

Recontextualizing the School Life Sciences Curriculum after Meeting Sustainability Science

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Abstract

In this article, the authors analyze the extent to which sustainability science subject matter is reflected in the Life Sciences school curriculum in South Africa. The authors used Bernstein's theory of the pedagogic device and key topics derived from the literature on sustainability science to frame the analysis. Document analysis was the method used to conduct a content analysis of the Curriculum Policy and Assessment (CAPS) document for Life Sciences. The results showed that although coverage is not extensive, some sustainability science topics are found in the prescribed Life Sciences curriculum, which teachers can use to address sustainability in the classroom. However, many more sustainability science topics should be included. The findings provide useful information for policymakers, teacher educators, resource developers, and schoolteachers. This analysis was limited to Bernstein's fields of recontextualization and production. Further research on reproduction is required to gain insight into what teachers do in classrooms when including sustainability science.

Keywords: Bernstein's pedagogic device, Life Sciences, school curriculum, sustainable development goals, sustainability science.

Introduction

Since the inception of biology as a school subject there has been an ongoing debate as to whether school biology should emphasize a *science of life* or a *science of living* approach. The former relates to the knowledge aim and the latter to the personal/social aim of school biology. Bybee (1977) argued that the history of school biology has been characterized by changing emphasis among three primary aims: the *knowledge aim*, the *methods aim* and the *personal/social aim*. According to Le Grange (2008) biology as a *science of life* comprises the theoretical, conceptual and procedural understanding of life, whereas biology as a *science of living* has a stronger human-centered approach, focusing on how biological issues have an impact on human life. For us, biology as a *science of living* does not only refer to how biology relates to human needs but also

about what humans positively do in the interest of the environment. The history of school biology in Britain and the USA shows that the utilitarian value/potential of the subject played a prominent role in its birth and growth, although in the USA it was mainly for personal/social relevance whereas in Britain also for economic utility. According to Rosenthal & Bybee (1984, p. 124), the question of whether school biology should be a *science of life* or a *science of living* remains unresolved, swinging the pendulum to extremes in school biology. We contend that this remains the case and with deepening environmental destruction, the pendulum might need to swing to a *science of living* approach.

The unprecedented levels of environmental and societal problems, many captured in the United Nations' seventeen Sustainable Development Goals (SDGs), might necessitate a stronger focus on biology as the *science of living*. This would mean greater emphasis placed on curriculum topics that align with sustainability, which we shall return to later in the article. In response to the complex, wicked problems facing people and the planet, the boundaries of academic disciplines have become more permeable, with some losing coherence, opening pathways for the development of interdisciplinary, multi-disciplinary and transdisciplinary fields (Le Grange, 2017). With growing prominence given to sustainability over the past five decades a new interdisciplinary/transdisciplinary field has developed called Sustainability Science (SS). SS draws on insights from the natural, social, and humanities sciences to produce knowledge that offers responses to the complex challenges confronting people/planet. It emphasises the interaction between economic, social and ecological systems to address sustainability challenges.

The purpose of this article is to evaluate the extent to which the school Life Sciences curriculum in South Africa includes sustainability science topics. Life Sciences replaced Biology as the name given to the school subject that involves the study of living organisms and their environments. In the Curriculum Policy and Assessment Statement (CAPS) for Life Sciences Grades 10-12, Life Sciences is defined as follows: "Life Sciences' is the scientific study of living things from molecular level to their interactions with one another and their environments" (DBE, 2011, p.8). We divide the rest of the article into the following sections. First, we discuss the theoretical framework, which is Bernstein's (1990) theory of the pedagogic device. Second, we discuss the emergence of Sustainability Science as an interdisciplinary/transdisciplinary field. Third, we briefly describe document analysis as the method used to analyze the Life Science curriculum document. Fourth, we analyze the CAPS document for Life Sciences to ascertain the extent to which the subject matter content includes sustainability science topics. Finally, we share some concluding comments with recommendations for further research.

Bernstein's Pedagogic Device

We use Bernstein's (1990) theory of the pedagogic device as a lens to examine the adoption of sustainability science in the Life Sciences Curriculum Policy and Assessment Statement (CAPS) for Grades 10-12 in South Africa. Bernstein's theory of the pedagogic device provides a framework for understanding how the transformation and transmission of knowledge occurs within education systems. His pedagogic device comprises the following interrelated fields: *field of production*; *field of recontextualization*; and *field of reproduction*. The *field of production* is where new knowledge is generated by academics and other knowledge workers. It involves the

generation of new ideas, theories and forms of inquiry. In the case of the Life Sciences, new knowledge has been traditionally produced in disciplines such as Zoology, Botany, Physiology, Anatomy, Genetics, Biochemistry and Ecology. However, we are witnessing traditional disciplines lose their coherence and are no longer able to singularly address the complex, wicked problems confronting the challenges faced by people and the planet (Le Grange, 2007). The upshot of this is the emergence of interdisciplinary, multi-disciplinary and transdisciplinary fields. For this article, we shall focus on the transdisciplinary field called sustainability science.

The *field of recontextualization* involves the process of selecting and adapting content from the *field of production* and determining what knowledge would be appropriate to suit the needs of school learners. In other words, knowledge from the *field of production* is selected, adapted, modified and transformed into a pedagogical discourse. In many education systems across the world this work is done by curriculum developers situated in national or state departments/ministries of education. In South Africa, for example, the CAPS is an outcome of such a process. Other agents in the *field of recontextualization* are textbook writers and lecturers involved in initial teacher education (Hordern, 2020). Although not the focus of this article, we wish to point out that Bernstein (1999, 2000) was concerned about how inequalities could be exacerbated in this field because of disparate access to quality curriculum materials and resources, which disadvantages working-class learners. Our interest is to examine to what extent sustainability science topics have featured in the *field of recontextualization* with respect to school Life Sciences in South Africa. Put differently, we wish to know whether transformation (from disciplines to transdisciplinarity) witnessed in the *field of production* is evident in the *field of recontextualization*.

The *field of reproduction* concerns what is transmitted to learners by teachers in classrooms – what knowledge teachers make accessible to learners. What is focused on in this field is what knowledge is taught, learned and assessed. Our focus in this article is on the first two fields (production and recontextualization) but will note some important implications for the *field of reproduction*, which cannot be separated from the other two. The *field of reproduction* contributes to the reproduction of inequalities in education and society if there are disparities in the quality of teachers, materials and resources.

Studies have been conducted on Bernstein's theory of the pedagogic device in other school subjects such as History (Bertram, 2012), and Physical Education (Ekberg, 2021). We focus on the school subject Life Sciences (Biology in many countries), with a particular focus on the inclusion of sustainability science in the *field of recontextualization*.

The Emergence of Sustainability Science

The roots of Sustainability Science (SS) lie in sustainability- or sustainable development-related academic efforts to reconcile environmental conservation and development. Its emergence began in the 1980s, where pioneering efforts included the World Conservation Strategy (IUCN, 1980), the Brundtland Commission report on sustainable development, *Our Common Future* (WCED, 1980), and the US National Academy of Sciences report, *Our Common Journey* (which incorporated science content) (NRC, 1999). The sustainability science section on the website of the Proceedings of the National Academy of Sciences USA (PNAS) comprises various sustainability-focused research articles that were revised by Kates (2017), and it

establishes seven core research questions for SS. Authors from different regions have published thousands of papers since the rise of the discourse on sustainability and/or sustainable development, during which Sustainability Science emerged (Kates, 2017). Furthermore, journals such as *Sustainability Science* and *Sustainability* have been launched in the past 20 years, and associations created, for example, the International Society for Sustainability Science (Fang et al., 2018).

Sustainability Science (SS) is a transdisciplinary field of study with a focus on understanding and addressing complex and interconnected environmental, social and economic sustainability challenges. This field of study emerged in response to the realization that conventional disciplinary approaches frequently prove inadequate in addressing sustainability challenges that are often complex and multifaceted. SS aims to contextualize society through research on sustainability and education programmes (Spangenberg, 2011; Salovaara, Soini and Pietikäinen, 2019) and encompasses both basic and applied research in a transgressive manner, focusing on societal transformation through contextualization of society to affect systemic change (Salovaara, Soini and Pietikäinen, 2019). Even though the two systems are complex, non-linear and strongly interlinked, Jerneck et al. (2011) explain the difference between nature and society, a key interaction of SS. Fundamental natural principles, such as gravity, natural selection and thermodynamics drive natural systems, whereas dynamics such as demography, power struggles, inequality, ideology, specialization, institutionalization, competition, capital accumulation and technological advances drive social systems (Jerneck et al., 2011). Anthropologically, social systems are politicized and goal-driven, whereas natural systems have no purpose; therefore, a distinction between natural and social systems is intentional (Jerneck et al., 2011).

As a nature-society system, questions are posed on the long-term trends and transitions providing directions for this century, the system's adaptability, vulnerability, and resilience and how models and theory can be better formulated to account for variation in nature-society interactions (Kates, 2017). SS presupposes the tradeoffs between the natural environment and human well-being, aims to define possible measurable thresholds providing effective warning against harmful impacts on nature-society systems and determines how a sustainable transition could be most effectively guided. The final focus pertains to how sustainability of alternative environmental and developmental pathways can be evaluated (Kates, 2017). Collaboration on SS has resulted in the emergence of inter-diverse research clusters, namely "urban planning, rural sociology, energy, health, soil, wildlife, agriculture, fisheries, ecological economics and forestry" (Spangenberg, 2011, p. 277). The World Commission on Environment and Development identified 6 global challenges for sustainable development: water, energy, health, agriculture, biodiversity, and urban development (Kates, 2017). In South Africa, key issues in SS have been identified by scholars, including increased unemployment, a decline in the Human Development Index, a digital divide between wealthy and poor, and consumption rates exceeding environmental limits (Burns, Audouin, and Weaver, 2006). The origin of sustainable development challenges lies in the divide between scientific knowledge producers and their users and is also influenced by a diverse range of political and economic value systems, as the world is separated into various perceived subjective and objective realms (Burns, Audouin and Weaver, 2006). Disciplines such as economics, sociology, geography, political science, and gender studies need to be applied to SS; however, the

complex interdependence of systems complicates the pursuit of solutions to related challenges (Jerneck et al. 2011). Problem-solving and critical research approaches aim to tackle complex interconnected sustainability challenges. A challenge in establishing SS development is securing the involvement of political, business, and industry stakeholders. For SS to be practiced more broadly, it is proposed that transdisciplinarity centres for SS be established to foster more effective integration between natural and social systems, and to bridge divisions between policymakers and implementing agencies (Burns, Audouin and Weaver, 2006).

SS aims to understand the relationship between human society and the environment on which it depends (Burns, Audouin, and Weaver, 2006) and covers a wide range of topics that address complex human-environment system interactions. Key topics include understanding the causes, impacts, and mitigation strategies for changes in the climatic and geochemical cycles, and studying biodiversity, conservation biology, and restoration ecology. Further topics include developing sustainable agriculture (maintaining soil health, ensuring food security, and reducing environmental impact), exploring renewable energy sources and efficient resource management and their economic and social impacts, and managing water use and conservation (Kates, 2017). Sustainable cities are explored through green infrastructure, transportation and urban planning. SS involves examining policies and governments' roles in promoting environmental sustainability, whilst addressing social inequalities and ensuring the fair distribution of resources and opportunities, as well as developing, implementing, and evaluating innovative sustainability-focused technologies and sciences. The United Nations' Sustainable Development Goals (SDGs) ought to work towards a sustainable future for all by developing education curricula (Salovaara, Soini and Pietikäinen, 2019). As a transdisciplinary field, SS strives to promote a sustainable society and to advance sustainable education and education for sustainable development, which are critical issues facing our century (Salovaara, Soini and Pietikäinen, 2019). SS goes beyond scientific engagement, through engagement with stakeholders' subjectivity. Thus, SS requires flexibility to accommodate various forms of knowledge and worldviews, which in turn requires recognizing the tensions between traditional scientific knowledge and other subjective knowledges. Collaboration between policymakers and potential users, sharing and integrating knowledge, is key when addressing sustainability problems, to possibly producing useful implementable knowledge (Kates, 2017). The application of SS is most likely to succeed in collaborative efforts or when viewed holistically (Spangenberg, 2011; Kates, 2017). Rather than merely adapting a multidisciplinary or interdisciplinary approach to address scientific problems, SS recommends transdisciplinarity, diversity and holistic thinking (Kates, 2017; Salovaara, Soini and Pietikäinen, 2019); integrating knowledge and being critically reflexive of the disciplines from which knowledge stems from (Spangenberg, 2011). Based on this understanding of SS, our focus shifts to exploring how key SS topics or principles are integrated into South Africa's Life Sciences curriculum. This evaluation of the *field of recontextualization* will involve analyzing the Grade 10-12 Life Sciences CAPS document to determine to what extent SS topics are promoted. The key topics, derived from the literature reviewed on sustainability science, are provided below:

1. Understanding the causes, impacts and mitigation strategies for climatic and geochemical cycle changes (climate change),

2. Studying biodiversity, which includes conservation biology and restoration ecology,
3. Developing sustainable agricultural practices to ensure food security, maintain soil health and reduce environmental impact,
4. Looking into renewable energy sources, the management thereof, and its economic and social impacts,
5. Managing the sustainable use and conservation of water resources,
6. Fostering sustainable urban environments focusing on planning, infrastructure and transportation,
7. Investigating environmental policy and governance that promotes sustainability,
8. Addressing social justice issues pertaining to fair opportunity and resource distribution,
9. Pursuing the United Nations' Sustainable Development Goals,
10. Developing, implementing and evaluating sustainability-focused sciences and technologies

Other research has been done on SS and schooling. In the USA, Feinstein and Kirchgasler (2015) conducted a document analysis of the Next Generation Science Standards (NGSS) in terms of sustainability and found that sustainability is mainly treated as technical problem-solving, specifically focusing on sustainability via ecosystems and human impact in terms of Life Sciences, but that there is limited attention to ethics, politics and systemic social change. A 2015 South African master's thesis case study focused on a Cape Flats school's environmental project (a fynbos garden), in which a direct connection is made between Life Sciences and indigenous flora and ecosystems (King, 2015). This project improved environmental awareness and local biodiversity learning; however, long-term success was hindered by resource constraints, emphasizing the importance of improving the *field of reproduction* in terms of SS. Bopape, Mudau and Msezane (2021, p.162) conducted multiple case studies in Gauteng, South Africa, exploring how secondary schools implement "greening" initiatives, linking it to Life Sciences via biodiversity gardens and waste management; and found positive learner engagement, but emphasized the needed responsibility of school leadership and community support.

Al Darayseh and AlHawamdeh (2024) analyzed the content of Grade 4 science textbooks for prevalence of SDGs within environmental, economic and social dimensions in the United Arab Emirates (UAE). They found that the environmental dimension was well represented, whereas social and economic dimensions were underrepresented and lacked depth in sustainability topics. A Qatar study thematically mapped their K-12 science and mathematics curricula to the SDGs and found the strongest coverage in biology-related SDGs, specifically relating to health and biodiversity (Said, Mansour, Abu-Tineh, Cevik and Al-Naimi, 2024).

A "sustainability gap" was identified by uneven SDGs coverage, weak social and economic aspect coverage and recommended curriculum revisions (Said et al., 2024, p.11). A cross-national curriculum review on Grade 9 science and social science curricula, covering 85 countries, found that climate, biodiversity and health were common sustainability topics, where climate change is the most common (UNESCO, 2024). It was concluded that most curricula are knowledge-heavy and rarely contain action-oriented and justice-focused content. In the Nordic region, a mixed methods approach (curriculum scan and teacher surveys) found that Life Sciences touched

sustainability in terms of ecology and biodiversity, identifying a strong integration of sustainability competences, but varying implementations and the need for systemic support and professional development of teachers (Nordic Council of Ministers, 2024). Through structured document analysis in South Africa, Msimanga & Ramnarain (2024) found coexistence of multiple ideologies (scientific realism, humanist and citizenship frames) showing how curriculum mediates science-society issues, indirectly highlighting the importance of explicitly including SS in Life Sciences curricula. Collectively, these studies demonstrate that sustainability content is recontextualized into school science curricula primarily through ecology, biodiversity, and climate change themes, with limited attention to ethics, governance, and systemic social change. This uneven representation of SS in school curricula suggests the need for stronger, clearer recontextualization, including a deeper exploration of the *field of reproduction* to understand how teachers translate sustainability science into classroom practice. The research reported here provides a first step towards achieving this aim by providing a foundation for further exploration.

Research Method

Document analysis is a qualitative research method that offers a cost-effective, unobtrusive, and nonreactive means of collecting empirical data (Bowen, 2009). While it is commonly used alongside interviews and observations to reduce bias and enhance credibility, in this phase of a broader research project, document analysis is employed as a stand-alone method. The findings of this phase of the research project will form the foundation for exploring how sustainability science is understood by teachers and how it is enacted in classroom practice.

This study utilizes content analysis, a form of document analysis that involves organizing information into categories aligned with the central purpose of the research (Bowen, 2009). Specifically, the CAPS (Curriculum and Assessment Policy Statement) for Life Sciences document was analyzed using key sustainability science themes identified through a review of relevant literature. Details of how the analysis was done is found in the next section.

Bowen (2009) outlines five primary uses of document analysis, and the most applicable to this study is the verification or corroboration of evidence. Accordingly, the analysis of the Life Sciences curriculum aimed to determine the extent to which sustainability science themes are integrated into the CAPS document.

Analysis of the Life Sciences Curriculum

The general aims of the South African Curriculum include ensuring that learners acquire meaningful knowledge, skills and values and promoting local contextual knowledge, while considering global imperatives, irrespective of their socio-economic background, race, gender or abilities (DBE, 2011), which links to SS topic eight. One out of the four purposes of the National Curriculum Statement Grades R-12 (NCS) relates to SS, focusing on equal societal participation. Moreover, three of the eight principles on which the NCS is based connect to SS, namely social transformation, “[h]uman rights, inclusivity, environmental and social justice,” and the appreciation of indigenous knowledge systems (DBE, 2011, pp. 4-5). There is also focus on collaboration between learners, being responsible toward others and the environment using science and

technology, and the understanding of the world's relational systems. This provides evidence that the national curriculum aims to address sustainability issues.

The Life Sciences curriculum includes three specific aims, relating to (1) knowing the content, (2) carrying out practical work and investigations, and (3) applying Life Sciences, the history of scientific discoveries and indigenous knowledge to everyday life (DBE, 2011). Even though the first two aims could be utilized to promote SS in the *field of reproduction* by teachers, only specific aim 3 (appreciating and understanding the history, significance and applications of Life Sciences in society) (DBE, 2011) explicitly connects to SS. Specific aim 3 emphasizes understanding how modern scientific and indigenous knowledge systems have their origins in different contexts and worldviews, and how Life Sciences knowledge can be applied across various aspects of society (DBE, 2011). In addition, we acknowledge that promoting sustainability science places great responsibility on the teachers who implement the curriculum in the classrooms.

Our analysis involved two complementary approaches: (1) analyzing the extent of representation of individual sustainability science topics across the curriculum, and (2) calculating the percentage of curriculum topics in each grade that explicitly or implicitly engage with sustainability science themes. These approaches provide both a holistic picture of integration and a thematic mapping of emphasis and omission.

Tables 1, 2 and 3 (see Appendix) comprise an in-depth analysis of the extent to which the Grade 10, 11 and 12 Life Sciences curriculum include sustainability science topics (representing analysis approach 1). Dark gray cells represent a direct connection to sustainability science, whereas light gray cells represent an indirect connection to sustainability science. In instances where dark gray or light gray cells have no text, this denotes connections to sustainability science that are regarded as self-explanatory. Empty cells have no connection. In our analysis, the SDGs (point 9) were not separately evaluated as a key topic of sustainability science, because it is intrinsically interconnected with the other key topics.

Analysis approach two involved calculations, for example, in Grade 10 the curriculum covers 40 topics; thus, the proportion of content related to sustainability was calculated as $7/40 \times 100 = 17.5\%$, as there are 7 gray cells. Separate percentages for each category within every grade and SS topic were calculated, distinguishing between dark gray cells (direct connections) and light gray cells (indirect connections). Finally, the authors constructed a summary table (Table 4) presenting the overall proportion of the entire Life Sciences curriculum (Grades 10 to 12) that engages with each SS topic.

On average, the proportion of Life Sciences topics linked to sustainability science varied considerably across grades. Approximately 8.9% of topics in the Grade 10, Life Sciences curriculum engaged with SS, largely through indirect connections, such as eutrophication and resource management. The Grade 11 curriculum demonstrated the highest degree of relation to SS (30.7%), where many of these topics were direct, such as biodiversity, plant reproduction, and ecological strands, emphasizing the importance of awareness of human impact on the environment. Only 8.2% of topics in Grade 12 linked to SS, with a focus on molecular biology and physiology, where sustainability links are mostly indirect. Based on these percentages, SS peaks in Grade 11, but is relatively underrepresented in Grade 10 and 12; therefore, showing a nonlinear progression.

When analyzed from the perspective of SS topics themselves, it was found that the strongest coverage across all three grades is based on biodiversity conservation and restoration, climate change and its impacts, and usage and conservation of water,

reflecting the curricular emphasis on human impact, conservation and ecology. Topics such as sustainable agriculture and management of energy and resources were moderately covered, being more strongly represented in Grade 11. Urban sustainability, environmental policy and governance, and social justice and equity were underrepresented across all three grades. Despite the potential relevance to areas such as biotechnology and food security, Grade 12 molecular and genetics topics encompass very limited sustainability framing.

These two complementary analysis approaches demonstrate that while the curriculum provides opportunities for engagement with SS, the topics are unevenly distributed across grade levels and sustainability topics. The curriculum itself covers environmental dimensions relatively well, but social and governance dimensions remain limited.

Conclusion

Environmental destruction has reached unprecedented levels, and human society is on an unsustainable course. This situation raises the perennial curriculum question: What knowledge is of most worth? In other words, what should be included in school and university curricula at a time when the planet faces ecological crisis?

Over past decades, traditional disciplines, created in and for a different world, have been losing coherence. New inter-, multi-, and transdisciplinary fields are emerging, including sustainability science, which draws on the natural sciences, social sciences, and humanities to address sustainability issues. This article examined how sustainability science has filtered into the Life Sciences curriculum for Grades 10-12.

The results show that sustainability science coverage is relatively low, especially in Grades 10 and 12. National curricula are typically revised every 5 to 10 years, which may explain the slow uptake. Nonetheless, the presence of sustainability science topics in the curriculum provides an important opportunity: teachers and teacher educators can use them to spark critical, complex conversations on sustainability in classrooms. Teacher agency is therefore central.

The findings also suggest that policymakers should consider expanding the representation of sustainability science in the Life Sciences curriculum, while addressing the non-linear progression across grade levels. This study focused on Bernstein's fields of recontextualization and production. We recommend further research into the *field of reproduction* to understand what teachers do with sustainability science in practice, and how this shapes student learning in Life Sciences classrooms.

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Appendix 1

Tables 1, 2 and 3 *Integration of Key Sustainability Science Topics in the Grade 10 -12*

Tables 1, 2 and 3, respectively, provide the extent to which the Grade 10, 11 and 12 Life Sciences curriculum includes the key sustainability science topics. Dark gray cells represent a direct connection to sustainability science, whereas light gray cells represent an indirect connection to sustainability science.

Table 2

Integration of Key Sustainability Science Topics in the Grade 11 Life Sciences Curriculum

Dark gray cells indicate a **direct** connection to sustainability science, while light gray cells indicate an **indirect** connection.

				Key Sustainability Science topic									
				Climate change causes, impacts and mitigation strategies	Biodiversity conservation and restoration ecology	Sustainable agricultural developments	Management of energy and resources	Water usage and conservation management	Urban sustainability	Environmental policy and governance promoting sustainability	Sustainable social justice and equity	Sustainability-focused sciences and technologies	
GRADE 11	Term 1	Strand 1: Diversity, Change and Continuity	Biodiversity and Classification of Living Organisms	Biodiversity								immunity and antibiotics	
			Biodiversity of Plants (developmental lines)	Bryophytes to Angiosperms				decreasing dependence on water for reproduction from bryophytes to angiosperms					
			Reproduction in Plants	Asexual and sexual reproduction in plants									
				Flowers as reproductive structures	different adaptations for pollination								
				The significance of seeds	seedbanks	seedbanks	seedbanks		seedbanks		seedbanks		
	Term 2	Strand 2: Plant and Animal Life Processes	Biodiversity of Animals (developmental lines)	Six phyla and key features		role of invertebrates in agriculture and ecosystems (pollination, soil aeration, decomposition)	role of invertebrates in agriculture and ecosystems (pollination, soil aeration, decomposition)						
			Energy transformations to sustain life	Photosynthesis									
			Animal Nutrition (Mammals)	Herbivores, carnivores, omnivores									
				Human nutrition									
				Ingestion, digestion, absorption, assimilation and egestion									
				Homeostatic control				malnutrition				diabetes	
				Importance of balanced diet									
			Tooth decay										
			Alcohol and drug abuse effects										
			Energy transformations to sustain life	Cellular Respiration (aerobic and anaerobic respiration)			anaerobic respiration and bread making				anaerobic respiration and bread making		
	Term 3	Strand 3: Environmental Studies	Gas Exchange	Differences between breathing, gas exchange and cell respiration									
				Efficient gas exchange organ requirements	different environments require different adaptations for gas exchange								
				Human gas exchange									
				Respiratory diseases	TB - biodiversity in microorganisms				smoking legislation in SA				
				Role of various organs in excretion									
			Excretion in Humans	Urinary System									
				Homeostatic control of water and salts									
				Diseases that affect kidney function									
				Population size	limiting factors, carrying capacity					limiting factors, carrying capacity			
				Population Ecology	Interactions in the environment (predation, competition, specialization, parasitism, mutualism, commensalism)								
			Social organization							herds, packs, dominance, division of tasks			
			Succession: Community change over time										
			Human Population		Impacts of human population growth on the environment carbon footprint, carbon dioxide emissions, deforestation, greenhouse effect, global warming, methane emissions, ozone	Impact of human actions on biodiversity	methane emissions						
			Water availability		droughts, floods, destruction of wetlands, poor farming practices	exotic plantations	poor farming practices, boreholes		cost, wastage, dam construction, wetland destruction, boreholes, water depletion	cost, wastage		cost of water	boreholes, dam construction
			Term 4	Strand 3: Environmental Studies	Water quality	thermal pollution	alien plants	water in agriculture		water for domestic use, industry, agriculture, mining, water purification and recycling	water for domestic use, industry, effect of mining on quality water	effect of mining on quality water, industry, agriculture	water for domestic use
	Human impact on the environment: human survival crises	Food security			human exponential population growth, droughts and floods, poor farming practices, wastage	monoculture, alien plants, loss of biodiversity (gene pool impact)	poor farming practices, monoculture, pest control, fertilisers, topsoil loss, reduction of agricultural land	wastage, genetically engineered food	poor farming practices, wastage		poor farming practices		genetically engineered food
	Loss of biodiversity				habitat destruction, overgrazing, monoculture, golf estates, urbanization, mining, deforestation, wetlands and grasslands loss, alien plant invasions, poaching	deforestation, wetlands and grasslands loss, overgrazing, monoculture, golf estates, poaching	deforestation, wetlands and grasslands loss, overgrazing, golf estates, poaching	wetlands and grasslands loss, golf estates	golf estates, urbanization	habitat destruction, overgrazing, monoculture, golf estates, urbanization, mining, deforestation, wetlands and grasslands loss, poaching, alien plant invasions			
		Solid waste disposal			prevention of soil and water pollution, managing dump sites	prevention of soil and water pollution, managing dump sites	prevention of soil and water pollution	prevention of soil pollution, managing dump sites	prevention of water pollution	recycling, using methane from domestic use, managing dump sites, prevention of pollution, managing dump sites	safe disposal of nuclear waste, managing dump sites, prevention of pollution	managing dump sites, prevention of soil and water pollution	recycling, using methane from domestic use

Table 3

Integration of Key Sustainability Science Topics in the Grade 12 Life Sciences Curriculum

Dark gray cells indicate a **direct** connection to sustainability science, while light gray cells indicate an **indirect** connection.

Key Sustainability Science topic									
		Climate change adaptation and mitigation strategies	Biodiversity conservation and restoration ecology	Sustainable development goals	Management of natural resources	Water usage and management	Urban sustainability	Environmental policy and governance promoting sustainability	Sustainable social justice and equity
Term 1	Strand 1: Life at Molecular, Cellular and Tissue Level	DNA	variation						
		RNA	variation						
		Mitosis	variation						
Term 2	Strand 2: Plant and Animal Life Processes	Differences between mitosis and meiosis							
		Diversity of reproductive systems							
		Male and female reproductive systems structure							
Term 3	Strand 2: Plant and Animal Life Processes	Human Reproduction							
		Unique human reproduction characteristics							
		Genes							
Term 4	Strand 4: Diversity, Change and Continuity	Inheritance and variation							
		Sex chromosomes							
		Mutations	tracing of genetic links						genetic engineering (stem cell, cloning, GMO, biotechnology), bioreactors
Term 2	Strand 2: Plant and Animal Life Processes	Humans respond to the environment through nerves and hormones							
		Human nervous system							
		Nervous system disorders (MS, Alzheimer's)							
Term 3	Strand 2: Plant and Animal Life Processes	Injuries							
		Effects of drugs							
		Receptors (human eye and ear)							
Term 3	Strand 2: Plant and Animal Life Processes	Endocrine glands							
		Homeostasis (negative feedback, thermoregulation)							
		Plant hormones							
Term 3	Strand 2: Plant and Animal Life Processes	Plant defence mechanisms							
		Origins of ideas about origins	biogeography						
		Artificial selection	crop selection						
Term 3	Strand 2: Plant and Animal Life Processes	Darwin's Theory of Evolution by Natural Selection	variation						
		Speciation	geographic isolation						
		Reproductive isolation							
Term 3	Strand 2: Plant and Animal Life Processes	Evolution in present times							
		Human Common Ancestors Evidence							
		Out of Africa Hypothesis	evidence of biodiversity						
Term 4	Strand 4: Diversity, Change and Continuity	Cradle of Humankind Importance	evidence of biodiversity						
		Alternatives to Evolution							different cultural or religious explanations included

Table 4
Average Percentage of Life Sciences Topics with Direct and Indirect Links to Sustainability \ Science

Sustainability Science Topics	Climate change causes, impacts and mitigation strategies	Biodiversity conservation and restoration ecology	Sustainable agricultural developments	Management of energy and resources	Water usage and conservation management	Urban sustainability	Environmental policy and governance promoting sustainability	Sustainable social justice and equity	Sustainability - focused sciences and technologies
Total amount of topics related to entire Life Sciences curriculum: 105	19.00	36.00	17.00	13.00	13.00	11.00	12.00	8.00	15.00
Percentage of entire Life Sciences curriculum related to SS topic - distant and direct (%)	18.10	34.29	16.19	12.38	12.38	10.48	11.43	7.62	14.29
Percentage Directly related (%)	15.24	18.10	9.52	4.76	5.71	4.76	7.62	1.90	9.52
Percentage Distantly related (%)	2.86	20.00	7.62	7.62	6.67	5.71	3.81	5.71	4.76

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