Modern Geográfia
Vol. 21, Issue 3, 2026: 43–64
DOI: 10.15170/MG.2026.21.03.03

Naidoo, Shaylen[1]

Planetary Boundaries in the South African School FET Geography Curriculum

ABSTRACT

This study examines the representation of the planetary boundaries framework within the South African Further Education and Training (FET) Phase Geography curriculum. Using a mixed-methods interpretive design combining lexical frequency analysis and critical curriculum interpretation, the research quantified the frequency and co-occurrence of terms associated with the nine planetary boundaries. The findings show that while the curriculum foregrounds sustainability and addresses issues such as freshwater systems and climate, it fails to explicitly embed the scientific concepts that underpin planetary thresholds. Critical domains such as biogeochemical cycles, atmospheric aerosol loading, and ocean acidification are largely absent. Interpreted through a critical curriculum theory lens, these silences restrict learners' capacity to situate local environmental challenges within global systemic risks, thereby undermining the development of transgressive learning and planetary consciousness. The findings contribute to international debates on how geography education can foster planetary literacy and systemic reasoning in diverse educational contexts. The study concludes that explicitly incorporating planetary boundaries and fostering systemic reasoning in learning outcomes would strengthen Geography's role in cultivating the critical knowledge and competencies required to navigate the Anthropocene.

Keywords: planetary boundaries, South Africa, geography, curriculum, environment, sustainable development, education

[1] University Lecturer, The Independent Institute of Education, Emeris Sandton, Faculty of Education, 112 Grayston Drive, Sandton 2196 South Africa, Email: shaynaidoo@emeris.ac.za, https://orcid.org/0000-0001-9291-5176

INTRODUCTION

The urgency of twenty-first-century environmental crises demands educational strategies that cultivate a critical understanding of environmental processes and sustainability challenges (Agbedahin & Lotz-Sisitka, 2019; Steffen et al., 2018; Drijfhout et al., 2015; Gandolfi et al., 2024; Lade et al., 2020; Lovejoy & Nobre, 2018). Anthropogenic impacts on socio-ecological systems require that Geography learners engage with the interconnections between the lithosphere, atmosphere, hydrosphere, and biosphere to understand resource limits and safe operating spaces within the planetary boundaries framework (Enke & Budke, 2023; Lenton et al., 2008; Miao et al., 2022; Mwendwa, 2017; Wittlich et al., 2023; Naidoo & Heath, 2024). This approach situates local issues—such as Cape Town's 'Day Zero' crisis or Vaal River and Baynespruit River eutrophication—within systemic global risks, moving beyond reductionist stewardship discourses to recognise humanity as a constitutive agent of environmental change (Cai et al., 2016; Drijfhout et al., 2015; Feldmann & Levermann, 2015; Zuma, 2017; Gandolfi et al., 2024; Lade et al., 2020; Lovejoy & Nobre, 2018; Sandin et al., 2015; Walker et al., 2019; Ziervogel et al., 2010).

Geography, at the interface of the biophysical and social sciences, is well positioned to develop systemic understanding and planetary consciousness (see Enke & Budke, 2023; Miao et al., 2022; Mwendwa, 2017; Wittlich et al., 2023; Naidoo, 2024; Naidoo & Heath, 2024; Lotz-Sisitka et al., 2021a). Yet the South African school curriculum emphasises anthropocentric framings and underplays integrative ecological reasoning (see Naidoo, 2025; Lotz-Sisitka et al., 2021a). This limits learners' capacity to conceptualise environmental thresholds and systemic risk, undermining engagement with sustainability in the Further Education and Training (FET) Phase (see Lotz-Sisitka et al., 2021b).

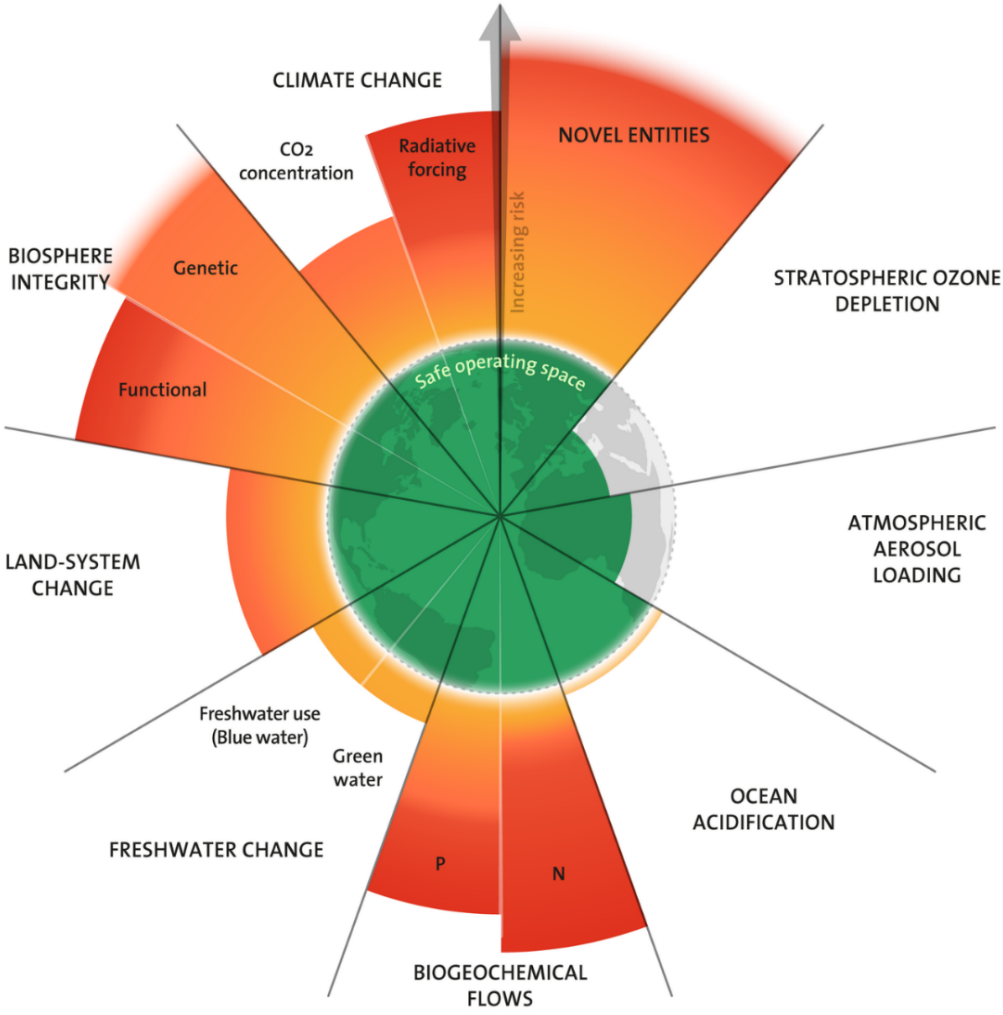
South African learners are disproportionately exposed to environmental crises, including climate instability, water scarcity, biodiversity loss, and land degradation, which exacerbate vulnerabilities in marginalised communities (Kutywayo et al., 2022; UNICEF, 2023). Embedding the planetary boundaries framework introduces scientifically grounded thresholds that define humanity's safe operating space while framing hazards as emergent from complex socio-ecological interactions (Steffen et al., 2015; Steffen et al., 2018; Rockström, 2015; Rockström et al., 2023; 2024). This enables learners to situate local vulnerabilities within global systemic risk and to foster threshold-based reasoning essential for equitable civic engagement and futures-oriented decision-making (Vogel et al., 2015; UNESCO, 2020; IPCC, 2019a). Against this context, the study appraises the Geography FET Curriculum and Assessment Policy Statement (CAPS) document (DBE, 2011) through the planetary boundaries lens. The analysis adopts a progressive learning pathway—from descriptive recognition, through integrative understanding, to threshold-oriented reasoning—to evaluate the curriculum's potential to foster planetary literacy. By examining content and epistemological orientation, the study identifies both silences and possibilities within the curriculum, highlighting its potential to support ecologically grounded and transgressive educational praxis.

LITERATURE REVIEW

Conceptual Foundations of the Planetary Boundaries Framework

The planetary boundaries framework identifies nine Earth system processes whose destabilisation threatens the conditions that support human societies (Steffen et al., 2015; Rockström et al., 2023). These include climate change, biosphere integrity, land-system change, freshwater use, biogeochemical flows, ocean acidification, atmospheric aerosol loading, stratospheric ozone depletion, and novel entities (Richardson et al., 2023; Rogelj et al., 2019). The category of novel entities—synthetic chemicals, plastics, and other anthropogenic compounds—extends beyond conventional pollution by capturing systemic risks whose long-term impacts remain uncertain (Richardson et al., 2023). Each boundary marks a safe operating space; recent assessments show that seven of the nine have already been exceeded, with ocean acidification the most recently transgressed and aerosol loading already breaching regional limits (Richardson et al., 2023). Figure 1 below illustrates the seven crossed boundaries as of 2025, as presented by the Stockholm Resilience Centre at Stockholm University.

Figure 1. The 2025 Update to the Planetary Boundaries.



Source: Azote for Stockholm Resilience Centre, 2025

Biosphere integrity remains of particular concern, with human appropriation of net primary production surpassing the proposed limit. These pressures highlight the need to interpret environmental issues from an interconnected Earth system perspective. In South Africa, pressures on freshwater availability, biodiversity integrity, and climate variability reflect local manifestations of global transgressions (Sinha & Kumar, 2019; Skowno et al., 2021; SANBI, 2018; Engelbrecht et al., 2015). For Geography learners, the framework supports linking local challenges—such as droughts or floods, river eutrophication, and biodiversity loss—to broader systemic risks, thereby fostering systems-based reasoning (Vogel et al., 2015; Lotz-Sisitka et al., 2021a).

International Cases on the Planetary Boundaries Framework in Education

Few national curricula adopt the planetary boundaries framework explicitly, yet its principles appear in Education for Sustainable Development initiatives (UNESCO, 2020; IPCC, 2019a; 2019b). Studies show its value for both higher education and school-level transformation (Leal Filho et al., 2021; Nyerere et al., 2021; Miao et al., 2022; Mwendwa, 2017; Wittlich et al., 2023). European curricula, such as those in France and Spain, include sustainability themes but omit explicit planetary boundary terminology (Enke & Budke, 2023). German cases indicate growing use of planetary health and sustainability frameworks, though again without explicit reference to planetary boundaries (Wittlich et al., 2023). In China and the United States, the emphasis remains on sustainability competencies rather than threshold- or boundary-based reasoning (Miao et al., 2022). Tanzania reflects similar patterns, with environmental education present yet lacking systemic frameworks (Mwendwa, 2017). These examples point to a global gap between policy aspirations and curriculum practice. For South Africa, reform would require a phased progression—from basic recognition of environmental issues to integrative understanding and, ultimately, to threshold-based reasoning in the FET Phase (Shumba et al., 2021).

The Environmental Crisis and Curriculum Reform in South Africa

South Africa illustrates how global boundary transgressions manifest in concentrated form. Freshwater scarcity is acute, demonstrated by the Day Zero crisis in Cape Town and the continued eutrophication of the Vaal River and the Baynespruit River as examples (Ziervogel et al., 2010; Dabrowski & De Klerk, 2013; De Klerk, 2016; Zuma, 2017; Ziervogel, 2019; Mashaba et al., 2025). Biodiversity integrity is also under threat, particularly within the fynbos biome (Ramarumo, 2022; Van Wilgen et al., 2022). Climate change compounds these pressures through rising temperatures and intensified extreme events (Mahlalela et al., 2020; Ndlovu et al., 2021; Engelbrecht et al., 2025). These impacts fall most heavily on marginalised communities, underscoring the ethical need for education that foregrounds socio-ecological justice. Geography education is well placed to support this work, helping learners understand the interconnections between human and physical geography (Lotz-Sisitka et al., 2016, 2021a, 2021b; Naidoo & Heath, 2024; Naidoo, 2024). Rogerson's (2025)

work on Johannesburg's rooftop agriculture illustrates how local socio-ecological practices can be framed within global sustainability transitions. Such studies demonstrate the need for geography education to cultivate spatial and systemic reasoning, enabling learners to recognise how local actions relate to planetary-scale dynamics.

Curriculum Policy Intentions and Pedagogical Practice in South African School Geography

The Geography FET CAPS (DBE, 2011) integrates Theoretical and Applied Geography across Physical and Human Geography topics (Naidoo, 2024). While this structure offers coherence, research identifies gaps in its engagement with the systemic imperatives of Education for Sustainable Development and Education for Climate Change (Lotz-Sisitka et al., 2021; Naidoo & Heath, 2024; Naidoo, 2024; Thenga, 2025). Policy frameworks, including the *National Climate Change Response White Paper* (South Africa, 2011) and the *National Climate Change Adaptation Strategy* (South Africa, 2019), emphasise education's role in building resilience. South Africa's commitments under the United Nations Framework Convention on Climate Change (UNFCCC) *Action for Climate Empowerment* (ACE) framework further require the integration of climate change education into formal schooling (Naidoo & Heath, 2024; Taviv et al., 2008). UNESCO's (2020) *Education for Sustainable Development Roadmap* similarly advocates embedding critical, systemic sustainability into curricula.

Despite these intentions, research highlights disjunctions between policy and practice. Climate change content in CAPS-aligned FET Phase Geography textbooks is often superficial, with limited attention to systems thinking or feedback mechanisms (Thenga, 2025). Pre-service teachers remain insufficiently prepared to address complexity and interdependence, reflecting broader shortcomings in teacher education (Naidoo & Heath, 2024). Geography continues to occupy a peripheral role in international and national sustainability initiatives, despite its potential to advance planetary literacy (Wilmot & Van der Merwe, 2025). Fragmented engagement with sustainability has led to calls for integrating technological tools, including artificial intelligence, to align content with adaptation and sustainability needs (Naidoo, 2024). Transformative pedagogies offer a path forward by embedding ecological systems thinking into the core of teaching practice rather than treating environmental content as supplementary (Lotz-Sisitka et al., 2016; 2024). The *Fundisa for Change* programme demonstrates the potential of professional development to strengthen teacher capacity in Education for Sustainable Development (Lotz-Sisitka et al., 2021a; Schudel et al., 2021; Naidoo & Heath, 2024). Its absence in formal DBE policy, however, underscores the need for systemic alignment between professional development and curriculum reform.

METHODS

Research Design and Methods

This study adopts a mixed-methods interpretivist design that integrates qualitative critical curriculum analysis with quantitative lexical and frequency analysis, emphasising the socially constructed nature of knowledge and the importance of understanding phenomena from the perspectives of the actors and texts involved (Creswell & Poth, 2018). The study employs lexical analysis (Hanks, 2013), a form of quantitative text analysis, to conduct a systematic and critical examination of the South African FET Phase Geography curriculum (DBE, 2011). Grounded in the principles of critical curriculum theory, this methodology is designed to move beyond a simple qualitative reading and provide a data-driven assessment of the curriculum's content (Hanks, 2013). The study triangulated the data with Manning and Schutze's (1999) statistical natural language processing framework to quantitatively analyse word usage and frequency; this approach identifies the prominence of key concepts from the planetary boundaries framework while also revealing underlying conceptual patterns and omissions. This integration of lexical analysis with critical curriculum theory provides a robust and replicable method for evaluating how the curriculum implicitly and explicitly constructs knowledge and values related to planetary sustainability, which is a core goal of critical content analysis (Krippendorff, 2012). While interpretivism underpins the interpretive reading of curriculum discourse, the quantitative lexical analysis provides empirical evidence of conceptual emphasis and silences. This integration of qualitative and quantitative strands is consistent with mixed-methods curriculum research (Creswell & Poth, 2018).

Data Source and Analytical Procedure

The primary data source is the official Geography FET CAPS policy document published by the DBE (DBE, 2011). This document is treated as a data corpus for lexical analysis. The analytical procedure comprised both quantitative and qualitative components, consistent with a mixed-methods interpretive design. The quantitative component entailed a lexical frequency and co-occurrence analysis of the Geography FET CAPS document (DBE, 2011). This analysis systematically quantified the presence and distribution of key terms associated with the nine planetary boundaries and produced graphical representations of their relative frequencies. These data provided an empirical foundation for identifying patterns of conceptual inclusion and omission within the curriculum. The qualitative component, grounded in critical curriculum theory, involved interpretive analysis of the curricular discourse to elucidate the epistemological orientations revealed by the quantitative findings. In this way, the lexical data served as a heuristic tool to guide deeper qualitative interpretation, enabling a dialectical synthesis between measurable textual patterns and their underlying discursive meanings. This integration ensured both methodological triangulation and epistemic coherence in evaluating how the curriculum constructs and legitimises knowledge related to planetary sustainability. The analytical procedure is structured to conduct a systematic lexical analysis of the curriculum document

(Manning & Schutze, 1999; Hanks, 2013). This process involves tokenising the text and quantifying the frequency of terms.

1. Text pre-processing: The document is publicly available in PDF format. Punctuation, numbers, and common English stop words (e.g., 'the,' 'is,' 'and') were removed to focus the analysis on substantive content. The remaining words were lemmatised to their root forms (e.g., 'boundaries' becomes 'boundary') to ensure that all variations of a concept are counted together.
2. Term frequency analysis: A term frequency analysis was performed to quantify the occurrence of key terms within the curriculum (Manning & Schutze, 1999). This analysis was twofold. First, a deductive approach was used, with a pre-defined list of keywords developed from the nine planetary boundaries (viz., climate change; novel entities, e.g., synthetic organic pollutants, radioactive materials, microplastics; stratospheric ozone depletion; atmospheric aerosol loading; ocean acidification; biogeochemical flows, specifically phosphorus and nitrogen cycles; freshwater use; land-system change; and biosphere integrity, including both genetic and functional diversity). The term frequency for each of these terms was calculated to measure the explicit attention given to each boundary within the document. The frequency of these terms provided insight into the curriculum's emphasis on systemic thinking, which is a core component of the planetary boundaries framework.
3. Lexical co-occurrence and collocation: A lexical co-occurrence analysis was conducted to identify how key terms are used in context by examining which words frequently appear near the planetary boundaries keywords. This procedure served two main purposes. First, it helped to evaluate epistemological coherence by determining if Physical Geography terms (e.g., 'climate') and Human Geography terms (e.g., 'society,' 'development') were consistently used together, indicating a systemic or integrated approach to human-environment relationships. Second, it allowed for the assessment of normative dimensions by identifying collocations with ethical terms (e.g., 'stewardship,' 'responsibility') to gauge the curriculum's explicit or implicit attention to ethical considerations.

This procedure provides a quantitative and reproducible method for a critical and systematic assessment of how the curriculum constructs knowledge and values (Hanks, 2013). The use of term frequency and other lexical analysis techniques, as outlined by Papp-Zipernovszky et al. (2022), allows for a direct measurement of the curriculum's focus on key concepts, complementing qualitative insights with empirical data. This approach is well established within content analysis and corpus linguistics for its ability to provide objective, data-driven insights into large textual bodies (Krippendorff, 2012).

RESULTS

Framing of Geography and its Intended Aims

Geography is presented as a discipline concerned with both human and physical environments, united by a spatial perspective. The FET Phase curriculum specifies: "Geography is the study of human and

physical environments. … The concept that unifies Geography is space. All geographical phenomena have a spatial dimension and operate in a continuously changing environment" (DBE, 2011, p. 8).

Alongside this framing, the document explicitly articulates sustainability and environmental responsibility as educational goals. The curriculum mandates "a commitment towards sustainable development … [and] making and justifying informed decisions and judgements about social and environmental issues" (DBE, pp. 8–9). Yet, as the term frequency analysis below demonstrates, these aims are only partially realised in the detailed curricular content.

Quantitative Frequency Distribution of Planetary Boundary Terms (As Part of a Mixed-Methods Analysis)

Figure 2 below shows the frequency at which each of the nine boundaries appeared in the documents after the term frequency analysis was conducted.

Figure 2. Term Frequency of Planetary-Boundary Keywords in the South African FET Geography CAPS (DBE, 2011); n = counts after pre-processing and lemmatisation.

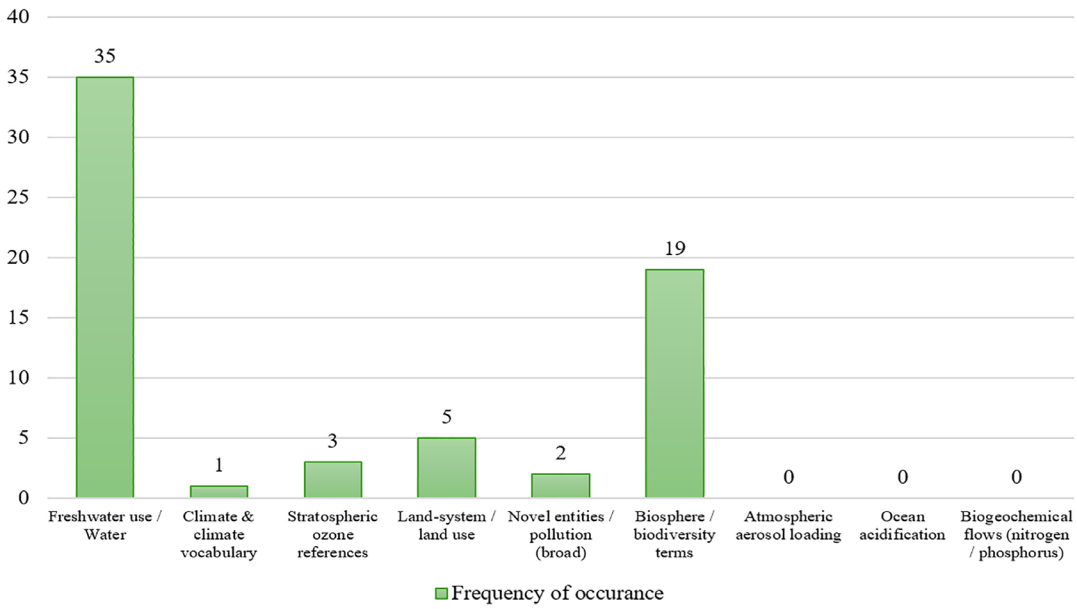
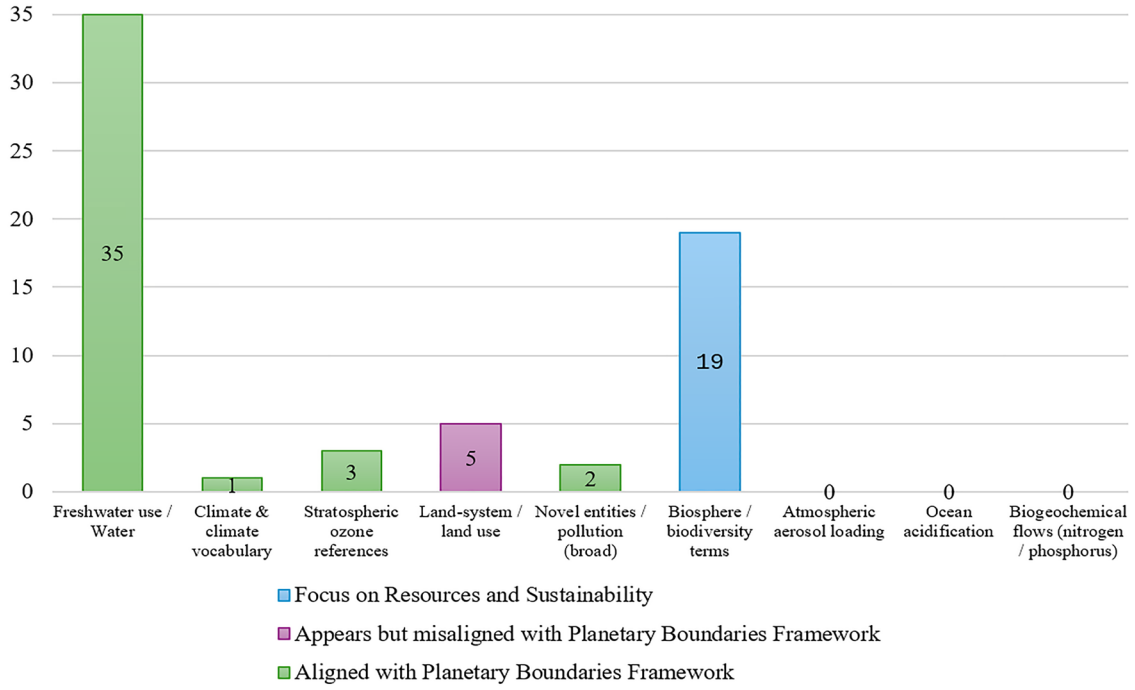


Figure 3 presents the alignment between the observed term occurrences and the planetary boundaries framework. The table indicates that the boundaries relating to freshwater use, climate change, stratospheric ozone depletion, and novel entities show clear correspondence with the wider planetary boundaries discourse. Terms associated with the biosphere, however—largely framed through references to soil—are positioned within a resource- and sustainability-oriented discourse rather than within a systemic understanding of biosphere integrity. Finally, all terms linked to land-system change are misaligned with the planetary boundaries framework, as they are predominantly situated within socio-economic framings rather than ecological or threshold-based conceptualisations.

Figure 3. Alignment of Curriculum Term Occurrences with the Planetary Boundaries Framework



Freshwater Use

Water emerges as one of the most strongly emphasised planetary boundary domains within the curriculum, with a frequency of n = 35 occurrences (DBE, 2011, p. 21). In Grade 10, Term 1, under the topic "The Atmosphere" (DBE, 2011, p. 21), water is introduced as a subtopic, namely "water in the atmosphere in different forms, such as water vapour and liquid" (DBE, 2011, p. 21). Later in the same grade, Term 4, the topic "Water Resources" (DBE, 2011, p. 26) explicitly foregrounds water as a curricular theme. Geography teachers are guided to employ websites such as World Water at http://www.worldwater.org/data.html and the Department of Water Affairs at http://www.dwa.gov.za as supplementary resources to deepen learners' understanding (DBE, 2011, p. 26).

This Term 4 topic is structured around subtopics including "Water in the World: different forms of water in the world: liquid, solid and gas; the hydrological cycle; [and] occurrence of salt water and fresh water: oceans, rivers, lakes, ground water and atmosphere" (DBE, 2011, p. 26). In addition, "Water Management in South Africa: rivers, lakes and dams in South Africa; factors influencing the availability of water in South Africa; challenges of providing free basic water to rural and urban communities in South Africa; the role of government – initiatives towards securing water: inter-basin transfers and building dams; role of municipalities: provision and water purification; and strategies towards sustainable use of water – role of government and individuals" is emphasised (DBE, 2011, p. 26).

At Grade 12 level, Term 1, water reappears under the topic "Geomorphology" (DBE, 2011, p. 43). Teachers are directed to utilise further websites, including the USGS Water Cycle page (USGS, n.d.), the Department of Water Affairs website (DWAF, n.d.), Ritter's *Fluvial Systems – Drainage*

Patterns (Ritter, n.d.), and the *Mass Movements* Slideshare presentation (Slideshare, n.d.), as well as resources on "rivers in the local environment (fieldwork) and GIS" (DBE, 2011, p. 43). Within this topic, the subtopic "Drainage Systems in South Africa" introduces learners to concepts such as "drainage basin, catchment area, river system, watershed, tributary, river mouth, source, confluence, water table, surface run-off and groundwater" (DBE, 2011, p. 43). Furthermore, "Catchment and River Management: importance of managing drainage basins and catchment areas; impact of people on drainage basins and catchment areas; and case study of one catchment area management strategy in South Africa" is explicitly stipulated (DBE, 2011, p. 43).

The curriculum also prescribes assessment integration: the Grade 10 end-of-year examination should include "Section B: Question 3: Short objective type questions for 15 marks to cover content on Population and Water Resources [and] Water resources for 30 marks [and a] Question 4: Short objective type questions for 15 marks to cover content on Population and Water Resources [and] Water resources for 30 marks" (DBE, 2011, p. 56).

Climate Change

Climate change occurs n = 1 time in the curriculum. In Grade 10, Term 1, within the topic "The Atmosphere" (DBE, 2011, p. 21), it appears as "the impact of climate and climate change on Africa's environment and people – deserts, droughts, floods and rising sea levels" (DBE, 2011, p. 21). Although the term itself is rarely used, an implicit connection is drawn through the preceding focus on "the Greenhouse Effect – impact on people and the environment; global warming: evidence, causes, and consequences, with reference to Africa" (DBE, 2011, p. 21). This structuring suggests that climate change is subsumed under broader atmospheric processes rather than treated as a distinct planetary boundary.

Stratospheric Ozone Depletion

Ozone occurs n = 3 times in the curriculum. In Grade 10, Term 1, again under "The Atmosphere" (DBE, 2011, p. 21), learners encounter "the ozone layer – in the stratosphere; causes and effects of ozone depletion; and ways to reduce ozone depletion" (DBE, 2011, p. 21). Within the same subtopic, "Composition and Structure of the Atmosphere," the stratosphere is specifically referenced n = 2 times: "the composition and structure of the atmosphere: troposphere, stratosphere, mesosphere and thermosphere; the ozone layer – in the stratosphere" (DBE, 2011, p. 21). This demonstrates that ozone depletion is recognised explicitly, albeit with limited conceptual extension to systemic planetary implications.

Land-System Change

The term *land* occurs n = 5 times in the curriculum. In Grade 12, Term 2, under the topic "Rural Settlement and Urban Settlement" (DBE, 2011, p. 45), land is referenced through multiple subtopics. These include "land use in rural settlements"; "social justice issues in rural areas, such as access to resources and land reform"; and "internal structure and patterns of urban settlements: land use zones; concept of urban profile; and factors influencing the morphological structure of a city; … and; changing urban patterns and land use in South African cities" (DBE, 2011, p. 45).

Teachers are guided towards the use of additional resources, namely "atlases; media information; http://www.statssa.gov.za; topographic and orthophoto maps; vertical photographs or satellite images (such as Google Earth); and telephone directory for types of economic activities in a settlement" (DBE, 2011, p. 45). The focus here is on socio-economic dimensions of land use rather than the ecological implications of land-system change as a planetary boundary.

Novel Entities

Pollution occurs n = 2 times in the curriculum. In Grade 12, Term 1, under the subtopic "Urban Climates" (DBE, 2011, p. 42), there is reference to the "concept of pollution domes – causes and effects" (DBE, 2011, p. 43). In Grade 10, Term 4, under the subtopic "The World's Oceans," learners encounter the "relationship between oceans and people: pollution, overfishing and desalination" (DBE, 2011, p. 26). Within the Geography FET CAPS document (DBE, 2011), pollution is referenced in limited and localised contexts, yet the planetary boundary of novel entities is entirely absent. The curriculum refers to pollution domes and marine pollution, but these framings correspond to traditional environmental degradation rather than the broader systemic category of novel entities, which includes plastics, synthetic compounds, and persistent organic pollutants. The planetary boundary of novel entities—which differs conceptually from conventional pollution and represents emerging global risks with uncertain ecological outcomes (Richardson et al., 2023; Rockström et al., 2023)—is therefore excluded from the curriculum's epistemic framing. This omission narrows learners' understanding of the complex, globalised nature of anthropogenic environmental change. Critical curriculum theory would interpret this as an ideological narrowing of pollution knowledge, whereby systemic and global threats are excluded from curricular legitimacy.

Biosphere Integrity

Biosphere and *integrity* appear n = 0 times in the curriculum. However, related inferences can be drawn. In Grade 11, Term 4, under the topic "Resources and Sustainability" (DBE, 2011, p. 36), learners are introduced to "concepts of sustainability and sustainable use of resources" (DBE, 2011, p. 36). Soil emerges prominently in this section, with subtopics such as "Soil and Soil Erosion; how soils are formed; soil as a resource; causes of soil erosion: human, animal, physical, and past and present;

evidence of soil erosion in South Africa; effects of soil erosion on people and the environment; and management strategies to prevent and control soil erosion" (DBE, 2011, p. 36).

The Grade 11 end-of-year examination further integrates this emphasis, stipulating: "Section B: Question 3: Short objective type questions for 15 marks to cover content on Development and Resources and sustainability; Development for 30 marks; [and] Resources and sustainability for 30 marks [and a] Question 4: Short objective type questions for 15 marks to cover content on Development and Resources and sustainability; Development for 30 marks; [and] Resources and sustainability for 30 marks" (DBE, 2011, p. 57).

Soil is also foregrounded in Grade 12, Term 3, under the topic "Economic Geography of South Africa" (DBE, 2011, p. 47), specifically in the subtopic "Agriculture" (DBE, 2011, p. 47) as "factors that favour and hinder agriculture in South Africa, such as climate, soil, land ownership and trade" (DBE, 2011, p. 47). Biodiversity—encompassing species, genetic, and functional diversity—is absent. Ecological knowledge is thereby reduced to soil as a resource and soil erosion. This reflects a utilitarian orientation rather than systemic concern for biosphere integrity. In critical curriculum theory terms, the omission constitutes a silence, as biodiversity knowledge is excluded despite its centrality to planetary sustainability.

Biogeochemical Flows

Biogeochemical, *nitrogen*, and *phosphorus* occur n = 0 times in the curriculum. While agriculture and food security are discussed in Grade 12, as "the importance of food security in South Africa – influencing factors; and case studies related to food security in South Africa" (DBE, 2011, p. 47), the underlying scientific cycles that regulate biogeochemical flows are excluded. Teachers are directed to support the topic with resources and content from "food security: http://www.fanrpan.org" (DBE, 2011, p. 47). Learners are therefore not exposed to the notion that human disruption of nitrogen and phosphorus cycles constitutes a planetary boundary. This omission limits systemic comprehension of agricultural-environmental interdependencies.

Ocean Acidification

Acidification occurs n = 0 times in the curriculum. Oceans are taught primarily in Grade 10, Term 3, under the topic "Water Resources," through the subtopic "The World's Oceans: oceans as sources of oxygen, food and energy; ocean circulation – warm and cold currents; ocean currents and their importance for fishing, trade and tourism; relationship between oceans and people: pollution, overfishing and desalination; and strategies for managing the world's oceans" (DBE, 2011, p. 26). In Grade 11, Term 1, oceans are revisited in "The Atmosphere" (DBE, 2011, p. 30), specifically "the role of oceans in climate control in Africa; El Niño and La Niña processes and their effects on Africa's climate" (DBE, 2011, p. 30). Additionally, oceanography appears under "Geographical Skills and Techniques" (DBE, 2011, pp. 29–30), where learners apply GIS to "climatology and meteorology,

as well as oceanography, using satellite images" (DBE, 2011, p. 29). However, the critical planetary concern of ocean acidification is omitted. This represents a major scientific gap in the curricular representation of ocean systems.

Atmospheric Aerosol Loading

Aerosols or equivalent terminology occurs n = 0 times in the curriculum. However, the "importance of the atmosphere; the composition and structure of the atmosphere: troposphere, stratosphere, mesosphere and thermosphere" (DBE, 2011, p. 21) is covered in Grade 10, Term 1, which focuses on the characteristics of the different layers of the Earth's atmosphere. In Grade 12, Term 1, under the subtopic "Urban Climates" (DBE, 2011, p. 42), urban air quality is framed narrowly through "concept of pollution domes – causes and effects" (DBE, 2011, p. 42). Teachers are advised to use supplementary materials such as "atlases; media information; http://www.weathersa.co.za for weather prediction, satellite images and synoptic weather charts; and http://www.weathersa.co.za" (DBE, 2011, p. 41). While this introduces learners to meteorological and climatic resources, aerosols as a systemic planetary boundary remain absent. This omission exemplifies a broader absence of air chemistry systems knowledge within the curriculum.

It is important to note, however, that lexical frequency patterns do not, in themselves, provide definitive evidence of epistemological or ideological intent within the curriculum. While the uneven distribution of planetary-boundary terminology highlights patterns of emphasis and omission, lexical analysis identifies what is present or absent at the level of explicit wording rather than the underlying rationales for those patterns. Accordingly, any interpretive claims emerging from these data should be understood as indicative rather than determinative.

CONCLUSIONS

The curriculum places strong emphasis on freshwater use, while other planetary boundaries—land-system change, biogeochemical flows, ocean acidification, and atmospheric aerosol loading—are absent. This imbalance reflects what Agbedahin and Lotz-Sisitka (2019) identify as uneven embedding of Education for Sustainable Development and Education for Climate Change. The effect is an epistemic narrowing that privileges local, utilitarian framings over the global, systemic dynamics central to the planetary boundaries framework (Richardson et al., 2023; Steffen et al., 2015). Because lexical analysis highlights patterns of presence and absence without revealing curricular intent, the interpretations offered here are analytically informed rather than conclusive. Critical curriculum theory is therefore used to situate these patterns within wider discursive tendencies. The absence of specific terms such as nitrogen, phosphorus, acidification, and aerosols points to more than limited vocabulary, although such gaps must be interpreted cautiously. Read alongside critical curriculum theory, these silences indicate a tendency to privilege certain forms of environmental knowledge, highlighting Lotz-Sisitka et al. (2024, p. 549) call for "more radical learning-centred transformation … in the sustainability

sciences." This reflects broader ideological decisions about which knowledges are legitimised (Sanjakdar & Apple, 2024). Consequently, the Geography FET CAPS (DBE, 2011) reproduces an anthropocentric, resource-based orientation rather than fostering relational understandings suitable for the Anthropocene (Le Grange, 2017; O'Donoghue, 2014).

Climate change receives only a single reference in the curriculum (DBE, 2011), a notable omission given contemporary evidence on tipping points (Lenton et al., 2008; Cai et al., 2016; Drijfhout et al., 2015). Projected warming and increased extremes in Africa (Engelbrecht et al., 2015; Engelbrecht et al., 2025) are not reflected in the curriculum. This limits learners' capacity to grasp non-linear and potentially irreversible Earth system changes (Steffen et al., 2018; Feldmann & Levermann, 2015) and reduces opportunities for anticipatory education relevant to events such as the Durban floods and the Day Zero drought (Enqvist & Ziervogel, 2019; Marcus & Spocter, 2025; Ziervogel, 2019). Although freshwater use is more extensively covered, the framing is predominantly technocratic, focusing on hydrological cycles and fluvial geomorphology. This approach neglects governance and justice dimensions central to South Africa's inequitable water landscape (Enqvist & Ziervogel, 2019; Sinha & Kumar, 2019). Research on land-use impacts (Dabrowski & De Klerk, 2013; De Klerk, 2016; Mashaba et al., 2025) shows that water systems are shaped by social and ecological interactions. These perspectives remain absent, reinforcing the marginalisation of situated knowledge noted by O'Donoghue et al. (2019).

The omissions and selective emphases in the Geography FET CAPS (DBE, 2011) raise the question of how geography education might be reconfigured to prepare learners for planetary challenges. Transgressive learning, as developed by Lotz-Sisitka et al. (2016; 2024), offers one option. It seeks to unsettle dominant epistemologies and promote dialogical, justice-oriented pedagogies that engage directly with socio-ecological crises. Integrating planetary boundaries into the curriculum could help learners situate local issues—such as drought in the Eastern Cape (Mahlalela et al., 2020) or biodiversity loss in the Vhembe Biosphere Reserve (Ramarumo, 2022)—within wider Earth system processes (Rockström et al., 2023; Lade et al., 2020). Comparable work on South African urban and heritage spaces shows the value of linking local socio-spatial dynamics with global systems (Rogerson, 2024), reinforcing the need for curriculum reform that is both contextually grounded and globally oriented.

International research similarly positions geography curricula as important for addressing climate and sustainability challenges (Miao et al., 2022; Enke & Budke, 2023). Yet, South African studies continue to identify gaps in how climate change is presented to school children (Lotz-Sisitka et al., 2021a; Thenga, 2025; Naidoo & Heath, 2024). Learners report concern about climate impacts but lack curricular tools to connect personal experience with systemic change (Kutywayo et al., 2022; UNICEF, 2023). A curriculum structured around planetary boundaries could strengthen alignment with UNESCO's (2020) *Education for Sustainable Development Roadmap* by supporting both understanding and agency. Such engagement is also political. Lotz-Sisitka et al. (2021b) argue for reclaiming education's transformative potential, positioning learners as co-creators of futures rather than passive recipients of content. Embedding justice-oriented and transgressive pedagogies along with the planetary boundaries thinking would enable geography education to contribute to what

Rockström (2015, p. 7) calls a "great transition" towards more sustainable trajectories. Similar gaps appear across European, Asian, and African curricula (Enke & Budke, 2023; Miao et al., 2022; Mwendwa, 2017), underscoring the wider relevance of embedding systemic Earth-system thinking within school geography.

To align geography education with contemporary imperatives, curriculum reform should include explicit learning pathways informed by the planetary boundaries framework. This involves revising policy texts, designing assessments that require integrative analysis, and strengthening teacher education to support systems-oriented pedagogy. South African case studies such as Day Zero, Durban floods, eutrophication of rivers, or invasive species in the fynbos can scaffold learners from basic description to threshold reasoning. Linking sustainability values to measurable Earth-system processes would better equip learners for informed civic participation and futures-oriented decision-making (Rockström, 2015).

The analysis shows that while the Geography FET CAPS addresses climatic systems, hydrospheric processes, and biodiversity, these topics are not framed within a coherent planetary boundaries logic. This limits learners' ability to understand interdependence within Earth systems and reflects a broader epistemic constraint that encourages fragmented knowledge. Nonetheless, the curriculum could foster planetary consciousness if reoriented around planetary boundaries as a conceptual anchor. Such a shift would support the DBE's commitment to responsible citizenship and strengthen South Africa's contribution to global debates on navigating the Anthropocene (Rogerson, 2024; 2025; Marcus & Spocter, 2025).

Finally, while lexical analysis offers systematic insight into explicit content, it cannot reveal the full epistemological or ideological orientations of curriculum design. Interpretive claims therefore draw on wider theoretical frameworks and do not assume authorial intent. The study also does not examine how teachers mediate or adapt the curriculum, nor how learners engage with sustainability concepts. Further research combining textual, classroom-based, and learner-focused inquiry can provide a more comprehensive understanding of how planetary boundaries and Earth-system thinking are enacted in South African geography education.

REFERENCES

Agbedahin, A. V., & Lotz-Sisitka, H. (2019). Mainstreaming education for sustainable development: Elaborating the role of position-practice systems using seven laminations of scale. *Journal of Critical Realism, 18*(2), 103–122. https://doi.org/10.1080/14767430.2019.1602975

Azote for Stockholm Resilience Centre. (2025). *The 2025 update to the Planetary boundaries* [Infographic]. Stockholm Resilience Centre. https://www.stockholmresilience.org/research/planetary-boundaries.html

Cai, Y., Lenton, T. M., & Lontzek, T. S. (2016). Risk of multiple interacting tipping points should encourage rapid CO_2 emission reduction. *Nature Climate Change, 6,* 520–525. https://doi.org/10.1038/nclimate2964

Creswell, J. W., & Poth, C. N. (2018). *Qualitative inquiry & research design: Choosing among five approaches* (4th ed.). SAGE Publications.

Dabrowski, J. M., & De Klerk, L. P. (2013). An assessment of the impact of different land use activities on water quality in the upper Olifants River catchment. *Water SA, 39*(2), 231–244. https://doi.org/10.4314/wsa.v39i2.6

DBE. (2011). *Curriculum and Assessment Policy Statement: Further Education and Training Phase Grades 10–12 Geography.* Government of South Africa. https://www.education.gov.za/LinkClick.aspx?fileticket=sdwEoyM0nY0%3D&tabid=570&portalid=0&mid=1558

De Klerk, A. R. (2016). *A comparative ecotoxicological study of two major South African river systems: A catchment-scale approach for improved risk assessment and environmental management through the integration of abiotic, biotic, biochemical and molecular endpoints* [Doctoral dissertation]. Stellenbosch University. https://core.ac.uk/download/pdf/188223798.pdf

Department of Water Affairs (DWAF). (n.d.). *South African rivers.* http://www.dwaf.gov.za

Drijfhout, S., Bathiany, S., Beaulieu, C., Brovkin, V., Claussen, M., Huntingford, C., Scheffer, M., Sgubin, G., & Swingedouw, D. (2015). Catalogue of abrupt shifts in Intergovernmental Panel on Climate Change climate models. *Proceedings of the National Academy of Sciences, 112*(43), 5777–5786. https://doi.org/10.1073/pnas.1511451112

Engelbrecht, F. A., Steinkopf, J., Chang, N., Biskop, S., Malherbe, J., Engelbrecht, C. J., Grab, S., le Roux, A., Vogel, C., Padavatan, J., & Thatcher, M. (2025). Extreme event attribution using km-scale simulations reveals the pronounced role of climate change in the Durban floods. *Communications Earth & Environment, 6*(1), 506. https://doi.org/10.1038/s43247-025-02460-5

Engelbrecht, F., Adegoke, J., Bopape, M. J., Naidoo, M., Garland, R., Thatcher, M., McGregor, J., Katzfey, J., Werner, M., Ichoku, C., & Gatebe, C. (2015). Projections of rapidly rising surface temperatures over Africa under low mitigation. *Environmental Research Letters, 10*(8), 085004. https://doi.org/10.1088/1748-9326/10/8/085004

Enke, K. A., & Budke, A. (2023, August). Preparing students for a changing world: How geography curricula in Europe are tackling climate change. *Frontiers in Education, 8,* 1216780. https://doi.org/10.3389/feduc.2023.1216780

Enqvist, J. P., & Ziervogel, G. (2019). Water governance and justice in Cape Town: An overview. *Wiley Interdisciplinary Reviews: Water, 6*(4), e1354. https://doi.org/10.1002/wat2.1354

Feldmann, J., & Levermann, A. (2015). Collapse of the West Antarctic Ice Sheet after local destabilization of the Amundsen Basin. *Proceedings of the National Academy of Sciences, 112*(46), 14191–14196. https://doi.org/10.1073/pnas.1512482112

Gandolfi, H. E., Rushton, E. A., Silva, L. F., & da Silva Carvalho, M. B. S. (2024). Teacher educators and environmental justice: Conversations about education for environmental justice between science and geography teacher educators based in England and Brazil. *Cultural Studies of Science Education, 19*(2), 257–286. https://doi.org/10.1007/s11422-024-10212-8

Hanks, P. (2013). *Lexical analysis: Norms and exploitations.* MIT Press.

IPCC. (2019a). *Global warming of 1.5°C.* IPCC. https://www.ipcc.ch/site/assets/uploads/sites/2/2022/06/SR15_Full_Report_HR.pdf

IPCC. (2019b). *Special report on the ocean and cryosphere in a changing climate.* IPCC. https://www.ipcc.ch/srocc/

Krippendorff, K. (2012). *Content analysis: An introduction to its methodology* (4th ed.). SAGE Publications.

Kutywayo, A., Chersich, M., Naidoo, N. P., Scorgie, F., Bottoman, L., & Mullick, A. (2022). Climate change knowledge, concerns and experiences in secondary school learners in South Africa. *Jàmbá: Journal of Disaster Risk Studies, 14*(1), a1162. https://journals.co.za/doi/abs/10.4102/jamba.v14i1.1162

Lade, S. J., Steffen, W., De Vries, W., Carpenter, S. R., Donges, J. F., Gerten, D., Hoff, H., Newbold, T., Richardson, K., & Rockström, J. (2020). Human impacts on planetary boundaries amplified by Earth-system interactions. *Nature Sustainability, 3*(2), 119–128. https://doi.org/10.1038/s41893-019-0454-4

Le Grange, L. (2017). Environmental education after sustainability. In *Post-sustainability and environmental education: Remaking education for the future* (pp. 93–107). Springer International Publishing. https://doi.org/10.1007/978-3-319-51322-5_7

Leal Filho, W., Sima, M., Sharifi, A., Luetz, J.M., Salvia, A.L., Mifsud, M., Olooto, F.M., Djekic, I., Anholon, R., Rampasso, I. and Kwabena Donkor, F. (2021). Handling climate change education at universities: An overview. *Environmental Sciences Europe, 33*(1), 1–19. https://doi.org/10.1186/s12302-021-00552-5

Lenton, T. M., Held, H., Kriegler, E., Hall, J. W., Lucht, W., Rahmstorf, S., & Schellnhuber, H. J. (2008). Tipping elements in the Earth's climate system. *Proceedings of the National Academy of Sciences, 105*(6), 1786–1793. https://doi.org/10.1073/pnas.0705414105

Lotz-Sisitka, H., Ali, M.B., Mphepo, G., Chaves, M., Macintyre, T., Pesanayi, T., Wals, A., Mukute, M., Kronlid, D., Tran, D.T. and Joon, D. (2016). Co-designing research on transgressive learning in times of climate change. *Current Opinion in Environmental Sustainability, 20*(1), 50–55. https://doi.org/10.1016/j.cosust.2016.04.004

Lotz-Sisitka, H., Le Grange, L., & Mphepo, G. (2024). Engaged sustainability science and place-based transgressive learning in higher education. *South African Journal of Science, 120*(9/10). https://www.ajol.info/index.php/sajsci/article/view/280729

Lotz-Sisitka, H., Mandikonza, C., Misser, S., & Thomas, K. (2021a). Making sense of climate change in a national curriculum. In I. Schudel, I., Songqwaru, Z., & Tshiningayamwe, S. (Eds.), *Teaching and learning for change* (1st ed., pp. 92–111). African Minds. http://hdl.handle.net/10962/435193

Lotz-Sisitka, H., Rosenberg, E., & Ramsarup, P. (2021b). Environment and sustainability education research as policy engagement: (Re-)invigorating 'politics as potential' in South Africa. *Environmental Education Research, 27*(4), 525–553. https://doi.org/10.1080/13504622.2020.1759511

Lovejoy, T. E., & Nobre, C. (2018). Amazon tipping point. *Science Advances, 4,* eaat2340. https://doi.org/10.1126/sciadv.aat2340

Mahlalela, P. T., Blamey, R. C., Hart, N. C. G., & Reason, C. J. C. (2020). Drought in the Eastern Cape region of South Africa and trends in rainfall characteristics. *Climate Dynamics, 55*(9), 2743–2759. https://doi.org/10.1007/s00382-020-05413-0

Manning, C., & Schütze, H. (1999). *Foundations of statistical natural language processing.* MIT Press.

Marcus, T., & Spocter, M. (2025). Citizen concerns about and responses to the water crisis in a high-income suburb in Cape Town, South Africa. *Modern Geográfia, 20*(3), 127–146. https://doi.org/10.15170/MG.2025.20.03.07

Mashaba, P. N., Myburgh, W. J., & Panagos, M. D. (2025). Spatio-temporal changes in the riparian vegetation associated with the Grassland Biome section of the Olifants River, Mpumalanga, South Africa. *Water SA, 51*(3), 215–227. https://doi.org/10.17159/wsa/2025.v51.i3.4114

Miao, S., Meadows, M. E., Duan, Y., & Guo, F. (2022). How does the geography curriculum contribute to education for sustainable development? Lessons from China and the USA. *Sustainability, 14*(17), 10637. https://doi.org/10.3390/su141710637

Mwendwa, B. (2017). Learning for sustainable development: Integrating environmental education in the curriculum of ordinary secondary schools in Tanzania. *Journal of Education for Sustainable Innovation*, *3*,(1), 76-86. https://doi.org/10.56916/jesi.v3i1.1174

Naidoo, S. (2024). Imagining a South African climate change adaptation-aligned school curriculum using generative artificial intelligence. *Journal of Geography Education in Africa, 7,* 117–140. https://doi.org/10.46622/jogea.v7i1.5427

Naidoo, S. (2025). Non-representational theory in the South African Geography FET CAPS. *African Journal of Teacher Education and Development, 4*(1), a105. https://doi.org/10.4102/ajoted.v4i1.105

Naidoo, S., & Heath, G. (2024). Representation of climate change adaptation in Geography Education modules at the University of KwaZulu-Natal (UKZN). *Journal of Geography Education in Africa, 7,* 41–61. https://doi.org/10.46622/jogea.v7i1.4991

Ndlovu, M., Clulow, A. D., Savage, M. J., Nhamo, L., Magidi, J., & Mabhaudhi, T. (2021). An assessment of the impacts of climate variability and change in KwaZulu-Natal Province, South Africa. *Atmosphere, 12*(4), 427. https://doi.org/10.3390/atmos12040427

Nyerere, J., Kapfudzaruwa, F., Fadairo, O., Odingo, A., Manchisi, J., & Kudo, S. (2021). Higher education and the Education for Sustainable Development in Africa (ESDA) programme. In *Sustainable development in Africa: Fostering sustainability in one of the world's most promising continents* (pp. 179–199). Springer. https://doi.org/10.1007/978-3-030-74693-3_11

O'Donoghue, R. (2014). Re-thinking education for sustainable development as transgressive processes of educational engagement with human conduct, emerging matters of concern and the common good. *Southern African Journal of Environmental Education, 30*(7), 7–26. https://doi.org/10.4314/sajee.v30i0.121961

O'Donoghue, R., Kibuka-Sebitosi, E., Tshiningayamwe, S., & Palmer, C. (2019). Navigating non-sense by exemplifying situated life experience and intergenerational heritage knowledge in Education for Sustainable Development learning spaces. *Southern African Journal of Environmental Education, 35.* http://hdl.handle.net/10962/388122

Papp-Zipernovszky, O., Mangen, A., Jacobs, A., & Lüdtke, J. (2022). Shakespeare sonnet reading: An empirical study of emotional responses. *Language and Literature*, *31*(3), 296-324. https://doi.org/10.1177/09639470211054647

Ramarumo, L. J. (2022). *Threatened plant species in Vhembe Biosphere Reserve, Limpopo Province, South Africa: Problems and prospects of conservation and utilisation* [Doctoral dissertation]. University of Fort Hare. https://core.ac.uk/download/pdf/539813088.pdf

Richardson, K., Steffen, W., Lucht, W., Bendtsen, J., Cornell, S. E., Donges, J. F., Drüke, M., Fetzer, I., Bala, G., von Bloh, W., Feulner, G., Fiedler, S., Gerten, D., Gleeson, T., Hofmann, M., Huiskamp, W., Kummu, M., Mohan, C., Nogués-Bravo, D., Petri, S., Porkka, M., Rahmstorf, S., Schaphoff, S., Thonicke, K., Tobian, A., Virkki, V., Wang-Erlandsson, L., Weber, L., & Rockström, J. (2023). Earth beyond six of nine planetary boundaries. *Science Advances, 9*(37), eadi8005. https://doi.org/10.1126/sciadv.adh2458

Ritter, M. (n.d.). *Drainage patterns*. University of Wisconsin – Stevens Point. http://www.uwsp.edu/geo/faculty/ritter/geog101/textbook/fluvialsystems/drainage_patterns.html

Rockström, J. (2015). Bounding the planetary future: Why we need a great transition. *Great Transition Initiative, 9,* 1–13.

Rockström, J., Donges, J. F., Fetzer, I., Martin, M. A., Wang-Erlandsson, L., & Richardson, K. (2024). Planetary boundaries guide humanity's future on Earth. *Nature Reviews Earth & Environment, 5*(11), 773–788. https://doi.org/10.1038/s43017-024-00597-z

Rockström, J., Gupta, J., Qin, D., Lade, S. J., Abrams, J. F., Andersen, L. S., Armstrong McKay, D. I., Bai, X., Bala, G., Bunn, S. E., Ciobanu, D., & Richardson, K. (2023). Safe and just Earth system boundaries. *Nature, 619*(7968), 102–111. https://doi.org/10.1038/s41586-023-06083-8

Rogelj, J., Forster, P. M., Kriegler, E., Smith, C. J., & Séférian, R. (2019). Estimating and tracking the remaining carbon budget for stringent climate targets. *Nature, 571*(7765), 335–342. https://doi.org/10.1038/s41586-019-1368-z

Rogerson, C. M. (2024). *Planning Urban Regeneration through Heritage Tourism: The Case of Kliptown, South Africa. Modern Geográfia, 19*(2), 71–89. https://doi.org/10.15170/MG.2024.19.02.05

Rogerson, J. M. (2025). *Rooftop Agriculture in the Urban Global South: The Experience of Johannesburg. Modern Geográfia, 20*(2), 1–19. https://doi.org/10.15170/MG.2025.20.02.01

SANBI. (2019). *National Biodiversity Assessment 2018: The status of South Africa's ecosystems and biodiversity. Synthesis report for policymakers and business.* SANBI. https://www.sanbi.org/wp-content/uploads/2024/06/2019_NBA-Synthesis-report.pdf

Sandin, G., Peters, G. M., & Svanström, M. (2015). Using the planetary boundaries framework for setting impact-reduction targets in LCA contexts. *The International Journal of Life Cycle Assessment, 20*(12), 1684–1700. https://doi.org/10.1007/s11367-015-0984-6

Sanjakdar, F., & Apple, M. W. (2024). *Engaging critical pedagogy in education.* Routledge. https://api.taylorfrancis.com/content/books/mono/download?identifierName=doi&identifierValue=10.4324/9781003307570&type=googlepdf

Schudel, I., Lotz-Sisitka, H., Songqwaru, Z., & Tshiningayamwe, S. (2021). Engaging Education for Sustainable Development as quality education in the Fundisa for Change programme. In I. Schudel, I., Songqwaru, Z., & Tshiningayamwe, S. (Eds.), *Teaching and learning for change* (pp. 3–21). African Minds. http://hdl.handle.net/10962/435031

Shumba, O., Mandikonza, C., & Lotz-Sisitka, H. (2021). Advancing assessment thinking in education for sustainable development with a focus on significant learning processes. In I. Schudel, I., Songqwaru, Z., & Tshiningayamwe, S. (Eds.), *Teaching and learning for change* (pp. 201–222). African Minds. http://hdl.handle.net/10962/435031

Sinha, P., & Kumar, R. (2019). A review on management of water resources in South Africa. *International Journal of Conservation Science, 10*(4), 821–840. https://ijcs.ro/public/IJCS-19-74_Sinha.pdf

Skowno, A. L., Jewitt, D., & Slingsby, J. A. (2021). Rates and patterns of habitat loss across South Africa's vegetation biomes. *South African Journal of Science, 117*(1–2), 1–5. https://doi.org/10.17159/sajs.2021/8182

Slideshare. (n.d.). *Mass movements.* http://www.slideshare.net/migratorycoconut/chapter-81-massmovements

South Africa. (2011). *National Climate Change Response White Paper* [White paper]. Government Printers. https://www.gov.za/sites/default/files/gcis_document/201409/nationalclimatechangeresponsewhitepaper0.pdf

South Africa. (2019). *National Climate Change Adaptation Strategy.* Government Printers. https://www.dffe.gov.za/sites/default/files/docs/nationalclimatechange_adaptationstrategy_uel0november2019.pdf

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., Biggs, R., Carpenter, S. R., De Vries, W., De Wit, C. A., & Folke, C. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science, 347*(6223), 1259855. https://doi.org/10.1126/science.1259855

Steffen, W., Rockström, J., Richardson, K., Lenton, T. M., Folke, C., Liverman, D., Summerhayes, C. P., Barnosky, A. D., Cornell, S. E., Crucifix, M., & Donges, J. F. (2018). Trajectories of the Earth System in the Anthropocene. *Proceedings of the National Academy of Sciences, 115*(33), 8252–8259. https://doi.org/10.1073/pnas.1810141115

Taviv, R., Mwakasonda, S., & Witi, J. (2008, October 1–3). Developing the greenhouse gas inventory for South Africa [Conference presentation]. 16th Annual International Union of Air Pollution

Prevention and Environmental Protection Associations Regional Conference, Nelspruit, South Africa. http://hdl.handle.net/10204/2502

Thenga, M. (2025). Barriers and opportunities in implementing climate change education in the FET Phase Geography curriculum in South Africa. *Journal of Geography Education in Africa, 8,* 1–15. https://doi.org/10.46622/jogea.v8i1.5382

UNESCO. (2020). *Education for sustainable development: A roadmap.* UNESCO Publishing. https://unesdoc.unesco.org/ark:/48223/pf0000374802

UNICEF. (2023). *Climate, energy and environment landscape analysis for children in South Africa (CEELAC).* UNICEF South Africa. https://www.unicef.org/southafrica/media/8536/file/ZAF-climate-energy-environment-landscape-analysis-children-SA-2023.pdf

USGS. (n.d.). *The water cycle*. https://ga.water.usgs.gov/edu/watercycle.html

Van Wilgen, N. J., Faulkner, K. T., Robinson, T. B., South, J., Beckett, H., Janion-Scheepers, C., Measey, J., Midgley, G. F., & Richardson, D. M. (2022). Climate change and biological invasions in South Africa. In *Invasive species and global climate change* (pp. 158–187). CABI. doi:10.1079/9781800621459.0009

Vogel, C., Schwaibold, U., & Misser, S. (2015). Teaching and learning for climate change – the role of teacher materials and curriculum design in South Africa. *Southern African Journal of Environmental Education, 31*(2), 78–97. https://scispace.com/pdf/teaching-and-learning-for-climate-change-the-role-of-teacher-3bocyh9s2u.pdf

Walker, X. J., Baltzer, J. L., Cumming, S. G., Day, N. J., Ebert, C., Goetz, S., Johnstone, J. F., Potter, S., Rogers, B. M., Schuur, E. A., & Turetsky, M. R. (2019). Increasing wildfires threaten historic carbon sink of boreal forest soils. *Nature, 572*(7770), 520–523. https://doi.org/10.1038/s41586-019-1474-y

Wilmot, D., & Van der Merwe, C. D. (2025). South African Geography educators' contributions to Geography Education: A perspective from the 35th International Geographical Congress, Dublin City University, Ireland, August 2024. *Journal of Geography Education in Africa, 8,* 33–47. https://doi.org/10.46622/jogea.v8i1.5434

Wittlich, C., Mönter, L., & Lathan, H. (2023). Planetary health and Education for Sustainable Development: An integrative approach with focus on climate change-related human health risks and their thematisation in school contexts. *Journal of Education for Sustainable Development, 17*(2), 200–217. https://doi.org/10.1177/09734082241238087

Ziervogel, G. (2019). Unpacking the Cape Town drought: Lessons learned (pp. 1–29). African Centre for Cities. https://www.africancentreforcities.net/wp-content/uploads/2019/02/Ziervogel-2019-Lessons-from-Cape-Town-Drought_A.pdf

Ziervogel, G., Shale, M., & Du, M. (2010). Climate change adaptation in a developing country context: The case of urban water supply in Cape Town. *Climate and Development, 2*(2), 94–110. https://doi.org/10.3763/cdev.2010.0036

Zuma, V. T. (2017). *Determination and characterisation of trace metals and persistent organic pollutants in Baynespruit River, Sobantu, KwaZulu-Natal, South Africa* [Unpublished doctoral thesis]. University of South Africa. https://ir.unisa.ac.za/handle/10500/23624