education, highlighting how personal and professional backgrounds shape pedagogical approaches. Similarly, a study by Jellema (2024) in BC revealed that teachers' understandings of SSI were value driven, suggesting that personal beliefs significantly influence how educators approach SSI implementation. This creates inconsistencies in delivery and effectiveness across classrooms. Jellema also observed a lack of PCK among Canadian science teachers. While educators recognize the value of controversial issues like climate change or genetic engineering, many default to traditional didactic approaches due to discomfort with open-ended discussions or fear of parental and/or community backlash especially in rural or conservative areas.

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In summary, a persistent challenge in SSI education is that teachers often lack clear strategies for facilitating open-ended discussions and may fear appearing biased or ideological (Bossér et al., 2015; Jellema, 2024). Erhabor and Reis's (2026) approach addresses this by providing concrete, structured activities that naturally scaffold student engagement with SSI. Hands-on tasks such as designing recycled paper products or constructing simple mechanical devices prompt meaningful questions (e.g., "Is recycling always environmentally beneficial?" or "Who should bear the cost of waste management?") while keeping the focus on materials and processes. This design reduces the pressure on teachers to deliver 'correct' answers of specific SSI, enabling students to explore, debate, and reason collaboratively within a guided, yet open-ended, learning environment.

However, for the aspect of PD need, a pan-Canadian review (Bencze, 2010) revealed that only about 23% of science teacher training programs explicitly address SSI pedagogy. Shakkouri (2017) reinforces this emphasis on SSI, noting that teacher education programs need to "better engage future teachers in citizenship education [SSI] in order to make educators more comfortable educating for citizenship in science" (p. ii). Jellema's (2024) study strengthens the claim that PD programs (for in-service teachers in this case) need design features that allow iterative lesson planning, community of practice, and classroom enactment (the learning study itself is offered as one remedy). This study reveals that despite curriculum redesign in BC, which emphasizes 21st-century competency-based skills through SSI, "many teachers are having difficulties realizing the mandate" (p. 58). This suggests fundamental gaps in teacher preparation and PD.

Resource Inequities and Curriculum Integration Challenges

Sadler (2011) stresses that SSI is intended to achieve broader science education goals (e.g., citizenship, reasoning), but also notes practical barriers when curricula are tightly packed and assessment and accountability systems do not reward debate, deliberation, or extended inquiry. Provincial inconsistencies in curriculum integration present further challenges to the effective implementation of SSI education across Canada. For instance, BC is seen as a leader in environmental and SSI education, whereas Alberta's economic ties to fossil fuels may inhibit open discussions on climate change (Yadav, 2025). BC's K–12 curriculum is concept-based and competency-driven, providing numerous opportunities for students to explore climate change topics across various subjects (Government of British Columbia, 2025). BC has embedded SSI into its curriculum through courses like *Science for Citizens 11*, which explicitly address real-world science applications and promote inquiry into social and environmental issues (British Columbia Ministry of Education, 2023). Whereas in Alberta, the integration of certain aspects of SSI education such as climate change education, is influenced by the province's strong economic ties to the fossil fuel industry (Yadav, 2025). Research by Enoch and Eaton (2021) indicates that industry-sponsored materials are present in educational resources, potentially shaping the narrative around energy production and environmental issues. This influence raises concerns about the objectivity of climate education and the preparedness of students to engage with environmental challenges critically. Moreover, the Council of Ministers of Education, Canada (CMEC) (2024) notes that significant disparities remain in access to culturally relevant and linguistically appropriate materials, particularly in French-language and remote schools, which further affects the quality and consistency of SSI delivery.

One example of this is evident in Sadler's (2011) study which underscored persistent disparities in SSI support between urban schools and those in rural, northern, and francophone communities across Canada. While urban schools often benefit from better infrastructure and

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access to educational materials, schools in more remote or minority-language settings face significant challenges. A study by Rivard and Gueye (2016) highlights that minority-language schools, particularly francophone institutions outside Quebec struggle with limited access to appropriate French-language educational materials, face difficulties in recruiting qualified science teachers, and often have scarce PD opportunities. These challenges are exacerbated in rural and northern regions, where schools often operate in isolation and lack the economies of scale enjoyed by larger urban institutions. Teachers in these settings frequently contend with heavier workloads and multi-grade classrooms, which further hinders the delivery of robust science education including SSI education. Moreover, testimony before the House of Commons Standing Committee on Official Languages in 2024 revealed that the shortage of qualified francophone teachers is particularly acute in rural areas and this can affect the teaching of SSI as limited qualified teachers can seriously influence the expertise in teaching SSI in schools (House of Commons of Canada, Standing Committee on Official Language, 2024).

Thus, a significant barrier for SSI education in rural, northern, francophone, and Indigenous schools is the limited access to expensive science equipment and culturally appropriate SSI materials (CMEC, 2024; Rivard & Gueye, 2016). Erhabor and Reis's (2026) approach illustrates that meaningful SSI learning hinges on resourcefulness rather than resource abundance. By leveraging inexpensive or freely available waste and recyclable materials, students can achieve learning outcomes comparable to or even exceeding those produced by conventional, high-cost interventions. Evidence from related international research further supports this principle. International scholars such as Angrist et al. (2022), Whipp (2021), Mann et al. (2021), Hernández-Barco et al. (2021), and Piassi et al. (2019) provide robust empirical and theoretical support for Erhabor and Reis's (2026) low-cost, community-driven approach. For example, Angrist et al. (2022) demonstrate that low-cost educational interventions, averaging just US$19.00 per student, could yield effects equivalent to tutoring programs costing US$2,500.00 for each student, underscoring the potential of creative, contextually grounded approaches in resource-limited settings in teaching science education.

In addition to curricular content overload, teachers frequently identify time constraints as a significant barrier to implementing SSI education while teaching science. As a result, SSI is often perceived as an additional component rather than an integral part of the curriculum, leading to its limited adoption in classroom settings. For example, the study by Krell et al. (2024) found that despite the recognized value of SSI in fostering scientific literacy, teachers often struggle to incorporate these issues due to time limitations. Similarly, Bossér et al. (2015) reported that teachers face considerable challenges when implementing SSI, including the difficulty of balancing student-centered teaching practices with curriculum demands. This study suggests that without adequate time and resources, teachers may find it challenging to facilitate meaningful discussions around SSI. Teachers reported that the pressure to cover extensive content for examinations leaves little room for SSI discussions, which are perceived as time-consuming and less directly linked to exam content.

Therefore, teachers often perceive SSI as peripheral 'add-ons' rather than integral components of the curriculum, which results in minimal implementation despite policy endorsements of SSI in education (Krell et al., 2024; Viehmann et al., 2024). Erhabor and Reis's (2026) low-cost educational approach addresses this by embedding SSI learning directly within existing subject areas. For example, chemistry concepts are explored through paper pulping reactions, physics principles through mechanical systems in can crushers, data literacy through

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waste audits, and communication skills through peer-led teaching. This interdisciplinary integration not only aligns with multiple curriculum outcomes simultaneously, but also enhances instructional efficiency, positioning SSI as a core rather than as an optional element of science education.

Sadler (2011) frames SSI as an approach aligned to broad curriculum goals such as 21st-century competencies, but also signals that uptake depends on policy emphasis, assessment regimes, and administrative support validating the subtheme that policy both enables and constrains SSI education. Canada's decentralized system creates both innovation opportunities and systemic inconsistencies for SSI education. Provinces like Ontario and BC support SSI through curriculum frameworks, but lack of national standards and uneven enforcement often result in fragmented implementation (Young et al., 2013).

Furthermore, effective implementation of SSI in educational settings is significantly influenced by school leadership (Lyon et al., 2022). Principals who actively support interdisciplinary learning and critical inquiry, foster environments conducive to SSI integration. However, many administrators may lack the necessary understanding or may be hesitant to engage with potentially controversial SSI topics (Chen & Xiao, 2021).

Shakkouri's (2017) research emphasizes that supportive administrators and colleagues allow for science to be linked to SSI education. However, this support is inconsistent across institutions. Recent research underscores the pivotal role of strategic implementation leadership in adopting new educational practices among public school teachers from elementary schools (Lyon et al., 2022). Such intentional design includes aligning school processes with educational agendas and providing both formal and informal support structures (Bryant & Walker, 2024). Conversely, a lack of administrative support can hinder SSI implementation. Without backing from school leadership, these challenges can become significant barriers to integrating SSI into the curriculum. Therefore, successful integration of SSI in schools is closely tied to the proactive involvement of school leaders. By fostering a supportive environment and providing necessary resources and structures, principals can facilitate the effective teaching of SSI, thereby enhancing students' critical thinking and engagement with real-world issues.

Thus, Erhabor and Reis's (2026) approach to training pre-service teachers on resourcefulness and leadership (as senior students act as mentors to their junior peers) can help build leadership qualities among pre-service teachers. The peer-facilitation approach employed in Erhabor and Reis's study directly addresses these constraints by enabling senior students to teach junior peers, effectively supporting multi-age learning environments and mitigating the impact of limited teaching staff. Additionally, the use of low-cost, locally sourced materials reduces reliance on external suppliers or specialized facilities, making meaningful SSI learning feasible in resource-constrained settings.

Assessment and Evaluation Practices

Teachers often lack appropriate rubrics and tools to assess SSI competencies such as ethical reasoning, the quality of argumentation, and civic engagement (Forbes & Davis, 2010; Viehmann et al., 2024). Forbes and Davis (2010) report that about 70% of Canadian pre-service teachers in their study expressed uncertainty in evaluating SSI learning outcomes, while an estimated 80% had no preparation for handling culturally diverse perspectives. The SSI education approach by Erhabor and Reis (2026), addresses this gap through alternative assessment strategies that capture deeper learning outcomes. Performance tasks, such as successfully producing recycled paper,

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demonstrate practical understanding of processes. Portfolios including photographs, reflection journals, and waste audit data provide evidence of sustained engagement and learning. Peer evaluation, in which students assess one another's teaching demonstrations, fosters accountability and critical feedback. Finally, observable behavior changes, such as active participation in campus sustainability campaigns, document the translation of knowledge into real-world action. Collectively, these assessment strategies extend beyond conventional tests, capture the full spectrum of cognitive, affective, and civic competencies that are central to SSI education.

Community Engagement, Cultural Responsiveness, and Sociocultural Dynamics

Effective integration of SSI in education is not only dependent on the classroom context but also deeply shaped by the broader community, including parental attitudes, local cultural values, and sociopolitical dynamics (Högström et al., 2024). For community engagement and sociocultural dynamics, schools do not operate in a vacuum; rather, they reflect and are shaped by the communities they serve (Bartlett et al., 2012). Studies suggest that parental beliefs play a significant role in shaping whether and how teachers adopt SSI. Parental pushback on controversial content can lead to teacher self-censorship or avoidance of certain topics, especially in politically conservative regions (Bayram-Jacobs et al., 2019). Bossér et al. (2015) reveal that teachers often adopt a neutral stance in the classroom to avoid controversy and perceptions of indoctrination. This approach, while aiming to sidestep potential conflicts, may inadvertently hinder the development of students' critical thinking and moral reasoning skills. In contrast, when schools actively engage families and communities in discussions around the purpose and value of SSI, they create more supportive environments for teachers to integrate SSI education into their teaching (Chen & Xiao, 2021).

Hence, it is essential to provide pre-service teachers with training that emphasizes the importance of facilitating balanced, evidence-based discussions on SSI along with strategies for building respectful partnership with parents and community. Such training should aim to equip educators with strategies to navigate controversial topics effectively and in a culturally responsive manner, fostering an environment where students can engage in critical inquiry without fear of bias or indoctrination.

Though Erhabor and Reis's (2026) approach does not explicitly incorporate Indigenous epistemologies, it's commitment to local contextualization provides a practical framework for respectful communal engagements. By centering on community-sourced materials and addressing place-based environmental problems, their approach creates opportunities to integrate diverse ways of knowing, making SSI education more culturally relevant and inclusive.

Discussion

The findings from this review of SSI education in Canadian science education through the analytical lens of Erhabor and Reis's (2026) study suggest the need for an approach that focuses on the use of low-cost, community-based educational materials and presents a practical and transformative method for addressing many of the challenges Canadian teachers face in integrating SSI education into their classrooms.

One of the core challenges in Canadian science classrooms is the lack of PCK to facilitate SSI learning (Bayram-Jacobs et al., 2019). Teachers often revert to traditional didactic methods due to discomfort with controversial topics and an absence of effective strategies to manage open-ended, values-laden discussions of SSI. Here, Erhabor and Reis's (2026) experiential approach

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using recycled, low-cost materials provides a critical pedagogical counterpoint. By engaging pre-service teachers in the design of locally meaningful learning tools such as environmental aids built from discarded plastic and local artifacts, this approach emphasizes learning by doing, reflection, and community engagement. It not only builds pedagogical confidence but also grounds abstract scientific concepts in tangible, socially relevant contexts. Canadian teacher education programs could benefit from adapting this approach, particularly in helping pre-service teachers practice SSI facilitation through hands-on, resource-sensitive projects that simulate controversial SSI in a safe learning environment.

While provinces like BC have embedded SSI into curricula, others lag behind due to resource disparities and rigid, content-heavy structures. The development of culturally responsive science curricula in Saskatchewan required collaboration with Indigenous communities, customized textbooks, professional learning for teachers, and the involvement of Elders and Knowledge Keepers, highlighting the importance of context-specific instructional resources for Indigenous science education (Aikenhead & Elliott, 2010). This situation mirrors that of under-resourced Nigerian classrooms, where Erhabor and Reis (2026) demonstrated that pedagogical integration of SSI does not require high-cost materials but rather creative engagement with community resources. This work underscores that effective SSI education can emerge from localized, culturally-grounded, and sustainability-driven activities. Canadian rural and underserved schools could adapt this principle by developing place-based SSI curricula using local environmental, social, or economic issues as entry points for example, fracking in Alberta, salmon depletion in BC, or water rights of First Nations communities.

Canadian educators often view SSI as an 'add-on' rather than integral to the curriculum due to time pressure and exam-oriented structures (Viehman et al., 2024). The use of low-cost educational material approach suggested by Erhabor and Reis (2026) offers a potential solution by embedding SSI learning into existing disciplinary structures through interdisciplinary project-based work. For instance, SSI education can be integrated with civic education and sustainability through collaborative projects on waste management. By aligning SSI content with already mandated learning objectives, this approach reduces redundancy while maximizing impact. Canadian schools could implement similar integrated projects where SSI themes intersect with core competencies like critical thinking, inquiry, and civic engagement, thus making SSI education more feasible within packed schedules of teachers.

Many Canadian pre-service teachers receive limited exposure to facilitating SSI education during field placements, in part due to mentor in-service teachers' unfamiliarity or discomfort with the approach (Burek & Zeidler, 2015). Erhabor and Reis (2026) address this issue by embedding SSI-oriented tasks directly into pre-service teacher practicum experiences via action research. In this case, the pre-service teachers were required to identify a local environmental problem, investigate it, design low-cost educational intervention, and evaluate its impact with the guidance of their senior pre-service teachers and mentor in-school teachers during practicum placements. This cycle fostered not only practical experience but also a mindset of reflection, inquiry, and agency. If adapted into Canadian teacher education programs, this approach could help bridge the theory-practice gap while building pre-service teachers' confidence in dealing with controversial and community-relevant SSI topics.

In Canada, sociocultural dynamics, especially in conservative or extractive industry-dependent rural communities, pose barriers to SSI integration (Sullivan et al., 2018; Therrien et al., 2022). Erhabor and Reis's (2026) approach directly engages these dynamics by framing

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educational projects around locally acknowledged problems, such as pollution or unsustainable waste practices. This contextualized engagement not only reduces resistance but also enhances relevance and community ownership. In terms of reducing resistance from parents and community ownership, the pre-service teachers were encouraged to source materials from their household and community and adopt such practices when teaching during their practicum.

Canada's francophone and remote schools suffer from limited SSI resources and linguistic diversity, similar to the challenges faced in multilingual Nigerian classrooms. Erhabor and Reis (2026) reflected the use of bilingual peer-teaching and visual aids with minimal text to bridge language gaps. This strategy could be valuable in Canadian francophone communities, where visual and oral storytelling, local languages, and culturally grounded metaphors could support inclusive SSI education. Importantly, this approach underscores the value of co-creating materials with learners, which increases cultural relevance and ownership.

The findings from Canadian studies underscore systemic and pedagogical barriers to SSI implementation, from inadequate teacher training to resource disparities and sociopolitical sensitivities. Erhabor and Reis's (2026) work offers a viable and inspiring counter-narrative demonstrating that SSI-aligned learning does not require financial excess but rather a pedagogical shift toward resourcefulness and community engagement. This approach, developed in a resource-limited Nigerian context, can inform Canadian science educators to not only become technically competent but also socially responsive and pedagogically creative. By embedding SSI into real-world, low-cost, and context-specific teaching practices, Canadian education systems can better support science teachers in developing learners who are critically literate, ethically engaged, and equipped to navigate the science-society interface. Hence, the scalability of Erhabor and Reis's (2026) low-cost approach in resource-constrained Canadian contexts, particularly in rural, northern, and francophone communities facing resource disparities seems promising.

Conclusion and Significance

The findings of this review demonstrate that while Canada has made important progress in embedding SSI within science education, significant barriers continue to hinder effective implementation of SSI in education. These barriers include uneven curriculum implementation across provinces, limited access to contextually relevant instructional resources, inadequate preparation of pre-service teachers, insufficient PCK and lack of appropriate SSI related PD among teachers, sociocultural sensitivities surrounding controversial issues, and persistent inequities affecting SSI education in rural, Indigenous, northern, and francophone communities. Collectively, these challenges suggest that successful SSI implementation requires more than curriculum reform; it demands pedagogical approaches that are practical, contextually responsive, and sustainable. Viewed through the analytical lens of Erhabor and Reis's (2026) low-cost, community-driven instructional framework, the reviewed evidence points to an alternative pathway for strengthening SSI education. Rather than relying primarily on expensive technologies or externally developed teaching resources, Erhabor and Reis's framework demonstrates how locally available materials, community knowledge, experiential learning, and collaborative problem-solving can be leveraged to create authentic and meaningful SSI learning experiences.

This review underscores the need to redesign teacher education, PD, and curriculum structures to enable effective SSI implementation in Canada. Drawing on the insights from Erhabor and Reis (2026), the authors recommend the integration of low-cost, community-oriented, and action-based educational practices as a pragmatic and scalable approach to preparing teachers,

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particularly in underserved areas. Equipping Canadian teachers to effectively integrate action-oriented SSI will require coordinated policy support, contextual responsiveness, and inclusive pedagogical innovation.

Generative AI Disclosure Statement

AI tools were used solely to support language editing, including grammar checking, sentence refinement, and the organization and arrangement of the manuscript. All substantive arguments, interpretations, analysis, and conclusions are the responsibility of the authors.

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