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ORIGINAL RESEARCH ARTICLE

Bridging Disciplinary Expertise and Innovative Instructional Design: A Bibliometric Mapping of Socio-Scientific Issues (SSI) Trends

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Abstract

Effective science education requires bridging disciplinary expertise with innovative instructional design, yet integrating Socio-Scientific Issues (SSI) into modern learning ecosystems remains fragmented. This study maps global research trends, thematic structures, and emerging gaps in SSI within science education through a comprehensive bibliometric approach to inform future pedagogical designs. Using Publish or Perish, we retrieved a dataset of 1,000 articles published between 1958 and 2026, accumulating 330,947 citations. We conducted co-occurrence analysis using VOSviewer on 5,504 identified terms and selected 80 highly relevant terms, grouped into four main thematic clusters representing social-policy issues, science education, conceptual foundations, and methodological approaches. Network visualization revealed science education as the central node connecting multidisciplinary themes, while overlay visualization demonstrated a clear temporal shift from early theoretical studies toward student-centered instructional practices and scientific literacy. Critically, density visualization exposed significant research gaps, including the limited integration of SSI into concrete instructional designs, insufficient focus on value-based dimensions, and a lack of context-specific practical implementations. This study concludes that to advance the Scholarship of Teaching and Learning (SoTL), future research must shift from descriptive data mapping to creating actionable, context-based instructional design models that translate SSI into classroom practice, thereby enhancing students' scientific literacy and critical decision-making competencies in complex learning environments.

Keywords: Socio-Scientific Issues; Instructional Design; Bibliometric Analysis; VOSviewer; Science Education; Scholarship of Teaching and Learning (SoTL).

ABSTRAK

Pendidikan sains yang efektif membutuhkan jembatan antara keahlian disiplin ilmu dengan desain pembelajaran yang inovatif, namun bagaimana Isu Sosial-Ilmiah (SSI) diintegrasikan ke dalam ekosistem pembelajaran modern masih terfragmentasi. Studi ini bertujuan untuk memetakan tren penelitian global, struktur tematik, dan kesenjangan yang muncul dalam SSI dalam pendidikan sains melalui pendekatan bibliometrik komprehensif untuk menginformasikan desain pedagogis di masa mendatang. Dengan menggunakan Publish or Perish, dataset sebanyak 1.000 artikel yang diterbitkan antara tahun 1958 dan 2026 diambil, mengumpulkan 330.947 kutipan. Analisis ko-okurensi dilakukan menggunakan VOSviewer pada 5.504 istilah yang diidentifikasi, memilih 80 istilah yang sangat relevan yang dikelompokkan ke dalam empat klaster tematik utama yang mewakili isu-isu kebijakan sosial, pendidikan sains, landasan konseptual, dan pendekatan metodologis. Visualisasi jaringan mengungkapkan pendidikan sains sebagai simpul pusat yang menghubungkan tema-tema multidisiplin, sementara visualisasi overlay menunjukkan pergeseran temporal yang jelas dari studi teoritis awal menuju praktik pembelajaran yang berpusat pada siswa dan literasi ilmiah. Secara kritis, visualisasi kepadatan mengungkap kesenjangan penelitian yang signifikan, termasuk integrasi SSI yang terbatas ke dalam desain instruksional konkret, kurangnya fokus pada dimensi berbasis nilai, dan kurangnya implementasi praktis yang spesifik konteks. Studi ini menyimpulkan bahwa untuk memajukan Kajian Pengajaran dan Pembelajaran (SoTL), penelitian di masa mendatang harus beralih dari pemetaan data deskriptif ke pembuatan model desain instruksional berbasis konteks yang dapat ditindaklanjuti yang secara efektif menerjemahkan SSI ke dalam praktik kelas, sehingga meningkatkan literasi ilmiah siswa dan kompetensi pengambilan keputusan kritis dalam lingkungan pembelajaran yang kompleks.

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Kata kunci: Isu Sosio-Ilmiah; Desain Instruksional; Analisis Bibliometrik; VOSviewer; Pendidikan Sains; Kajian Pengajaran dan Pembelajaran (SoTL).

INTRODUCTION

In the contemporary era, science education has undergone a global paradigm shift, transitioning from the acquisition of isolated conceptual knowledge to the cultivation of critical scientific literacy capable of addressing complex, real-world societal dilemmas. Global crises, such as anthropogenic climate change, public health emergencies, and rapid technological disruptions, demand that citizens possess the capacity to make informed, socio-ethical decisions. This pedagogical imperative is deeply embodied in the integration of Socio-Scientific Issues (SSI), which serve as controversial, open-ended problems bridging scientific disciplines with broader environmental and ethical dimensions. Cultivating these competencies within modern learning ecosystems is widely recognized as a cornerstone for fostering active global citizenship and higher-order thinking. Consequently, understanding how these multifaceted issues are structured within the broader educational literature has become paramount for global curriculum modernization and educational equity.

Despite the consensus on the importance of Socio-Scientific Issues, a persistent challenge in science education is that the integration of SSI into instructional practice remains highly fragmented and conceptually isolated. Modern learning ecosystems often treat scientific content and pedagogical strategies as separate entities, creating a significant divide between discipline-specific expertise and innovative instructional design. Educators face major hurdles in translating technical scientific knowledge into actionable classroom activities that simultaneously address cognitive, moral, and socio-ethical dimensions. Furthermore, standard curricular frameworks frequently prioritize rigid, examination-driven content over the fluid, interdisciplinary discourse required to navigate controversial real-world topics. This structural fragmentation limits the effectiveness of SSI-based instruction, leaving a profound disconnect between the theoretical promises of scientific literacy and the actual competencies acquired by students within complex classroom environments.

Extensive scholarly efforts have been dedicated to examining the application and outcomes of SSI across diverse educational environments. Specifically, studies evaluating classroom interventions and student reasoning have been conducted by Sadler (2009), Klosterman et al. (2012), Hancock et al. (2019), Owens et al. (2021), and Owens et al. (2022). Concurrently, empirical research analyzing argumentation, inquiry-based learning, and specific pedagogical

tools has been presented by Evagorou and Osborne (2013), Hernández-Ramos et al. (2021), Karakaş (2022), Georgiou and Kyza (2023), and Nugroho et al. (2025). However, a critical evaluation of these previous investigations reveals significant structural weaknesses. Most of these existing empirical studies are highly context-specific, small in scale, and heavily focused on immediate cognitive outcomes rather than long-term instructional processes. Additionally, traditional systematic and qualitative reviews within this corpus suffer from methodological limitations, as they fail to synthesize large-scale bibliographic datasets or analyze the holistic intellectual structure and long-term development of the field over multiple decades.

To address these persistent academic limitations, this study establishes a distinct research novelty by shifting the focus toward a large-scale, comprehensive structural synthesis that bridges disciplinary science with instructional science. Unlike conventional qualitative overviews or restricted meta-analyses, this research provides an expansive mapping of the SSI literature by evaluating a vast dataset of 1,000 articles spanning nearly seven decades from 1958 to 2026. The true novelty lies in the methodological execution, which simultaneously integrates network, overlay, and density visualizations within a unified, instructionally oriented framework. By extracting and filtering 5,504 co-occurrence terms through VOSviewer, this study moves beyond mere descriptive publication counting. It uncovers how technical, domain-specific scientific topics intersect with pedagogical methodologies, offering an unprecedented, data-driven perspective on how the Scholarship of Teaching and Learning (SoTL) has evolved to meet global educational standards over time.

The primary research gap addressed by this study resides in the absolute lack of holistic, long-term bibliometric mappings that connect the structural, temporal, and thematic concentrations of SSI within a single, integrated instructional framework. Previous review studies have fundamentally isolated these dimensions, examining publication counts, keyword clusters, or pedagogical outcomes as separate, disconnected variables. This fragmentation restricts a deeper, systemic understanding of the deep-seated imbalance between the theoretical ideals of SSI and its practical classroom implementation. This study distinguishes itself from prior literature by explicitly utilizing co-occurrence data density to isolate under-researched domains, such as the synthesis of value-based dimensions and context-specific instructional designs. By directly contrasting high-density conceptual nodes with low-density application nodes, this research systematically exposes where the scientific community has succeeded in theory but lagged behind in practical instructional innovation.

This investigation is firmly anchored in a multi-layered theoretical framework that combines constructivist learning theory, socio-cultural theory, and argumentation theory. Constructivism posits that learners actively construct meaning when confronted with authentic, ill-structured dilemmas, making SSI an ideal pedagogical vehicle for cognitive growth. Socio-cultural theory complements this by emphasizing that meaning-making is a collaborative process shaped by discourse and social interaction within specific educational communities. Furthermore, argumentation theory—particularly models adapted from the Toulmin Argument Pattern—provides the logical structure students need to evaluate evidence, justify claims, and counter opposing viewpoints. In this study, these grand theories are interconnected to form a cohesive analytical lens, allowing the researchers to evaluate whether the global literature reflects a balanced integration of cognitive development, social interaction, and systematic reasoning within classroom practices.

The conceptual architecture of this study revolves around four core domains: Socio-Scientific Issues (SSI), innovative instructional design, scientific literacy, and co-occurrence bibliometric indicators. Within this framework, SSI is conceptualized as open-ended, controversial socio-ethical dilemmas that demand interdisciplinary problem-solving. Instructional design denotes the systematic pathway through which complex disciplinary expertise is transformed into actionable classroom methodologies and media. Scientific literacy is defined as a holistic competency encompassing conceptual mastery, evidence evaluation, and critical decision-making. Methodologically, co-occurrence indicators serve as the mathematical proxy for thematic relationships, operating on the principle that the simultaneous appearance of specific terms reflects a conceptual link. By operationalizing these concepts through VOSviewer, this study maps how closely aligned instructional interventions are with the core socio-ethical and cognitive targets of science education.

What makes this research uniquely compelling and critical to investigate is its capacity to expose the deep systemic

disconnect between idealized pedagogical theories and actual empirical research trends. While the scientific education community has long championed the integration of ethics and values into classroom instruction, this study reveals the stark reality of how these dimensions remain structurally marginalized in global publications. It is highly interesting to observe how a field can generate over 300,000 citations while still leaving critical areas, such as scalable instructional frameworks and local context implementations, largely underexplored. Uncovering these hidden imbalances is vital because it provides data-driven evidence for curriculum designers and educational policymakers to reallocate resources. This study serves as a critical catalyst for transforming science education from a purely descriptive domain into an actionable, practice-oriented field of instructional excellence.

Grounded in these critical educational considerations, this study aims to systematically map the global research landscape of Socio-Scientific Issues within science education using an advanced bibliometric approach. Guided by the rigorous standards of instructional science, this investigation seeks to achieve three primary objectives: (1) identify and categorize the dominant thematic clusters within the SSI literature based on co-occurrence term networks; (2) analyze the temporal evolution and historical shifts of these research topics over a 68-year period; and (3) uncover critical research gaps and density imbalances to guide future pedagogical designs. By fulfilling these objectives, this study aims to advance the Scholarship of Teaching and Learning (SoTL) by providing a comprehensive, evidence-based foundation that shifts the field from abstract theoretical mapping to actionable, context-based instructional design models.

RESEARCH METHODS

To achieve a comprehensive, macro-level synthesis that addresses the identified research gaps, this investigation moves beyond subjective reviews and adopts a rigorous, data-driven methodology. The structural, temporal, and density-based dimensions of the global SSI literature are systematically captured through an advanced bibliometric workflow, introduced below and detailed in the following sub-sections.

2.1. Research Design

This study adopted a quantitative bibliometric research design to map, visualize, and systematically analyze the macro-level intellectual structure, thematic trajectories, and latent research gaps within the global Socio-Scientific Issues (SSI) literature in science education. Bibliometric analysis is a rigorous, mathematical approach that uses computational tools to process large bibliographic datasets, enabling objective identification of knowledge clusters and conceptual evolutions often invisible in traditional qualitative reviews. To align this methodological architecture with the study's primary objectives, the research design was structured around three interconnected, data-driven pillars: network visualization for structural mapping, overlay visualization for temporal evolution, and density visualization for research gap isolation. This multi-layered visualization design ensures that the field is evaluated not merely by descriptive volume, but through the mathematical proximity and co-occurrence frequency of key terms. To provide a clear overview of this study's operational alignment, Table 2 systematically details the specific research questions and their corresponding mathematical types of analysis.

Table 1. Research Questions and Corresponding Types of Bibliometric Analysis

RQ Number	Research Question	Types of Bibliometric Analysis
RQ 1	What are the dominant thematic clusters and structural configurations that characterize the global literature on Socio-Scientific Issues (SSI) within science education?	**Co-occurrence Network Visualization:** Mapping term links, link strengths, and cluster divisions to identify the primary conceptual sub-domains.
RQ 2	How have the thematic trends and core concepts within the SSI research domain evolved temporally over the 68-year historical period from 1958 to 2026?	**Co-occurrence Overlay Visualization:** Analyzing the chronological distribution of terms based on mean publication years to identify paradigm shifts.

RQ 3	Which conceptual nodes and pedagogical areas within the SSI literature exhibit low-density concentrations, representing critical research gaps for future instructional design?	**Co-occurrence Density Visualization:** Evaluating item weight and cluster intensity to isolate saturated topics from underexplored practical domains.

Following the alignment of the research questions with their respective analytical modes, the operational workflow governing the execution of this bibliometric design must be explicitly delineated. To visualize the precise steps through which the data was processed, Figure 1 illustrates the comprehensive systemic path of the research.

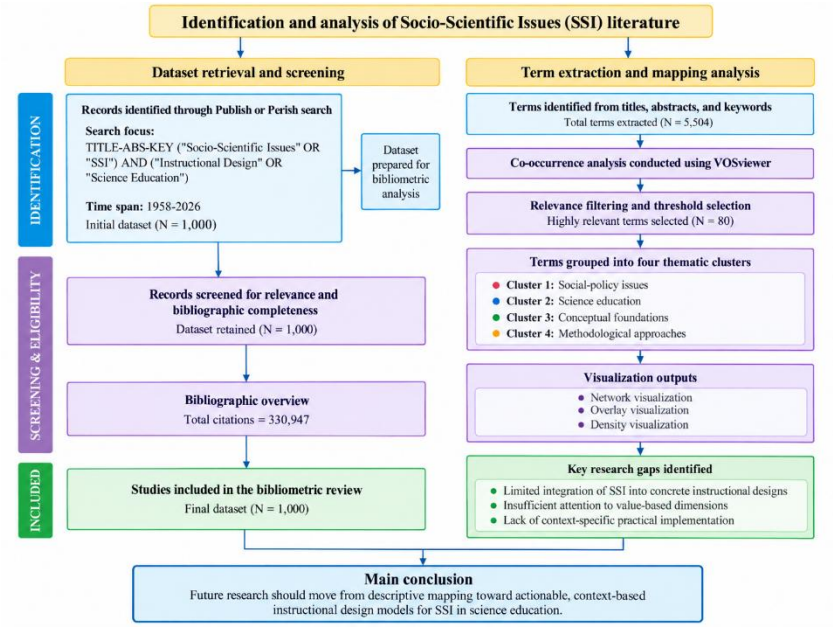

Figure 1. Systematic Path and Workflow of the Bibliometric Research Process

As delineated in the structural flowchart of Figure 1, the research moves through a linear, highly controlled sequence of data extraction, filtering, mathematical modeling, and multi-layered visualization mapping. This systematic path ensures that the dataset transitions from an unstructured collection of metadata into an organized, highly interpretable visualization matrix. Having established the overarching research design and its systematic operational path, the study next moves to the precise protocols used for data collection.

2.2. Data Collection

Data collection was executed through a comprehensive, automated electronic document retrieval process using the advanced Publish or Perish software interface, targeting the extensive global repository of Google Scholar to capture a diverse range of international publications. The primary search query was restricted to the exact phrase "socio-scientific issues" in the keyword field to maintain thematic focus, and the temporal parameters included all publications up to 2026. This long-tail retrieval strategy yielded a final sample of exactly $N = 1,000$ scholarly records published between 1958 and 2026, totaling 330,947 citations and representing the contributions of 195,454 authors globally. The entire metadata file containing complete bibliographic variables—including article titles, abstract text, author keywords, publication years, source journals, and individual citation counts—was exported directly in standardized Research Information Systems (.RIS) format to guarantee data integrity. To clarify the technical parameters and data characteristics of this retrieval phase, Table 3 systematically outlines the metadata attributes captured during data collection.

Table 2. Comprehensive Technical Parameters and Attributes of the Collected Bibliometric Dataset

Metadata Indicator	Technical Specification / Attribute Values
Search Software Tool	Publish or Perish (Version 8.19)
Primary Data Source Repository	Google Scholar Index
Search Keyword / Search Query	"socio-scientific issues" (exact phrase)
Temporal Coverage Range	1958 – 2026 (68-year historical period)
Total Number of Retrieved Publications (N)	1,000 scholarly papers (maximum threshold)

Cumulative Citation Count	330,947 citations
Total Number of Contributing Authors	195,454 authors
Export Data Format Type	Research Information Systems (.RIS file format)
Extracted Metadata Fields	Titles, Abstracts, Keywords, Year, Source, Citation Metrics

The metadata profiles summarized in Table 3 indicate that the retrieved dataset possesses a rich, high-density collection of text data and citation metrics suitable for deep structural modeling. The high citation-to-paper ratio highlights the SSI domain's strong academic footprint, making it an excellent candidate for tracking term co-occurrence. With the raw .RIS file successfully compiled and verified, the methodological workflow transitioned to the core data-analysis phase.

2.3. Data Analysis

Data analysis used advanced term co-occurrence mapping and network modeling in VOSviewer, using text-mining algorithms to extract linguistic data directly from the combined title and abstract fields of the 1,000 retrieved publications. Co-occurrence analysis operates on the principle that when specific terms appear together in the same title or abstract, they share a distinct conceptual relationship, with the frequency of their co-appearance reflecting the cognitive proximity of those concepts within scholarly discourse. The linguistic extraction algorithm initially identified a total pool of 5,504 unique multi-word and single-word terms across the entire dataset.

To reduce noise and isolate the most conceptually significant ideas, we applied a strict mathematical threshold: we retained only terms with a minimum frequency of 10 occurrences, reducing the pool to 115 threshold-meeting terms. Next, a standard algorithmic relevance-scoring filter selected the top 60% most relevant terms, yielding a final standardized set of 80 highly relevant conceptual nodes. These 80 nodes were mathematically mapped based on their total link strengths, resulting in a complex network comprising 4,506 distinct inter-term links and a cumulative link strength of 1,279. This analytical framework allowed VOSviewer to categorize the terms into four primary thematic clusters using a modularity-based clustering technique, as shown in the software initialization stage illustrated in Figure 2.

Figure 2. Visual Representation of the Computational Sub-stages within the VOSviewer Analysis Environment

As shown in the interface schema in Figure 2, the computational execution moves from broad text ingestion to precise relevance filtering, transforming raw linguistic frequencies into stable conceptual weights. The resulting four thematic clusters allow the study to dissect the precise boundaries where disciplinary science content diverges from or intersects with innovative instructional design. After executing these algorithmic clustering procedures, the study establishes its analytical parameters through a specialized research instrument matrix.

2.4. Research Instrument

The research instrument in this bibliometric study is conceptualized as a systematic, mathematically controlled term-filtering and thematic-classification protocol embedded within VOSviewer's text-mining architecture. Unlike traditional field instruments such as questionnaires or test items, a bibliometric instrument relies on linguistic indicators and co-word parameters to capture a domain's intellectual essence without introducing subjective researcher bias. The instrument explicitly structures the 80 selected terms into four distinct dimensions, each representing a primary thematic pillar of the global research landscape. These four operationalized dimensions are categorized as follows: Cluster 1 maps Social-Policy Issues (n=44 items), Cluster 2 captures Science Education Core (n=22 items), Cluster 3 defines Conceptual Foundations (n=9 items), and Cluster 4 tracks Methodological Approaches (n=5 items). This structure allows the instrument to assess whether the global literature demonstrates a balanced integration of cognitive development, social interaction, and systematic reasoning. Table 4 outlines the operational indicators, target attributes, and structural scope of this bibliometric profiling instrument.

Table 3. Structural Matrix and Metric Distribution of the Bibliometric Classification Instrument

Cluster Dimension	Primary Indicator Themes	Key Exemplar Terms Included	Item Count	Target Population Scope	Geographic / Location Focus
Cluster 1	Social-Policy Issues & Regional Challenges	Sub-Saharan Africa, policy, poverty, risk, social work, SSA country, welfare	44 items	Global policy documents & regional context papers	International focus with high concentration in Sub-Saharan Africa
Cluster 2	Science Education & Instructional Core	Science, student, argumentation, scientific literacy, instruction, teacher	22 items	Secondary and higher education science classrooms	Global academic institutions and instructional spaces
Cluster 3	Conceptual & Theoretical Foundations	Theory, philosophy, value, sociology, history, contribution, challenge	9 items	Epistemological and socio-cultural frameworks	Theoretical literature across global education databases
Cluster 4	Methodological Trends & Reviews	Systematic review, trend, web, literature review, article analysis	5 items	Synthesis and meta-analytical research corpuses	Global digital indexes and indexing networks

The indicators and metrics presented in Table 4 outline the operational architecture of the bibliometric classification instrument, demonstrating its capacity to evaluate the multi-dimensional facets of the SSI domain. By tracking the item distribution across these clusters, the instrument can verify whether instructional science features prominently in contemporary publications or remains a secondary focus. To ensure stable results, the study enforced rigorous validation and reliability protocols.

2.5. Validity and Reliability

The study established validity and reliability by adhering strictly to standardized bibliometric protocols and clear algorithmic parameters, eliminating subjective researcher intervention and ensuring full procedural reproducibility. Construct validity was secured by restricting data retrieval to the verified, peer-reviewed global indexing index of Publish or Perish, ensuring that the processed metadata exclusively represents genuine scholarly contributions. Furthermore, content validity was enhanced by extracting terms from both titles and abstracts, ensuring that the resulting co-occurrence network captures the core conceptual substance of the papers rather than superficial or misleading title keywords. Reliability was mathematically managed by enforcing clear, rigid algorithmic constraints within VOSviewer, including a fixed binary term occurrence counting method and an exact relevance threshold of 10 occurrences to eliminate statistical anomalies and noise. Because the text-mining and mapping algorithms operate on deterministic mathematical formulas, any independent investigator using the same search criteria, temporal

range, and filtering thresholds will generate the same network, overlay, and density visualizations. This complete procedural transparency and algorithmic consistency establish a high level of external reliability, confirming that the identified clusters reflect the stable intellectual architecture of the SSI domain rather than transient statistical artifacts.

2.6. Subject and Location of Research

The subjects of this research comprise 1,000 global scholarly publications centered on Socio-Scientific Issues (SSI), operating as a comprehensive macro-level dataset that mirrors the intellectual output of thousands of international educators, curriculum designers, and educational scientists. Because this study uses a macro-level bibliometric design, it replaces the traditional focus on a localized physical classroom with an expansive evaluation of the global digital knowledge ecosystem, tracking how scientific literacy has been operationalized across diverse institutional spaces over a 68-year historical period. This comprehensive sampling strategy ensures that the research captures macro-level paradigms across shifting socio-political eras. The geographic and institutional locations reflected within the dataset span a highly diverse international spectrum, with distinct high-density thematic concentrations mapping explicitly to regional environments such as the United States, Ghana, Kenya, Nigeria, and broader Sub-Saharan Africa. This broad geographic coverage suggests that while the theoretical tenets of SSI developed in major Western research hubs, its empirical application and regional adaptation face unique, context-specific challenges across developing educational systems. By treating this vast international corpus as its primary research subject, this study effectively transcends localized limitations, providing a data-driven foundation that informs curriculum modernization, instructional technology integration, and educational equity initiatives on a global scale.

RESULTS RESEARCH

3.1 Descriptive Analysis of Bibliometric Data

The bibliometric analysis included 1,000 publications on Socio-Scientific Issues (SSI) indexed in Publish or Perish, covering 1958 to 2026. These publications accumulated 330,947 citations and involved 195,454 authors, indicating a substantial and growing research base in this field. The dataset was further analyzed using VOSviewer, focusing on co-occurrence terms derived from titles and abstracts. We initially identified 5,504 terms, of which 115 met the minimum threshold of 10 occurrences. After relevance filtering, we selected 80 key terms and grouped them into four thematic clusters. These steps were carried out to analyze 1,000 articles using Publish or Perish and VOSviewer.

1. The analysis began by selecting Google Scholar as the source and setting the maximum number of retrieved articles to 1,000, with the publication year range extending up to 2026.

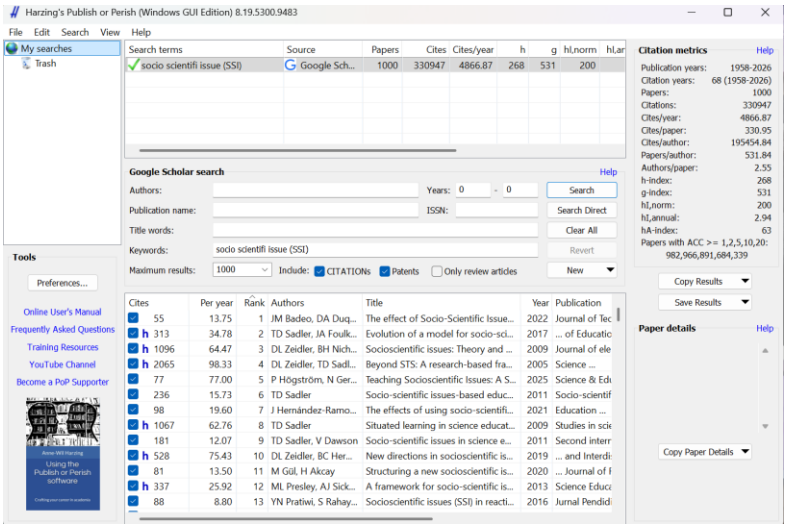

Figure 3 Publish or Perish Data

The metadata search results from Publish or Perish using the keyword Socio-Scientific Issues (SSI), with a time range set from the earliest available year and a maximum of 1,000 records (including citations and patents), yielded a total of 1,000 papers published between 1958 and 2026 (68 years). The total number of citations accumulated over this period is 330,947. Additionally, the total number of authors contributing within this time span is 195,454 authors.

2. The next step, after obtaining RIS data consisting of 1,000 articles related to socio-scientific issues (SSI), was to continue the analysis using VOSviewer to examine the extent of relationships among these articles. At this stage, the author chose to analyze the RIS metadata of the 1,000 articles by constructing a map based on the co-occurrence of terms within the dataset. Co-occurrence refers to the simultaneous appearance of two or more terms within a single document (e.g., title, abstract, or keywords). In this context, when two terms frequently appear together in the same articles, they are considered to have a meaningful relationship or to represent closely related research topics.

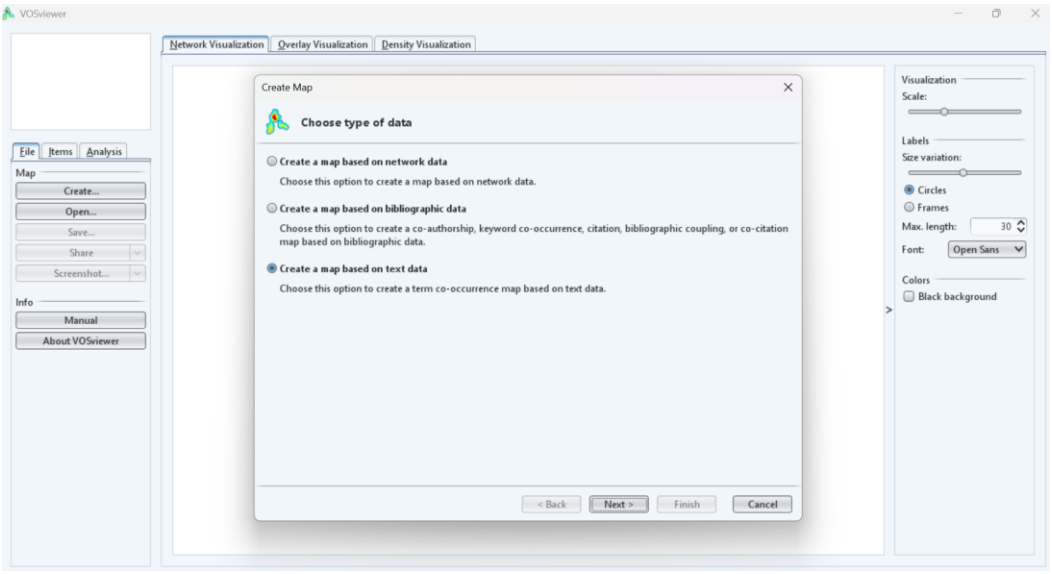

Figure 4 Screenshot of the initial interface when entering VOSviewer.

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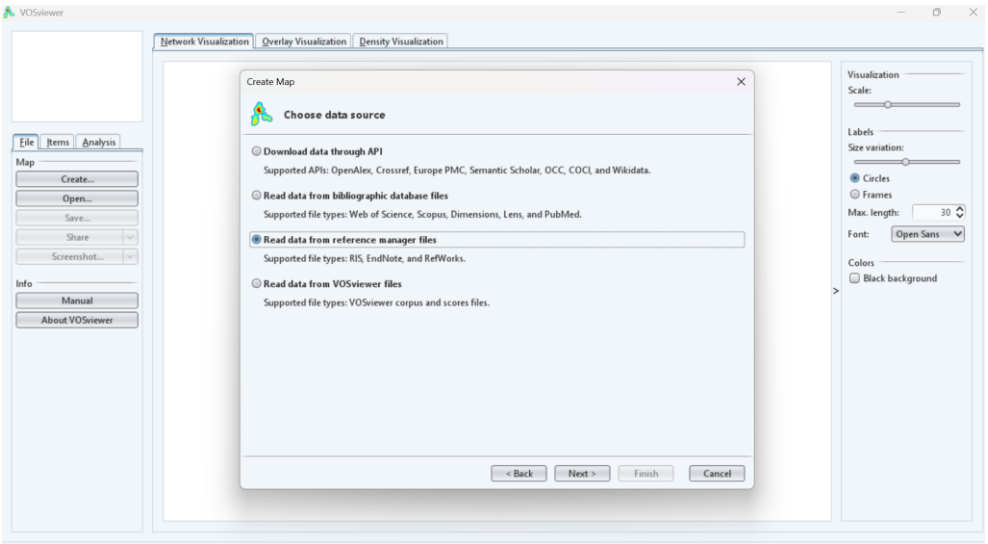

Figure 5 Screenshot during the reference selection stage.

4. At this stage, the author selected the **title and abstract** fields for analysis, in which the system examines the keyword **Socio-Scientific Issues (SSI)** based on the article titles and abstracts.

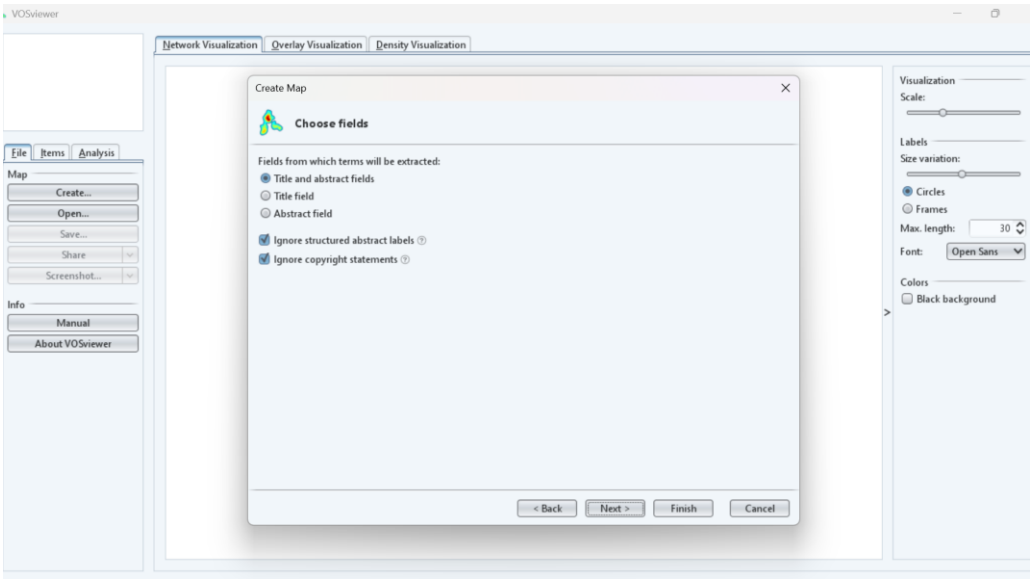

Figure 6 Screenshot during title and abstract field selection stage

5. From the 1,000 articles analyzed, VOSviewer identified a total of 5,504 terms related to **Socio-Scientific Issues (SSI)** based on the titles and abstracts. Of these, 115 terms met the minimum threshold of 10 occurrences and were subsequently validated for further analysis.

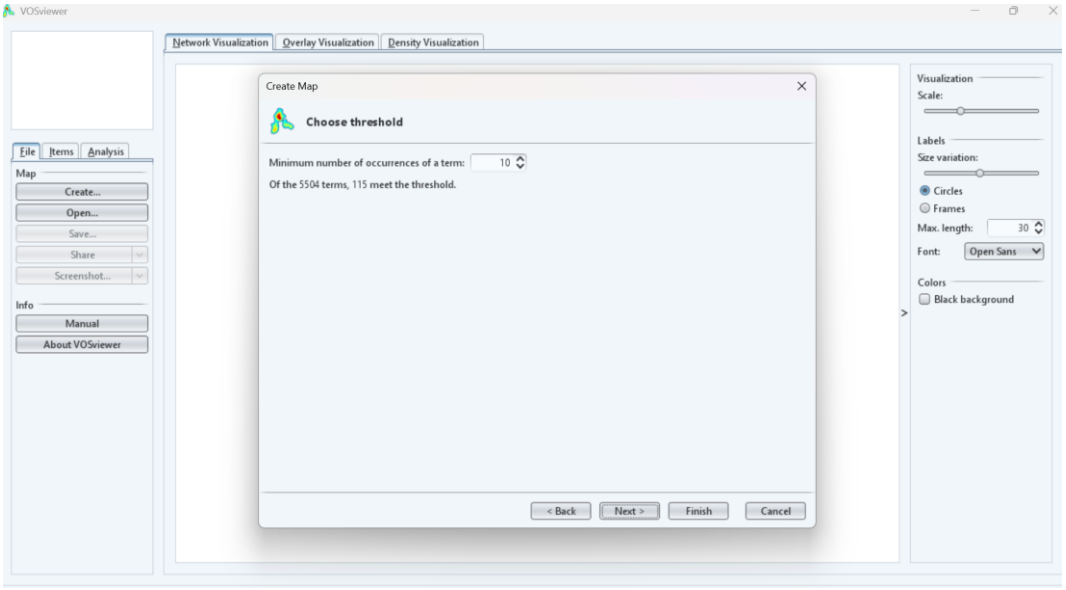

Figure 7 Screenshot after selection from 5504 terms become 115 threshold

6. From these 115 terms, VOSviewer selected the top 60% most relevant terms, resulting in 80 terms that are considered highly relevant to the SSI keyword.

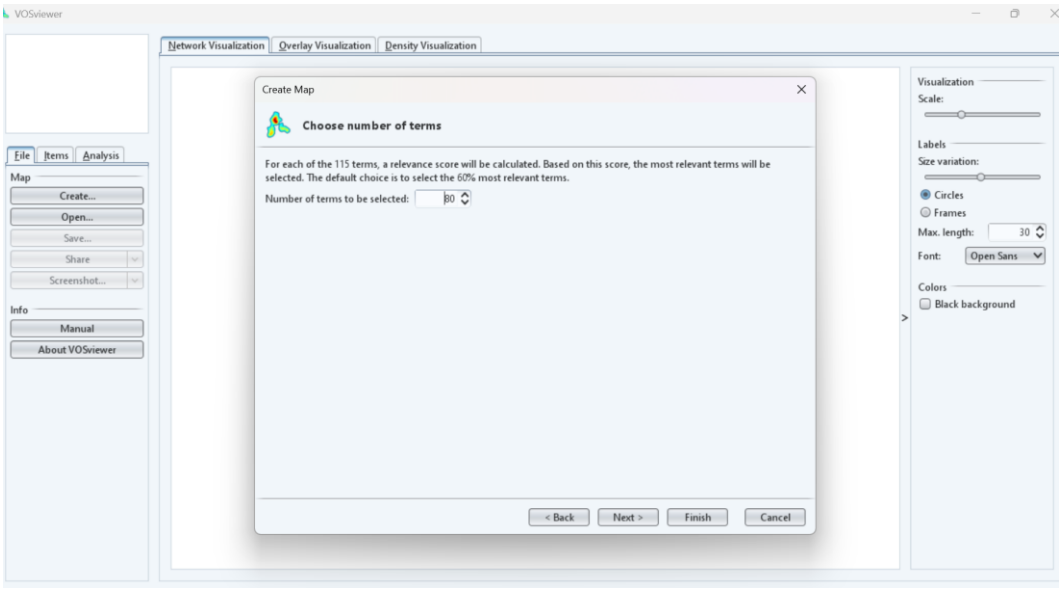

Figure 8 Screenshot of resulting 80 highly relevant terms to SSI keyword

7. From the 80 items, four clusters were identified, with a strong link strength of 1,279 and a total of 4,506 links.

Cluster 1 (44 items)	Cluster 2 (22 items)	Cluster 3 (9 items)	Cluster 4 (5 items)
Access	Argumentation	Challenge	History
Africa	climate change	Child	Philosophy
Area	Context	Literature	Sociology
Article	Decision	Review	Teaching
Book	Influence	social support	Value
Contribution	Instruction	Stress	
Country	Learning	systematic review	
Disability	Nature	Trend	
Evidence	Nos	Web	
Focus	Science		
Gender	science classroom		
Ghana	science content		
Health	science education		
Implementation	scientific issue		
Individual	scientific literacy		
Kenya	social issue		
Nigeria	Society		
Number	socio scientific issue		
Paper	socioscientific issue		
Person	Ssi		
Policy	Student		
Political science	Teacher		
Poverty			
Quality			
Risk			
Social			
social capital			
social network			
social policy			
social problem			
social science research			
social security			
social security administration			
social work			
Socio			
Ssa			
ssa country			
sub saharan Africa			
Survey			
Theory			

united states
Woman
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Year

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3.2 Network Visualization: Thematic Structure of SSI Research

Network visualization maps the structural configuration and conceptual proximity of terms within the dataset, providing insights into how disparate domains interface with one another. The network analysis yields a total of 4,506 links with a cumulative link strength of 1,279.

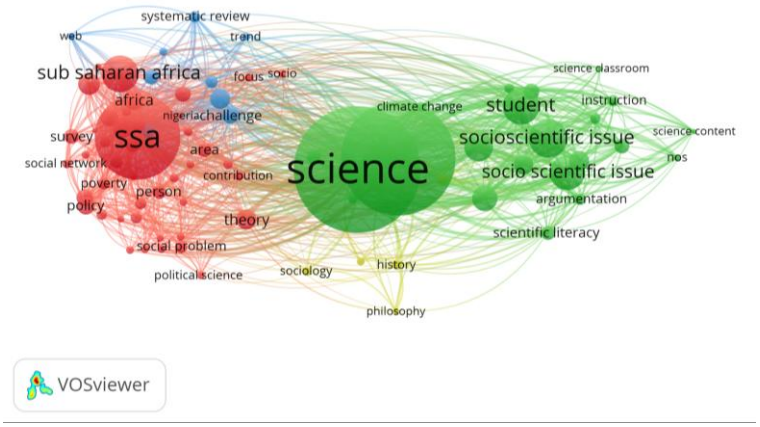

Figure 9: Conceptual network layout of SSI research domains.

Within this structural network, "Science Education" serves as the central coordinating node that tethers the social-policy dimensions of Cluster 1 to the foundational and applied domains. Empirical literature demonstrates that when science education acts as the central hub, it successfully shifts from isolated scientific facts to a relational framework that connects scientific knowledge with socio-ethical realities (Sadler, 2009; Zeidler et al., 2005). The thickest linkages appear between "Science," "Student," "Socio-Scientific Issue," and "Scientific Literacy," validating that the current structural core of the discipline remains firmly focused on student-centered cognitive development within science classrooms.

3.3 Overlay Visualization: Evolution of Research Trends

The overlay visualization presents the chronological progression of the SSI domain, tracking how thematic nodes have shifted over the decades. The temporal trajectory reveals a clear evolutionary path from abstract conceptualization to applied classroom practices (Hancock et al., 2019; Owens et al., 2021).

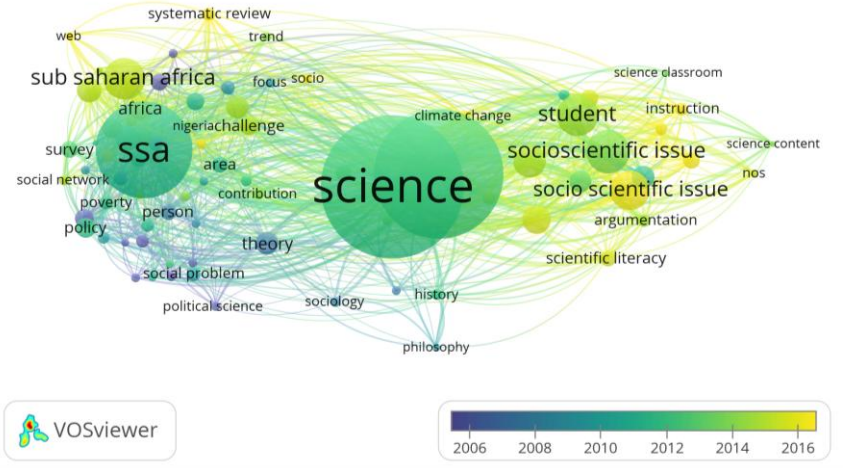

Figure 10: Timeline mapping the evolution of global SSI research trends.

- Early Phase (Blue Spectrum): Dominated by macro-level terms such as *policy*, *social problem*, and *theory*. During this foundational era, scholarship focused on establishing the socio-political boundaries and justification for introducing controversial themes into educational policies.
- Intermediate Phase (Green Spectrum): Marked by the integration of concrete scientific contexts, using terms like *climate change*, *nature of science (NOS)*, and *environmental issues*. Here, the literature focused on linking core scientific curricula with real-world global crises (Georgiou & Kyza, 2023; Klosterman et al., 2012).
- Recent Phase (Yellow Spectrum): Heavily concentrated on micro-level educational deployment, featuring terms such as *student*, *instruction*, *argumentation*, and *classroom practice*. This indicates that contemporary scholarship has reached an active implementation paradigm, emphasizing actionable learning ecosystems and student-centered competencies (Nugroho et al., 2025; Owens et al., 2022).

3.4 Density Visualization: Concentration of Research Topics and Gaps

Density visualization measures the concentration of research attention by calculating the frequency and weight of co-occurring nodes, effectively highlighting over-saturated fields versus underexplored intellectual gaps.

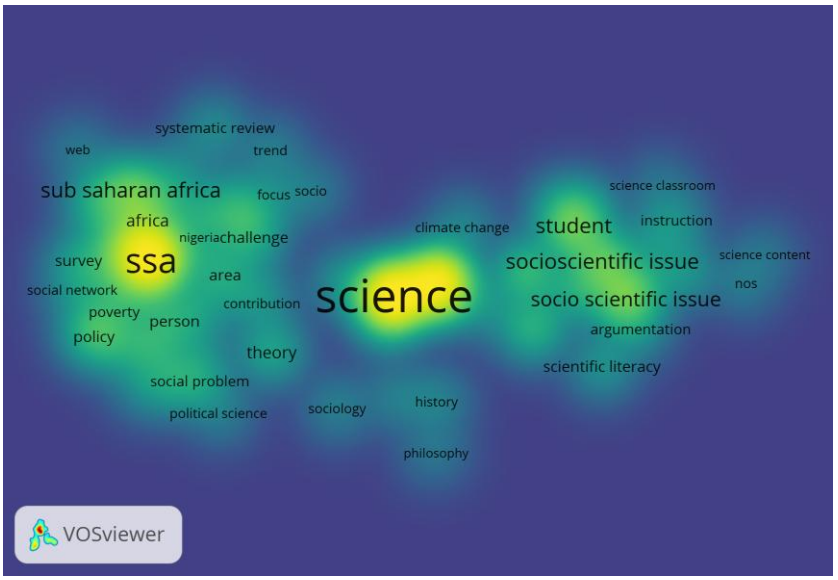

Figure 11: Density matrix illustrating saturated domains versus prominent research gaps.

The density landscape demonstrates an extreme data imbalance. Saturated high-density regions are clustered around *general science themes* and regional descriptive data mappings (e.g., *SSA*). Moderate density is visible around *student learning outcomes* and *argumentation protocols*. Conversely, critical low-density voids appear around the terms *philosophy*, *value*, and *instructional design*. This structural unevenness indicates a major disconnect in the literature: while scholars widely acknowledge the cognitive benefits of SSI, there is a severe shortage of concrete, scalable instructional design models and value-driven frameworks capable of systematically translating these theoretical ideals into everyday classroom practice (Hernández-Ramos et al., 2021; Karakaş, 2022). This gap directly underscores the need to transition toward practice-oriented designs that align with the core mission of the Scholarship of Teaching and Learning (SoTL).

DISCUSSION

The structural configuration of Socio-Scientific Issues (SSI) research, as mapped through the co-occurrence network of 1,000 documents from 1958 to 2026, highlights an epistemic tension between high-density descriptive themes and critical low-density design voids. While the data confirms that science education acts as the primary coordinating hub connecting multi-perspectival domains, this structural integration remains superficial. The close alignment between the concepts of science, students, and socioscientific issues demonstrates that while the field has

successfully moved away from teaching isolated scientific facts, it has hit a roadblock in general descriptive mapping. This data saturation in general science themes reveals a major gap: the literature frequently advocates for the cognitive advantages of SSI—such as argumentation and scientific literacy—but fails to provide the scalable, concrete instructional designs needed to implement them in the classroom. This imbalance directly challenges early foundational frameworks that assumed classroom integration would naturally follow theoretical consensus. Instead, the lack of structured learning models acts as a systemic barrier, leaving practitioners with conceptual justifications but no actionable tools to navigate controversial topics in complex learning environments.

The chronological progression shown in the overlay visualization highlights a clear shift from macro-level socio-political theories to student-centered instructional practices. However, an analysis of this temporal shift reveals an underlying disconnect in how these pedagogical strategies are applied. Contemporary research heavily highlights student outcomes like argumentation protocols and critical decision-making, yet it systematically overlooks the specific instructional processes required to build these skills. This empirical trend presents a clear contradiction to the core tenets of constructivist and argumentation theories, which state that cognitive competencies cannot be separated from the design of their learning environments. By focusing on measuring student outcomes rather than evaluating the instructional interventions themselves, modern scholarship functions as a descriptive evaluator rather than a transformative framework. This gap underscores the urgent need to realign SSI research with the core mission of the Scholarship of Teaching and Learning (SoTL), shifting the focus from simply documenting student literacy levels to engineering and testing adaptive learning systems and context-based curriculum designs.

The low density of terms like philosophy, value, and sociology highlights a significant limitation in how SSI is currently implemented. Although theoretical literature widely defines SSI as ill-structured, controversial challenges that blend science with ethical and social layers, current empirical studies treat SSI primarily as a cognitive tool to boost content retention or basic argumentation skills. This reductionist approach strips SSI of its socio-ethical complexity, turning meaningful real-world controversies into rigid classroom exercises. This trend runs directly counter to advanced holistic frameworks that view moral reasoning and values as essential to functional scientific literacy. The lack of focus on value-based dimensions suggests that modern science education struggles to systematically incorporate ethics into instructional design. To address this, the field needs to move away from purely cognitive metrics and adopt multi-perspectival frameworks that explicitly integrate moral philosophy, risk assessment, and value-driven decision-making into student investigations.

From a pedagogical perspective, this empirical imbalance can be addressed by integrating the concept of *Rahmah* (compassion-driven stewardship) and *Muraqabah* (mindful ethical awareness) into the design of SSI instruction. Incorporating these principles transforms SSI from a standard cognitive exercise into a value-driven framework where scientific inquiry is inherently linked to social responsibility and ethical mindfulness. Under this approach, addressing environmental or socio-scientific crises is no longer just about building technical argumentation skills; it becomes an exercise in *Rahmah*, encouraging students to develop a deep sense of care and stewardship for both communities and ecosystems. At the same time, *Muraqabah* instills a reflective practice within scientific decision-making, prompting students to critically examine the long-term ethical implications of technological and scientific advancements. This dual framework directly targets the low-density voids identified in the literature by providing a clear, value-based foundation for instructional design. Bridging technical expertise with ethical mindfulness allows future research to deliver actionable, context-based learning models that prepare students to navigate complex, real-world challenges with both intellectual clarity and moral responsibility.

CONCLUSION

5.1 Conclusion

1. This study mapped a large-scale dataset of 1,000 documents on Socio-Scientific Issues (SSI) from 1958 to 2026, revealing a robust and expansive intellectual structure that links scientific knowledge with complex real-world

social contexts.

2. Co-occurrence analysis identified 80 highly relevant terms structured into four main thematic clusters representing social-policy issues, science education, conceptual foundations, and methodological approaches, with science education serving as the primary coordinating hub.
3. Overlay visualization demonstrated a distinct chronological transition in the literature, shifting over several decades from macro-level socio-political concepts and early theoretical frameworks toward student-centered instructional practices and active scientific literacy.
4. Density visualization highlighted a significant research gap and thematic imbalance, exposing high data saturation around general descriptive science themes and a severe lack of coverage regarding concrete instructional designs, value-based dimensions, and context-specific classroom applications.
5. In alignment with the pillars of the Scholarship of Teaching and Learning (SoTL), the overall findings reveal that while the field has successfully validated the cognitive outcomes of SSI, it remains fragmented in providing actionable, scalable learning models necessary for practical classroom implementation.

5.2. Suggestions

To address the critical research gaps identified in this study, future research must shift away from general descriptive data mapping and focus on engineering and testing actionable, context-based instructional design models that integrate scientific, social, and ethical dimensions. Scholars should develop structured learning systems that explicitly incorporate value-driven frameworks, risk assessment, and moral philosophy to guide students through ill-structured controversies rather than treating SSI merely as a cognitive tool for content retention. Additionally, future empirical studies should focus on long-term, scalable classroom interventions across diverse learning environments to bridge the gap between pedagogical theory and real-world implementation, while evaluating how digital learning systems or adaptive curriculum designs can support teachers in navigating controversial global topics effectively.

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