Introducing the concept of evolution into South African schools

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Evolution is the highest ordering principle in biology, dealing with questions about ultimate causation of form and functioning at all levels of life. Its introduction into the school curriculum provides children with access to ways of thinking that can make them more enlightened citizens and prepares them for tertiary-level study. The South African school curriculum before 1994 ignored evolution because it conflicted with the religious beliefs of the government. This paper identifies content statements that relate to evolution in the most recent Natural Sciences Learning Area Statement (Grades R–9) and the Life Sciences subject statement (Grades 10–12) for South African schools. The analysis shows that key foundational concepts are developed in the Natural Sciences learning area, but the term 'evolution' is absent. In the Life Sciences subject statement, evolution, speciation, natural selection, common descent and gradualism are introduced in Grade 12. Both curriculum statements emphasize the need to recognize alternative ways of knowing, including faith-based and indigenous knowledge systems. While the curriculum statements are undoubtedly an improvement on the old syllabus, we conclude that they fail to integrate the various lines of evidence into an integrated Darwinian theory of evolution, they conflate different domains of knowledge, and they misrepresent key concepts such as natural selection. By denying learners, especially those from impoverished environments, meaningful access to higher-order concepts and ways of thinking, they endanger the social justice imperative which frames the entire National Curriculum Statement.

Introduction

Biology is an extraordinarily diverse field of study, including the investigation of all aspects of living systems. Mayr[1] suggests that biology is structured around three questions, which he terms the 'what', 'how' and 'why' questions. Descriptive biology answers the 'what' questions, and seeks to describe all levels of organization in living systems from molecules to whole organisms. The science of taxonomy is based on descriptive biology and is used to organize species into increasingly inclusive groups up to the level of Kingdom. Functional biology answers the 'how' questions, by investigating the proximate causation of biological phenomena; for example, how chlorophyll molecules trap light energy or how kidneys remove waste products from blood. 'Why' questions are the highest level of questions in biology, since they seek the ultimate causes for structures and functioning of living organisms; those relating to the historical and evolutionary factors that account for observed structures and functioning. This paper shows how evolution is being introduced implicitly and explicitly in the South African school curriculum, in ways that approach, but fall short of, achieving high levels of scientific literacy for all South African learners.

It is possible to teach biology at the level of descriptive and functional biology, without ever addressing ultimate causation. To do so, though, would be to ignore the central concept in modern biology — Darwinian evolution. Its explanatory power provides a framing device for scientists to understand the underlying principles and processes involved in all levels of organization of life, from molecules to whole ecosystems.[2] The way of thinking exemplified by the Darwinian revolution is termed 'conscilience of inductions', and is based on disparate lines of evidence leading to a common explanatory framework.[3] Darwin built his case for evolution by natural selection using evidence drawn from a variety of apparently distinct natural processes and disciplines, including artificial breeding, palaeontology, biogeography, embryology, comparative morphology and behaviour. When all these sources are considered, evolution by natural selection emerges as a far more plausible explanation than creation. However, the value of understanding evolution lies beyond its importance in biology, since it provides access to a way of thinking that can be applied in everyday life, as, for example, in the criminal justice system, where several lines of evidence are considered before a verdict is reached.

Evolution by natural selection, nevertheless, remains a controversial school topic in many countries, notably the United States.[4,5] While each state in the U.S. develops its own science content standards, these are strongly influenced by the National Science Education Standards (NSES), most recently revised in 1995.[6] Darwinian evolution features prominently in the NSES, and appears in all state biology standards, but the emphasis on evolution varies across states.[6] Nevertheless, many students in America do not accept the validity of evolutionary theory, partly as a result of their own strong preconceptions but also because of the uninformed way in which evolution is taught.[7] Recently, the concept of 'intelligent design' has replaced creation science as a means of reconciling religious beliefs with the empirical evidence of science.[7] Shaver[5] argues that the ongoing debate about the relative merits of Darwinian evolution and creation science results in school-age American children being denied information that is necessary for a fundamental understanding of science.

The evolution–creation controversy is rarely an issue in most other Western countries.[8] This reflects cultural–societal differences: more than one-third of American adults believe the Bible to be literally true, including creation and the age of the Earth, compared with only 7% of British adults holding the same view.[9] Societal attitudes play out in the school curriculum; for example, a 1999 poll showed that almost 80% of Americans want creationism taught in public schools.[9] Despite wider openness to evolution among the British public, Reiss and Tunnicliffe[10] caution that Darwinian evolution conflicts with important cultural beliefs held by a significant minority of British learners and warn teachers not to trample on the cultural values of families. Unfortunately, they do not elaborate on how to teach the prescribed areas of study relating to evolution without offending this minority.

In South Africa, the creation–evolution debate never arose in school biology, because education policy was based on Calvinism, which has as its cornerstone the absolute sovereignty of God.[11] The low levels of scientific literacy among South African children have been demonstrated consistently in three successive international studies of mathematical and scientific literacy,[12–14] indicating that a major reform in the school science curriculum is long overdue.

The lack of exposure to Darwinian evolution at school level did not prevent significant evolutionary research and teaching in some South African universities and research institutes. However, evolution through natural selection has remained within the domain of a few

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intellectuals and has not permeated the general public's understanding and interpretation of life. A bifurcation in biological knowledge occurred with academics pursuing its cutting-edge dimensions, while learners remained caught within outdated material that pointed them in completely the wrong direction in terms of the highest ordering concept in biological thinking.

One of the first tasks undertaken by the democratically elected South African government in 1994 was to reform education so as to provide all South Africans with equal opportunities to quality learning. Social transformation is foregrounded in the new curriculum, as is the production of internationally competitive, literate, creative and critical citizens.[15]

In the process of introducing a more modern school curriculum, free of previous inhibitions, many professional biologists and academics hoped that Darwinian evolution would take up its rightful place in the biology curriculum. South Africa is richly endowed with natural resources that could facilitate the teaching of evolution in a learner-centred, experientially rooted manner. These include a wealth of biodiversity and environments,[16] a well-documented fossil record,[17] an extensive geological record, active research programmes investigating evolutionary relationships and mechanisms of evolution among extant species, and a network of museums and national parks throughout the country.

But has curriculum reform since 1994 enabled learners to build an understanding of the concept of evolution? What would a Biology curriculum need as its basic concepts to build up a solid understanding of evolution by natural selection? These are the basic questions this paper sets out to answer. It begins in reverse order with the question of what basic concepts South African learners would need to understand the principles of evolution. We then examine the most recent policy documents for Natural Sciences (Grades R–9)[15] and Life Sciences (Grades 10–12)[18] in order to identify where and how Darwinian evolution is included in the new school science curriculum.

A paradigm shift

Adopting an evolutionary understanding of life requires a paradigm shift from an intuitive and/or faith-based belief in the constancy of the physical environment and all extant species; beliefs that are plausible in terms of children's everyday experience of an unchanging Earth and unchanging life on Earth.[19] To change such strongly held beliefs to a better scientific explanation successfully requires carefully structured experiences and activity throughout the school career. Evans[19] showed that children progress from a spontaneous generation explanation for the origin of species at 6–8 years, through an exclusively creationist explanation at 8–10 years, to either a creationist or evolutionist explanation by 10–12 years of age. The evolutionist explanations were based on Lamarckian rather than Darwinian thinking, which was also characteristic of a group of first-year university students in South Africa.[20] The adoption of evolutionist explanations in Evans's study[19] was positively correlated with knowledge of the natural history of fossils and adaptation, and also with parental evolutionist beliefs. The children in this study had not received formal instruction in Darwinian evolution, and their views reflect their intuitive theories about the origins of life, based on their experience of natural history and their parents' views of the origins of life.

Darwin's theory of evolution was developed in a time when the dominant mode of thinking was creationist[21]. Thus, much of Darwin's argument is intended to disprove that a Creator created the Earth and all species independently of each other. Darwin built upon geologists' discovery of the great age of the Earth, the continuous geological processes that caused changes in the Earth's surface, and the discovery of extinct fossil life-forms.[1] These three factors undermined a creationist interpretation, although they did not by themselves prove that species evolve from other, pre-existing species.[21] Darwin's fundamental contribution was invoking 'natural selection' as the mechanism accounting for multiplication of species (horizontal evolution) and the adaptation of species for their individual ecological niches (vertical evolution). Natural selection provided an explanation for vertical and horizontal evolution by natural processes, rather than requiring a supernatural designer or creator.

Since children's thinking about the origin of species to some extent mirrors the creationist thought prevalent in the eighteenth and nineteenth centuries, we might expect that an ideal school biology curriculum would trace Darwin's argument through an understanding of deep time, changing Earth and extinct life through to natural selection as an explanatory principle for vertical and horizontal evolution.[21] However, these foundational concepts must eventually be woven together to achieve the realization that species evolve, through natural selection, from other species. Costa[3] argues convincingly for basing the teaching of evolution on Darwin's own journey to his final explication of the theory of evolution by natural selection. He criticizes approaches to teaching Darwinian evolution that are based on micro-evolution; for example, the development of antibiotic resistance in pathogens or the evolution of the human immunodeficiency virus, and suggests that teachers should follow the logic of Darwin's reasoning to focus on the evidence that Darwin himself used to support the theory of evolution. This paper uses Mayr's[1, 21] analysis of the theory of evolution as a foundational framework on which South African school biology could be structured so as to provide a convincing account of evolution. We have found that many introductory books on Darwinian evolution, and school and college level texts develop some, if not all, of the theories listed below.

Mayr's treatment of the Darwinian paradigm

Mayr[1] identifies five theories within Darwin's theory of evolution, each supported by evidence.

1. The theory that life steadily evolves over time

This theory was necessary to break down the prevailing view of the constancy of species. The fossil record supports the nonconstancy of species over time, or vertical evolution, and biogeographical observations support the nonconstancy of species in space, or horizontal evolution.[21]

Darwin's conclusions on the evidence presented by the fossil record can be summarized as follows[21]:

- *All fossils can be fitted into the existing Linnaean classification scheme,* which indicates a long history of taxonomic groups, with very little complete innovation, as might be expected if each species was created independently.
- In general, *the older a fossil is, the more it differs from modern species.* This observation supports an interpretation of a long and gradual process of evolution, with increasing similarity to modern species.
- *Fossils from consecutive rock formations are more similar to each other than are fossils from more distant formations.* This phenomenon suggests that fossils in consecutive rock formations form an evolutionary sequence, with those in the more recent rock formations having evolved from those in the preceding rock formation.

- *The recent fossils of a particular geographical area resemble modern species of that area.* An explanation for this phenomenon is that modern species have evolved from the extinct species.

The four observations listed above are necessary if learners are to link an awareness of fossils to the process of Darwinian evolution. The school curriculum should, therefore, include opportunities for learners to discover the story of macroevolution, as told in the fossil record.

2. The theory of common descent

The theory of common descent proposes that organisms descend from common ancestors by a continuous process of branching. It provides a powerful explanation for within-group similarities, based on comparative anatomy, the Linnaean hierarchy, the patterns of geographical distribution of species within and between environments, and patterns of development in embryos, which frequently pass through stages similar to corresponding stages in an ancestral group.[1] The fossil record also supports a theory of common descent.

The theory of common descent is an extremely powerful explanatory tool for patterns observed in biodiversity. It is based on methods of careful observation and comparison, which permit the identification of patterns of similarity and difference among organisms. Thus, while it may not be possible for school children to gain first-hand experience of embryonic development, or biogeography, the curriculum should provide the opportunity for learners to organize local biodiversity according to observed patterns of similarity and difference. This should be followed with 'why' questions, leading learners to an understanding of common descent.

3.Theory of the multiplication of species

The multiplication of species refers to the horizontal evolution of species in space, termed speciation, which is included in microevolution.

Since Darwinian evolution proposes that all species are descended from other pre-existing species, the process of speciation is key to understanding evolution. The long periods of time required for new species to evolve mean that it cannot be demonstrated directly during a human lifespan, but intraspecific variation provides evidence of how speciation begins. Speciation may result in adaptive radiation, as observed by Darwin on the Galápagos Islands, where 13 different species of finch, descended from an ancestral species on the South American mainland, have become adapted to different ecological niches on the islands.

There are numerous examples of adaptive radiation within the South African natural environment; for example, three regions and eighteen centres of plant endemism have been identified in the country.[16] More than 60% of the over 30 000 plant species found in southern Africa are endemic to the area, rising to 70% of the total flora of the Cape Floristic Region being endemic. Some centres of endemism contain closely related species that represent recent adaptive radiation, while others represent relict populations of a taxonomically diverse flora that was once more widespread. Amongst vertebrates, the cichlid fishes of Lake Malawi have the highest speciation rate of all taxonomic groups, resulting in an estimated 500 species, each adapted to a particular ecological niche.[22]

4. Theory of gradualism

Throughout his writings, Darwin emphasized the gradual nature of evolutionary change in populations. He interpreted intraspecific variation among populations as evidence of evolution in progress, since any of the varieties, under conditions of geographic isolation, could evolve to become new species.[1]

More recent work, in particular by Eldredge and Gould,[23] proposes that evolution sometimes proceeds relatively rapidly, followed by long periods of relative stasis. 'Rapid' in the context of geological history refers to thousands of years, therefore Eldredge and Gould's theory of punctuated equilibrium does not contradict Darwin's theory of gradual evolution, but adds a new dimension, which is based on observation and evidence, particularly from the fossil record. This illustrates the essence of growth in scientific thought, which is shaped and modified as new evidence is presented and debated within the scientific community.

5. Theory of natural selection

Natural selection is considered to be Darwin's principal contribution to our understanding of evolution, and is therefore a crucial component in developing learners' understanding of the mechanism whereby species evolve. The theory of natural selection is based on over-production of offspring in each generation, variation among individuals, competition for resources, and differential survival of individuals.[21] The term 'fitness' is used to describe the capacity for survival and reproduction of an individual. The concept of fitness can be extended to a group of closely related individuals that cooperate in the challenges of survival, thus increasing the 'inclusive fitness' of the group, and increasing the chances of their alleles surviving into the next generation. When Darwin presented his theory of evolution by natural selection, the genetic basis for inheritance was unknown. Once genes had been discovered, it became clear that natural selection operates on heritable characteristics of individuals, resulting in an increase in the incidence of favourable alleles in the population. Variation in physical characteristics is easily demonstrated in natural populations, such as butterflies, and domestic species such as cattle. The over-production of offspring is illustrated by the massive production of offspring by many species, most of which become food for other species, thus illustrating differential survival. Many mammal and bird species in southern Africa exhibit competition for mates, particularly where one male guards a group of females, thus excluding bachelor males from breeding. Artificial selection illustrates the potential effect of selective breeding in increasing the frequency of favourable characteristics in a population. Knowledge of the genetic basis of inheritance provides support for the mechanisms underlying selective breeding, thus pointing to a genetic basis to evolution by natural selection.

Biology in the South African school curriculum

Having identified the foundational concepts of evolution that could be convincingly developed in South African schools, we then analysed the latest curriculum documents to identify where, when and how these principles are introduced. Evans's research[19] indicates that adoption of an evolutionary explanation is related to natural history knowledge, and that children achieve the necessary cognitive structures to adopt an evolutionary explanation for life by the age of 10–12 years, which corresponds with Grades 5–7 in South African schools. Thus an ideal curriculum should provide structured opportunities to develop knowledge of natural history before and during the critical phase of 10–12 years of age, and presentation of evolutionary theory should not begin before this phase.The school curriculum for Grades R–9 is governed by the Revised National Curriculum Statement (RNCS),[15] and that for Grades 10–12 by the National Curriculum Statement (NCS).[18] The RNCS for Natural Sciences is organized around

three learning outcomes (LO), which must be achieved by the end of Grade 9. These are:

- LO1: Scientific investigations
  The learner will be able to act confidently on curiosity about natural phenomena, and to investigate relationships and solve problems in scientific, technological and environmental contexts.
- LO2: Constructing science knowledge
  The learner will know and be able to interpret and apply scientific, technological and environmental knowledge.
- LO3: Science, society and the environment.
  The learner will be able to demonstrate an understanding of the interrelationships between science and technology, society and the environment. (p. 6)

In outcomes-based education, content is the vehicle that enables learners to achieve the assessment standards for each grade, and ultimately the learning outcomes for the band of schooling. Whereas the curriculum documents provide detailed descriptions of the learning outcomes and the assessment standards, the content is specified only in terms of broad general topics. Developers of learning programmes (who may be groups of teachers) are expected to determine the breadth and depth of each content topic, taking into account the context of the learners and the school. Teachers are advised to adhere to principles of progression and integration when devising learning programmes, but to focus, above all else, on the attainment of the learning outcomes.

The strand *Life and Living* is one of four knowledge strands in the Natural Sciences Learning Area. The remaining three knowledge strands are *Matter and Materials, Energy and Change,* and *Planet Earth and Beyond.* Natural Sciences are required to constitute 13% of school time in Grades 7–9, which translates to roughly 140 hours per year per grade. Equal time must be devoted to each strand.

The RNCS for Natural Sciences specifies core knowledge and skills to be covered in 70% of the lessons. The core knowledge is declared policy, which means that educators are obliged by law to cover the topics. The remaining 30% allows provinces and groups of schools free choice in terms of content, provided that the selected content is used to build the learning outcomes.

After Grade 9, learners enter the Further Education and Training (FET) band of schooling, which covers the final three years of schooling in South Africa. At this level, learners may elect to study Life Sciences as one of the seven subjects for the Further Education and Training Certificate (FETC). The National Curriculum Statement for Life Sciences[18] follows the same three general learning outcomes as the Natural Sciences Learning Area, but here the focus is solely on living systems. Four content areas are included in the Life Sciences: *Tissues, cells and molecular studies*; *Structure, control and processes in basic life systems of plants and humans*; *Environmental Studies*; and *Diversity, change and continuity*. Life Sciences are allocated roughly 170 hours of teaching time per year per grade. In Grades 10–12, 80% of the total content is specified, with the remaining 20% at the discretion of the teacher.

Core knowledge relevant to evolution

The core knowledge for Natural Sciences does not specifically mention the word evolution, but it contains many statements that provide the foundations for understanding the concept. These core knowledge statements are listed in full in Table 1 and relate to the five theories identified by Mayr[1, 21] as key components in the development of the theory of evolution.

In Grades 7–9, content statements that could be linked to evolution constitute 11 of the 66 prescribed content statements, or 17% of the total number of statements. Thus, if the learning programme allocates equal time to each content statement, prescribed content relevant to evolution could occupy approximately 17 hours per year per grade.

In Grades 10–12, evolution is mentioned in the core content a number of times. Table 1 includes the analysis of the core content of Life Sciences, showing that about one quarter of the Grade 12 curriculum covers ideas relevant to evolution, translating to roughly 40 hours of teaching time.

The views of science presented in the curriculum documents provide an indication of the space allowed in the curriculum for views other than evolutionary ideas. Here, ambiguity prevails in both documents. The RNCS for Natural Sciences defines science as an attempt to understand the natural world through systematic and objective processes of inquiry, which include observation, experimentation and reproducibility. It identifies steps in the process of constructing scientific knowledge, such as generating hypotheses, setting up a 'fair test', collecting data, analysing and synthesizing data, and drawing conclusions. In this respect, it reproduces a view of science that is based on empiricism. However, the document also places emphasis on valuing traditional and indigenous knowledge systems, making the point that empiricism is but one way of viewing the world. The simultaneous existence of alternative world-views is regarded as a challenge for curriculum policy, development of learning programmes and assessment. The RNCS does not prescribe a particular approach to teaching science, but invites research into the challenges and opportunities offered by science curriculum development in the South African context.

The NCS for Life Sciences acknowledges the contribution of science to an understanding of life processes, but it also values indigenous knowledge systems as a way to expose learners to different world-views. In LO3 (science, technology, environment and society) it emphasizes the nature of science and its limitations. It also highlights 'other' ways of knowing and doing, citing African indigenous knowledge systems as an example. One of the assessment standards in LO3 requires learners to *'compare the influence of different beliefs, attitudes and values on scientific knowledge'*[18] (p. 15). Thus, among the exemplars used for the assessment standard 'Interpreting and making meaning of knowledge in Life Sciences', the following appear:

> Engages in debates regarding the origin of life;
>
> Compares different theories regarding the origin of life and identifies their shortcomings;
>
> Analyses and evaluates theories on changes in different species over time.[18] (p. 25)

Discussion

South African learners will emerge from the Natural Sciences curriculum at the end of Grade 9 with a good understanding of the nonconstancy of the environment and life on Earth, an understanding of natural selection, an awareness of the reality of extinction, an awareness of adaptations, and some exposure to biodiversity and classification. Thus, the elements identified by Evans[19] as being associated with the adoption of an evolutionist view of life are present in the curriculum statement. The South African curriculum introduces most of these concepts in the Senior Phase (Grades 7–9), when learners are 12–15 years old. The learners included in Evans's study[19] had already adopted either an evolutionist or creationist way of thinking about the Earth by the time they were 12 years old.

In terms of Mayr's[1] five theories central to evolution, the Natural Sciences curric-

Table 1. Core content statements that relate to evolution in the Natural Science Learning Area Statement[15] and the Life Sciences Subject Statement.[18]

Relationship to evolution	Statement	Place in the curriculum
Nonconstancy of the Earth; deep time.	*The Earth is composed of materials which are constantly being changed by forces on and under the surface.*	Unifying statement for the sub-strand 'The Changing Earth'.
	Erosion of the land creates the landforms that we see and also results in the deposition of rock particles that may be lithified to form sedimentary rocks. Erosion and deposition can be very slow and gradual or it can occur in short catastrophic events like floods.	Core content Grades 4–6.
	Lithospheric plates larger than some continents constantly move at rates of centimetres per year, in response to movements in the mantle. Major geological events, such as earthquakes, volcanic eruptions and mountain building, result from these plate motions.	Core content Grades 7–9.
Nonconstancy of Earth's surface, climate and life; deep time. Does not use the term 'evolution', but hints at a link between current biodiversity and the history of environmental change and changes in life-forms. Emphasizes fossils and relationships between extinct and extant species. Human evolution.	*The huge diversity of forms of life can be understood in terms of a history of change in environments and in characteristics of plants and animals throughout the world over millions of years.*	Unifying statement for the sub-strand 'Biodiversity, change and continuity'.
	South Africa has a rich fossil record of animals and plants which lived millions of years ago. Many of those animals and plants were different from the ones we see nowadays. Some plants and animals nowadays have strong similarities to fossils of ancient plants and animals. We infer from the fossil record and other geological observations that the diversity of living things, natural environments and climates were different in those long-ago times.	Core content Grades 7–9.
	Fossils are the remains of life forms that have been preserved in stone. Fossils are evidence that life, climates and environments in the past were very different from those of today.	Core content Grades 7–9.
	Many of the organisms in South Africa's fossil record cannot be easily classified into groups of organisms alive today, and some are found in places where present-day conditions would not be suitable for them. This is evidence that life and conditions on the surface of the Earth have changed through time.	Core content Grades 7–9.
	Fundamental aspects of fossil studies. Cradle of Humankind – South Africa?	Core content Grade 12.
Extinction.	*Mass extinctions have occurred in the past, suggesting that huge changes to environments have occurred.*	Core content Grades 7–9.
	Popular theories of mass extinction	Core content Grade 12.
Biodiversity and classification, although not explicitly linked to evolution.	*There is a large variety of plants and animals, which have interesting visible differences but also similarities, and they can be grouped by their similarities.*	Core content Grades R–3.
	Classification is a means to organize the great diversity of organisms and make them easier to study. The two main categories of animals are vertebrates and invertebrates, and among vertebrates the five classes are amphibians, birds, fish, reptiles and mammals.	Core content Grades 7–9.
	Plan, conduct and investigate plants and animals – a comparison	Core content Grades 10–12.
Introduces the idea of variation, which is central to natural selection. The process of natural selection.	*Offspring of organisms differ in small ways from their parents, and generally from each other. This is called variation in a species.*	Core content Grades 7–9.
	Natural selection kills those individuals of a species which lack the characteristics that would have enabled them to survive and reproduce successfully in their environment. Individuals which have characteristics suited to the environment reproduce successfully and some of their offspring carry the successful characteristics. Natural selection is accelerated when the environment changes; this can lead to extinction of species.	Core content Grades 7–9.
	Each species of animal has characteristic behaviours which enable it to feed, find a mate, breed, raise young, live in a population of the same species, or escape threats in its particular environment. These behaviours have arisen over long periods of time that the species population has been living in the same environment.	Core content Grades 7–9.
Adaptation.	*All organisms have adaptations for survival in their habitats (such as adaptations for maintaining their water balance, obtaining and eating the kind of food they need, reproduction, protection or escape from predators.)*	Core content Grades 7–9.
	Different types of plants and animals are adapted to living in different climatic regions.	Core content Grades 7–9.
Evolution as such, speciation, common descent, gradualism, natural selection.	*Collect and analyse data on evolutionary trends in a population (e.g. human beings).*	Core content Grades 10–12.
	Biological evidence of the evolution of populations.	Core content Grade 12.
	Origin of species.	
	Evolution theories, mutation, natural selection, macro-evolution and speciation.	

ulum statement builds awareness of deep time, the nonconstancy of species and the environment, gradualness, and adaptation. All these concepts were understood by natural scientists before Darwin, but they could be explained satisfactorily in terms of successive creation event.[21] Natural selection in the RNCS for Natural Sciences is misrepresented as nature actively killing less well-adapted individuals, whereas it is more accurately represented as differential survival and reproduction of some individuals and their closest genetic relatives, resulting in increased frequencies of their (favourable) alleles in the population.[21] The Natural Sciences curriculum statement carefully avoids mention of the word 'evolution' throughout the document, referring instead to 'change over time' and 'development'. In fact, the theory that life evolves is not

given as the explanation for the evidence from the fossil record, nor as the consequence of natural selection. By the end of Grade 9, learners have not received sufficient grounding in identifying patterns of similarity among related organisms, which would lead to an understanding of common descent. They have also not been exposed to the multiplication of species, as exemplified by closely related groups of organisms in particular geographic areas. We would hope that these key concepts, together with the explication of evolution should arise in Grades 10–12.

The RNCS for Natural Sciences has successfully implemented a strategy that teaches about evolution but leaves out the offensive word. Thus, 'development' and 'change' are less offensive alternatives, but at the end of Grade 9, we predict that learners (and many teachers) do not know that they have learnt about and taught evolution. The RNCS is a great improvement on previous science curricula in terms of exposing learners to the ideas that are the building blocks of evolutionary thought. However, excluding the unlikely scenario that the teacher or textbook skillfully and successfully assembles the blocks into a convincing account of the grand concept of Darwinian evolution, the idea will remain incoherent.

The emphasis of the Life Sciences curriculum for Grades 10–12 is strongly application-orientated, at the expense of the development of biological concepts. The emphasis on human and social biology is strongly foregrounded in a curriculum that is clearly intended to be 'biology for all' rather than 'biology for future biologists'. Evolution is named as part of the core content, but it receives very little attention until Grade 12. Thus, for two years after Grade 9, there is little or no development of the concept that life evolves by natural selection. Fossils re-emerge as 'fundamental aspects' in Grade 12, after receiving extensive treatment in Grades 7–9. Natural selection is re-introduced, despite its inclusion in Grades 7–9. Speciation, common descent, gradualism, and evolution are listed as topics to be covered in the core content, thus providing full coverage of all five theories contained within Darwinian evolution. Genes, inheritance and gene expression are included in the Grade 12 core content in the content area '*Tissues, cells and molecular studies*', thus effectively isolating genetics from evolution. The Assessment Guidelines for Life Sciences[24] specify that examinations from Grades 10–12 must consist of two papers, with Paper 1 covering *Tissues, cells and molecular studies* (including genetics) and *Structure, control and processes in basic life systems of plants and humans,* whereas Paper 2 examines *Environmental Studies*; and *Diversity, change and continuity.* This division of subject matter effectively isolates genetics from evolution, and reduces opportunities for creating conceptual links among the four content areas.

Even though evolution is named in the Life Sciences curriculum statement, it is tempered by two content statements under Learning Outcome 3 (Life Sciences, Technology, Environment and Society), which read as follows:

- Beliefs about creation and evolution.
- Changes of knowledge through contested nature and diverse perceptions of evolution.[18] (p. 40)

Isaac,[25] who was a member of the committee that drafted the RNCS for Natural Sciences, describes the tension between developing a curriculum statement that is sensitive to the priorities of a society in transition, while also taking into account the goal of global competitiveness. Thus, he says that evolution is not the prime organizer of knowledge within the life and living component of Natural Sciences. The focus is instead on understanding the principles of Darwinian evolution rather than accepting the theory dogmatically, so that the curriculum encourages discussion and debate. He reiterates the view that the world-views of all South African learners need to be respected.

The end result of the desire to be both scientifically and politically correct, is that the curriculum for Natural Sciences introduces some of the foundational knowledge necessary for understanding evolution, but never mentions the word evolution, and leaves the door open to other ways of knowing, including creationism.[26] Thus, learners will be in no position to debate evolution, because they do not know that they have learnt about evolution. The Life Sciences curriculum statement is more explicit in its references to evolution, but lumps all topics relevant to evolution in Grade 12, and fails to build on concepts that were developed in Grades 7–9. The Life Sciences curriculum also makes explicit mention of evolution–creation debates, thus conflating two domains of knowing: the empirical and the faith-based. The Natural Sciences curriculum, in particular, makes specific reference to the fossil record and its underlying message of changing landforms and changing life. Both curriculum statements fail to capitalize on the abundantly available extant biodiversity in southern Africa, which could be used to illustrate the principles of speciation and common descent, in the way that Darwin drew on the Galápagos finches to demonstrate speciation, and the vertebrate forelimb to exemplify common descent.

Considering the use of evolutionary concepts in the post-apartheid curriculum reform process of Natural Sciences and Life Sciences, a number of key issues deserve further comment and research: for instance, the issue of the difference between school science and university science and the articulation points between them. School science has a dual communal and specializing role. It has to ensure that the citizens of South Africa develop a basic scientific literacy relevant to everyday use, but it must also induct learners into the discipline of science as a topic for further study. The issue of teaching evolution impacts on this duality, since on an everyday level it contradicts common sense and the deeply held religious beliefs of many communities within South Africa, whilst, at the same time, being the key concept uniting the biological sciences. We have encountered a whole range of responses to this issue. One is to create a 'science' that fits into the belief structures of a community as the creation scientists have done by replacing evolution with intelligent design. Another is to relativize all contributions to the evolutionary debate, whether these be scientific, traditional, cultural, ideological or religious, and to allow them all equal recognition. A third is to obscure what the basic concepts of evolution are by placing them within a curriculum in such a manner that only an expert would recognize how to put them together into a coherent sequence. This third option at least offers the beginnings of a workable compromise between the specializing logic of evolutionary concepts and the localizing forces of everyday knowledge and tradition. The RNCS does provide the key building blocks necessary for a comprehensive understanding of Darwinian evolution. But what it does not do is provide the plan or sequence of steps to get there.

If we assume that a deep understanding of evolution at a school level is an important aspect of the education of our children for its intrinsic educational merit, its utility as a coherent organizing principle in biology and as preparation for scientific study at a tertiary level, then the compromise solution of the Natural Sciences and the Life Sciences curricula is inadequate for a number of reasons. It requires highly specialized teachers who already have a

deep understanding of evolution to put the pieces of the curriculum together in a coherent fashion, so that evolution clearly emerges as a dominating principle. It also assumes learners who are already skilled at making inferential leaps and integrating patterns, a facility that is encouraged in formal knowledge-rich environments. Thirdly, it demands well-resourced schools that can provide the material linkages to take advantage of the rich natural resources South Africa offers in terms of understanding evolution. Such preconditions are unlikely to be met in the poverty-stricken environments of most South African learners. The consequence is that only the better-off will grasp the core concepts, thus perpetuating the unequal educational dispensations of the past.[26]

Perhaps it is time to consider implementing the final stage of a trajectory that began with a creationist outlook and progressed to the implicit introduction of all the necessary components to understand Darwinian evolution. Taking the final step of directly and explicitly teaching the principles of Darwinian evolution at school exposes South African children of all backgrounds to one of the key organizing principles underlying the modern view of life and our world.

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