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Human evolution in the South African school curriculum

A decade after the introduction of the topic into the South African public school curriculum, the theory of evolution by natural selection is poorly understood among those who teach it, and that flawed understanding is transferred to those attempting to learn it. The curricula, support material and textbooks designed to underpin teaching and learning of evolution are often inaccurate. Deeply held religious views in the country, especially Christianity, remain a stumbling block towards understanding and accepting evolution. The lack of scientific literacy allows for the continuation of Social Darwinism and racial stereotypes and deprives the victims of those ills of the knowledge and mechanisms of thought to counter these ideas. This review explores the relatively sparse but nevertheless well-conducted research into evolution education in South Africa. We conclude that an understanding of human evolution is essential to the country's growing democracy because it provides a framework within which South Africans can understand and appreciate the diversity and heterogeneous nature of our society.

Significance:

- Various obstacles in the teaching and learning of evolution are identified, and generalisable recommendations are provided to improve evolution education on a practical level.
- Evolution education is important for the South African public: to take pride in our rich fossil resources; to understand and appreciate human diversity; to dispel the racist myths of Social Darwinism; and to ensure the success of our education system by teaching the consilience of induction and logical reasoning.
- This synthesis of the research provides a starting point for anyone wanting to conduct evolution education research in South Africa in the future, specifically those in the fields of curriculum reform, life sciences or biological anthropology.

Introduction

The ability to discuss and debate controversial topics fairly, logically and democratically, is necessary for democracy to work.[1] One such topic is human evolution. Any accurate account of human evolution must be Africa-centred, and a thorough understanding of the concept will allow South Africans to appreciate the vast human diversity, socially and biologically, of our heterogeneous population. Research has shown that even small educational programmes can change students' attitudes towards human variation.[2] To escape the vestiges of Social Darwinism still prevalent in South African society, we need to cultivate a society that is scientifically literate, that understands human variation through the framework of human evolution and that can discuss and debate these issues effectively.

The aim of this review was to summarise and synthesise the research that has been undertaken on evolution education in South Africa. We highlight the interventions, observations and suggestions for education discussed in each study and interpret them within the larger contexts of South African history and evolutionary theory.

During apartheid, South Africa's school system was segregated into the National Education System (based on Christian National Education (1967–1994)) and the Bantu (sic) Education System (initiated in 1952). Science education was discouraged in the Bantu (sic) Education programme, and when taught, was done so in a hyper-factualised manner, one non-conducive to learning.[3,4] While science education was allowed under Christian National Education, the science of evolution specifically was ignored. The 'hidden' curriculum during this time made creationism, patriotism, race relations and religion part of the everyday school experience of white learners.[3]

Until 1994, evolution was seldom mentioned in South African government schools, because the laws of the country, and thus the state education system, were founded on strict Calvinism, which dictated the absolute sovereignty of the Christian god.[5] Evolution was mentioned in the state school curriculum only once in 1947, as part of an overview of historical figures. Despite the fossil evidence of early humans reported by South African universities at the time, even this one mention of evolution was removed in the 1950s in favour of a creationist approach.[3]

In 1925, when Raymond Dart introduced to the world what was dubbed the 'Taung child' – the fossilised skull and endocranium of an *Australopithecus africanus* – Jan Smuts, then President of the South African Association for the Advancement of Science, noted that the discovery vindicated Darwin's insights, and observed that it was likely that modern humans arose as a species in Africa, and not Asia or Europe as was previously believed.[6] Although neglected in schools, palaeoanthropology in South Africa has generally taken for granted the significance of evolutionary theory, and in some South African universities, notably the University of the Witwatersrand, the study of hominin fossils has flourished. This acceptance allowed the country to exploit our rich fossil resources as well as to produce appropriate scientists to study them. These well-trained palaeoanthropologists provided a stabilising influence to the otherwise vociferous advocates of eugenics and biological determinism in South Africa. However, while intellectuals at South African universities studied these remarkable finds, the South African school system, and the public emerging therefrom, grew ever more distrusting of the science. Consequently, the gap between scientists and the public widened.[4]

One of the first tasks of the democratically elected government in 1994 was to reform education, with the goal of producing internationally competitive, literate, creative and critical citizens.[5,7] Curriculum reform took place in

three stages[8]: (1) racist and sexist language, as well as outdated and controversial subjects, were removed from syllabi; (2) curricula design was according to an outcomes-based education model called Curriculum 2005, which was intended to change the education system in such a way that learners not only gained knowledge, but also acquired the skills to use the knowledge to reach certain outcomes; and (3) Curriculum 2005 was reviewed before implementation, resulting in the Revised National Curriculum Statement: Natural Sciences for Grades R–9[9] and the National Curriculum Statement for Grades 10–12[10]. These curricula were implemented gradually: Grades 1–3 in 2004, Grade 6 in 2005, Grades 7 and 10 in 2006, Grades 8 and 11 in 2007, and Grades 9 and 12 in 2008.[8]

In the National Curriculum Statement, the word 'evolution' was carefully avoided until Grade 12, where about 40 hours of teaching time (25% of the Grade-12 Life Sciences curriculum) was dedicated to concepts relevant to evolution.[11] Since 2008, the Life Sciences curriculum for Grade 12 has included all the basic aspects of evolutionary theory, including: an overview of the history of evolutionary thought including Darwin's and related theories of scientists other than Darwin, biological evidence for evolution by natural selection, the mechanisms of micro- and macro-evolution, mass extinctions and hominin evolution.[8,11]

Despite the progress made in South Africa in including evolution in the curriculum, understanding and acceptance of the topic is still low in the country. Research has shown that many people nowadays react to the theory of evolution much as they did during Darwin's time – they are distrustful and disbelieving and greatly resistant to change.[12] As a result, many teachers, schools and school systems in South Africa either avoid teaching evolution (even though it is included in the set curriculum), or do not teach it appropriately.[11] This problem is compounded by the fact that evolution is an inherently difficult concept to teach and to learn.[8] The lack of education, along with sometimes deliberate misdirection, has, regrettably, fuelled the growth of misconceptions and distrust in evolutionary theory.[11]

Problems with the teaching and learning of evolution have been well documented in other countries, especially in the United States of America, and review articles provide much valuable information about how we might improve evolution education.[13] A major difficulty in the science education system in South Africa is one of justice. If learners are denied access to higher-order thinking skills such as the consilience of inductions (combining multiple disparate avenues of evidence into a coherent theory[5]), and a correct understanding of subjects like evolution, the social justice imperative that frames the national Curriculum Statement is undermined[1,4,5]. Moreover, misconceptions around evolution often result in further learning problems when scientifically incorrect prior knowledge is committed to long-term memory and functions as the basis for further learning.[14]

Methodology

The following is a critical review of the evolution education research done in South Africa thus far as published in peer-reviewed journals. Additional criteria for inclusion in this review were:

- studies on evolution as the subject of instruction in formal institutions of learning;
- observational or intervention studies done on a South African sample; and
- studies with samples or subjects being South African curriculum documents and/or textbooks, or South African school learners or teachers, and/or South African university students and/or lecturers, respectively.

Google Scholar was used to conduct a preliminary literature search with the following search terms: "Evolution Education in South Africa", "Teaching Evolution in South Africa", "Learning Evolution in South Africa" and "South African Evolution Curriculum". Each search was extended up until the 10th page of search results. The results generally referred to the word 'evolution' as it relates to change (notably referring to the political environment in the country and South African curriculum reform), the evolution of South African animals, the geological changes related to South African environments or one of the fossil finds credited to South African sites.

All relevant and accessible articles were downloaded.[3-5,15,16] Those relevant articles that were not accessible were retrieved through a library request or via the specified journal platform. The literature referenced by the preliminary articles was then used to find further relevant research.

Review

The search resulted in a total of 14 publications dating from 1994 to 2016. It should be noted that there may have been more than these publications that were not found through our methodology. One of the publications is a compilation of 13 chapters on work of the Human Sciences Research Council.[6] While this publication was valuable for contextualising the other research, it did not comply with the inclusion criteria and was thus excluded. The remaining 13 publications are journal articles. Of these, three studies analysed the influence of textbooks and the curriculum statement on learning evolution[5,14,17]; four focused on teacher reactions to and acceptance of teaching evolution[1,3,4,11]; and six studies reported on student reactions to, and acceptance of learning about, evolution[8,15,16,18-20].

Research based on text analyses

In analyses of textbooks and curriculum statements[5,14,17], it has been found that the evolution curriculum and the evolution content in textbooks often achieve the opposite of what is desired: that is, they perpetuate misconceptions and unscientific ideas about evolution by using improper and misleading terminology and by reporting inaccurate information.

Teachers rely on the set curriculum and other educational resources for guidance on how to facilitate learning, especially during periods of curriculum reform.[17] In the case of evolution, many teachers lack the content knowledge and training to teach the topic and, therefore, rely heavily on the prescribed texts for the content, learning activities and assessments needed to facilitate learning.[3,11,14,17]

A *misconception* is a false or mistaken view or opinion and can be formed in two major ways: *acquired errors* or *true misconceptions.*[14] An acquired error is when incorrect ideas are taken up from an external source through rote learning – the idea is acquired verbatim from a parent, teacher or textbook and integrated into an individual's existing cognitive structure. True misconceptions are formed when individuals attempt to meaningfully incorporate an idea into their cognitive structure to form a mental model or schema, but the idea is misinterpreted, and becomes scientifically incorrect.[14]

Teachers who hold misconceptions about evolution are unable to identify and filter out these misconceptions from inaccurate textbooks.[14] In fact, these personally held biases might be reinforced by seeing the same misconceptions and scientific inaccuracies reproduced in print. In many cases, unscientific ideas are not the result of mistaken interpretation by students (*true misconceptions*), but the misdirection perpetuated by inaccurate textbooks, support material, curricula and teachers (*acquired errors*).[14]

Many of the misconceptions and unscientific ideas in evolution education emerge when curriculum slippages occur.[17] Curriculum slippages are small distortions between the initial ideal (and often idealised) curriculum and the curriculum as it is experienced by the learner. The *ideal curriculum* is the initial curriculum as it was envisioned during the planning phase. Planners attempt to capture this ideal in paper form, and this written version becomes the *formal curriculum* in all policy documents. The *perceived curriculum* is created from the *formal curriculum* when textbook authors and publishers interpret the policy documents in their own way. The textbooks and lesson plans from publishers are used in the classroom and the *enacted curriculum* becomes the *experienced curriculum* as learners participate in the learning environment.[17]

Scientifically incorrect statements (or *manifest errors* – errors that are obvious and easily identified) were found in every document analysed

in all three text-analysis studies. These studies included the formal curricula – Natural Sciences Learning Statement (Grades R–9, with Grades 7–9 analysed by two different authors)[9] and the Life Sciences Subject Statement (Grades 10–12)[10] – as well as perceived curricula – eight recommended Life Sciences textbooks in total[5,14,17].

Manifest (or actual) errors in curricula or support material were commonly characteristic of one of two alternative frameworks: 'evolution on demand' and 'survival of the fittest'. An alternative framework is an unscientific way of thinking that can generate many different individual misconceptions.[14,17]

'Evolution on demand' is characterised by teleological (explaining phenomena by the purpose they serve rather than their actual causes) and anthropomorphic (attributing human characteristics and behaviour to objects or animals) thinking. Five common unscientific ideas about adaptation fall into this framework[14]: (1) changing food types or environments cause evolution to occur; (2) individuals evolve (3) within their lifetime and (4) they decide to undergo these changes because they know the changes will be favourable; and 5) this evolution occurs in order to prevent extinction.

The alternative framework 'survival of the fittest' implies that[14]: (1) only the fittest, or those with favourable adaptations, survive; (2) less favourably adapted organisms will die or become extinct; (3) only the fittest will reproduce, while those not considered fit cannot reproduce; (4) all the offspring of those with favourable traits will inherit the favourable traits; and (5) the whole population will eventually be made up of only individuals with favourable traits. In addition to these manifest errors, in very few of the texts, was identification of common misconceptions attempted, despite having multiple opportunities to do so.[14]

More dangerous than the obvious and easily identifiable manifest errors, are *latent errors*. Latent errors are not errors per se, but rather seemingly harmless statements that might be misinterpreted by readers and thus contribute to the development of true misconceptions. Latent errors can result from the way the text is structured, as is the case with fragmentation and sequencing issues, or they can emanate from misleading and improper use of language.[17]

Text analyses have shown that the curricula and supporting material that underpin learning of evolution are fragmented into different phases and strands, which inhibits learners from understanding evolution holistically.[5,14,17] Evolution topics are also unequally distributed in difficulty, especially across Grades 10–12.[8] In addition to curriculum fragmentation, is the problem of inappropriate sequencing, where the concepts required to understand evolution are not addressed in a logical order, in addition to being fragmented.[14,17]

The concept of evolution by natural selection was originally formulated by using the consilience of inductions.[5] The consilience of inductions is an important skill for learners to master, not only in order to understand the theory of evolution, but also in order to guide their own logic of thought. Learners who are subjected to a fragmented curriculum and are not equipped with the skills necessary to perform the consilience of inductions will inevitably fail to create holistic mental models (schema) in order to correctly incorporate evolution into their knowledge base.[5] Language-related latent errors include poor to incomplete explanations and misleading wording, especially the use of paradoxical jargon (or risk terms), metaphors and euphemisms.

Misleading wording conveys inaccurate ideas which can lead to the formation of true misconceptions. This scenario occurs when a word has two meanings: one everyday and one specific to the science of evolution – these are called *risk terms*. Two examples of these risk terms are 'organism' and 'adapt'. Individual organisms do not adapt to their environment.[14] Rather, individual organisms can *acclimatise* or *adjust* to their environment within a single lifetime, while populations *adapt*, over many generations. Textbooks and learning material often imply that individual animals can choose to change to fit into their environment in an attempt to survive (as is seen in the 'evolution on demand' alternative framework). This implies that individual organisms have internal agency and believing this can lead to teleological misconceptions.[16] Use of these risk terms are often latent errors, but when used consistently without explanation, can contribute to manifest errors in the text.

Metaphors are commonly used to draw parallels between situations and euphemisms are used to avoid terms that might seem blunt or offensive. In their analyses, Dempster and Hugo[5] found that the word 'evolution' is specifically avoided in favour of terms like 'change' and 'development' until Grade 12, when considerable time is allocated to the topic (25% of the Life Sciences curriculum). They note that learners are taught the principles of evolution early on, without appreciating that they are learning about evolution.[5] Up until their last year of school, Life Sciences learners are therefore unaware that they have learnt about evolution at all. By denying learners meaningful access to higher-order thinking skills, the social justice imperative stated in the National Curriculum Statement is undermined.[5]

Perspectives from teaching and learning

Life Sciences teachers in South Africa are averse to teaching evolution mainly because they lack the content knowledge to do so and they are concerned about the controversial nature of the topic, specifically as it relates to religion.[11] Some teachers experience a conflict between their own religious beliefs and the requirement to teach evolution and some are worried about parents' and students' attitudes towards evolution.[3,4,11] Teachers in religious schools especially are faced with anti-evolution policies.[11,20] As a result of poor evolution education in schools (and before 2008, no evolution education in state schools), students arrive at university without adequate prior content knowledge or scaffolding on which to build learning of evolution, further complicating higher instruction.[4] Without proper teacher education, the legacies of Social Darwinism and a general mistrust in science will prevail in South African society.[4,5]

Teachers are unequipped to teach evolution

The Department of Basic Education has established various teacher training programmes since evolution entered the Life Sciences curriculum. One such programme was conducted by Sanders and Ngxola[11], who used a convenience sample of 125 secondary school Life Sciences teachers from a series of workshops designed to prepare them to teach evolution for the first time. They found that many teachers, schools and entire school districts simply omitted subject areas with which they felt uncomfortable. From one of these workshops emerged the disturbing admission that almost half of the 70 Grade-11 teachers in attendance omitted genetics from their teaching. Genetics is a topic that is poorly understood by many South African teachers and is not externally examined.[11] Teachers attending these workshops – actively practising teachers – knew that they were unequipped to teach evolution.

In a survey of student teachers who were not yet practising educators, 70% of respondents considered themselves prepared to teach evolution, even though the data show that they did not understand evolution or even the nature of the science well enough to teach it.[3] Many respondents held common misconceptions about evolution, such as: evolution is the purposeful development of higher forms; or humans developed from other primates like chimpanzees and gorillas.[3]

Teachers are afraid of controversial subjects

Not only do teachers themselves not have the subject knowledge to teach evolution (whether they realise it or not), but they also face the ever-present concern that evolution is a controversial topic.[1,11] Controversy is generally seen in a negative light because of the conflict it might cause. However, the ability to discuss controversial topics in a logical, respectful and insightful manner forms a cornerstone of democracy. South Africa's democracy is relatively young, and in many aspects still incomplete. True democracy requires an informed citizenry, in which individuals are capable of making wise and informed choices and behaving in a democratic manner in their daily lives.[1]

As with the lack in content knowledge, South African teachers are not trained to facilitate the discussion of controversial topics in the classroom. Indeed the complete avoidance of the topic of evolution, along with other

controversial topics such as race, sexuality, sex education, corporal punishment and xenophobia reflects this inability.[1,14,17]

Two major obstacles identified by teachers in regard to facilitating discussions about controversial topics are (1) the limited time allocated to teach and (2) the methods of assessment used to gauge learning.[1,11] Very little time is afforded to educators to ensure that all the curriculum content is covered – content which is later assessed through high-stakes assessments. In interviews with teachers and students at schools in South Africa and those in England, Chikoko and colleagues[1] found that schools and universities are likened to factories in which time constraints and standardised assessments produce graduates like products on a factory line. Both students and teachers are afraid to broach controversial issues in the classroom for fear of persecution. From the students' perspective, they might lose marks they need to achieve a pass in a subject. Teachers, on the other hand, want to maintain a closed and safe environment for fear of legal action from students, the school or parents.[1] Such an environment is non-conducive to open discussion and sets a bad example of democratic behaviour.

Contention with religion

A worldview is the lens through which we see the world and the filter through which we process information. A person's worldview predisposes them to a specific way of thinking that is constructed through life experiences.[13,19,20] Worldviews are generally subconscious, culturally dependent and non-rational.[13] They form the fundamental organisation of a person's mind and create the assumptions that predispose a person to think, feel and act in a predictable manner.[13] A person's worldview determines how they will gauge the plausibility of an assertion, thus providing a *plausibility structure* of ideas, activities and values.[21] *Confirmation bias* is when a person values evidence that reinforces beliefs already held and ascribes more legitimacy to experts who agree with them and share their beliefs. People are predisposed to reinforce their connection with those with whom they share important commitments and to reject claims that might separate them from their peers.[13]

Science and religion influence the way in which people view the world. A theistic worldview is often built on a framework of faith-based, absolute and unchanging knowledge from a higher power or creator. In contrast, the worldview that underpins science is generally inherently materialistic and requires observation and iterative empirical testing to produce knowledge that is, in turn, constantly subjected to doubt. It is, however, possible to accept two opposing worldviews at the same time. Conversely, someone might reject an idea as untrue simply because it opposes their worldview.[19]

Sanders and Kagan[20] use the framework of border crossing to explore the understanding and acceptance of evolution among Grade-12 students in a Jewish school. Border crossing is an apt framework to use when one considers science and religion as two different worldviews: these religious students entering a science classroom have to transition from their personal and familiar worldview to that prescribed by science, analogous to crossing the border from one's country to another. The greater the divide between the student's own personal worldview and the scientific worldview, the more challenging the border crossing becomes. Sanders and Kagan[20] use a framework with four types of border crossing, depending on the level of difficulty students face during the transition from one worldview to the other: (1) a *smooth transition* is characterised by a student who can cross the border between worldviews with ease; (2) a *managed transition* is when a student requires some adjustment to their worldview as they move into the world of science but still copes with the transition; (3) a *hazardous crossing* is when a student finds the transition extremely difficult, but still manages to cross; and (4) an *insurmountable* crossing is when a student finds the transition impossible because the value systems between the worldviews are too different.

People are generally able to distinguish between scientific and religious worldviews and a person does not need to abandon a personal worldview in order to function within a scientific worldview.[16,18,20] Although religious people might find the border crossing into a scientific worldview hazardous or insurmountable, they might still be able to maintain their own worldview outside of the science classroom. Research has consistently shown that it is possible to believe in different, contradicting, ideas at one time.[13,18] Even though an acceptance of evolution is positively correlated with understanding evolution, it is not necessary. A person can understand evolutionary theory without accepting it as true. Conversely, a person can accept evolution but not understand it.[13]

Anderson[18] examined the effect that evolutionary teachings had on students' views of god as creator and found that the teaching of evolution increased students' knowledge of evolution over a 3-year period and that it decreased students' susceptibility to logical fallacies. They also found that a belief in 6-day creationism dropped significantly in their student sample, although a belief in god as creator remained stable. Although they do not provide recommendations for teaching evolution, they do recommend that religious leaders 'do not attack evolution'[18], citing that this may heighten the perception that simultaneous beliefs in god and in evolution are incompatible. They also recommend that the Bible's version of the origin of earth should not be taught literally and that fundamentalist Christians might be at risk of losing their faith, because a literal belief in the Bible is inconsistent with the facts of evolution.[18] Anderson's[18] final recommendation advocates for an integration of evolutionary theory and faith, called theistic evolution.

Three major categories of misconceptions are formed when the theory of evolution is integrated within a faith-based religious system: essentialism, teleology and intentionality.[13] Essentialism is the belief in immutable categories or kinds – the idea that every individual belongs to a discrete and rigidly defined category based on observable properties that stem from unobservable causes; the properties are fixed, unchangeable and transmitted from parent to offspring.[13] Teleology is the idea that the form of a thing is needs based; that it was designed with a purpose in mind. Teleology explains phenomena by the purpose they serve rather than their actual causes.[13,14] And finally, intentionality is the assumption that events are purposeful and goal directed and that they are caused by intentional agency.[13]

Moore et al.[16] studied the language used when learning about evolution, employing a phenomenology-based probe to investigate the conceptions of a group of first-year university students who had not yet received any instruction in evolution. Moore and colleagues recognised that students tended to ascribe agency to the random processes of evolution – a common misconception in learning evolution. Two types of agency exist: internal agency describes when an organism drives its own change in a chosen direction, while an outside force, usually an omnipotent deity, dictates external agency.[16] In contrast to other studies, Moore et al.[16] found that students often ascribed internal agency to individuals in the language they used to describe evolution. These results are similar to those found by Sanders and Makotsa[17], who noted that this type of latent error and paradoxical jargon can lead to the development of true misconceptions about evolution.

Figurative language is potent because it may convey meaning over different contexts. This plasticity, however, carries the capacity to distort meaning.[16] Students are often unable to distinguish between the subject-specific shorthand or paradoxical jargon of a scientific field and the everyday use of figurative language.[17] Moore et al.[16] recognise the need to tailor and regulate the language and vocabulary used to teach evolution, especially when scaffolding upon terms and concepts that students already know. Employing anthropomorphised or teleological language, even figuratively, results in misunderstandings in learning.

Abrie[3] studied student teachers' attitudes toward, and willingness to teach, evolution in a changing South African environment. The sample included student teachers with no prior exposure to evolution (those graduating from National Curriculum Statement schools before 2008) who learnt about and had to teach evolution after they graduated. These student teachers were largely religious and rejected the theory of evolution. Despite their low acceptance of evolution, most (76%) agreed that it was important for Life Sciences teachers to understand the subject. Survey respondents felt that they should have the choice to not teach evolution (63%) and that learners should also be able to choose to learn evolution (44%). Only 42% of student teachers in Abrie's[3]

study thought that evolution should be a compulsory part of the Life Sciences curriculum. In contrast, 63% of student teachers supported the compulsory teaching of religion and 50% of respondents felt that evolution should be taught alongside creationism and intelligent design.

Abrie[3] also noted that deeply held religious beliefs are likely retained after instruction, even at the level of higher education, and will influence the way in which student teachers teach evolution to schoolchildren. There is no guarantee that National Curriculum Statement guidelines will be followed, and as has already been evidenced, some teachers choose to ignore the topic entirely.[3,11] This neglect has severe repercussions on student learning and achievement, especially considering that, since 2008, the higher grades are externally examined and that half of the second Life Sciences examination (25% of the Life Sciences syllabus in Grade 12) consists of content relating to evolution.[5]

In South Africa, many bridging programmes exist to remedy the lack of entry-level knowledge that students attending university are required to have. Waetjen and Parle[4] provide some reflexive insights into the practicalities of teaching evolution as part of such a bridging course called 'Africa in the World', presented in the Humanities Faculty at the University of KwaZulu-Natal. The reflective nature of Waetjen and Parle's[4] article allows them to disclose rich data about their experiences in teaching evolution. They note that African students are especially averse to learning about evolution because the topic is seen as 'Westernised science' that goes against their belief system. The irony, pointed out by the researchers, is that, beyond ancestral beliefs, the belief system in question (Christianity) is a consequence of colonisation.

The legacy of Social Darwinism

Among the difficulties of teaching evolution is the legacy of Social Darwinism, which is particularly difficult to overcome in South Africa where racialised politics have tainted the reputation of evolutionary science. Social Darwinism is the application of the concepts of natural selection to human societies. This application increases the problem of teaching evolution correctly in order to dispel harmful myths, misconceptions, prejudice and stereotypes. If discussed in class (or any environment for that matter), the topic of human origins, combined with racialised politics and an overwhelmingly fundamentalist Christian belief system, often creates heated debate.[4]

Even when using endemic examples of human fossils and highlighting the evolutionary importance of the African continent, negative portrayals of Africa and its people have left a legacy that is a significant barrier to understanding human evolution. South Africa has claim to the Cradle of Humankind, but researchers report that students see this type of publicity as an attempt to assert the 'primitiveness' of African people – a difficulty that might be overlooked when teaching evolution.[4] Some students felt that the facts of evolutionary theory portrayed African people as 'closer' to earlier species of *Homo* and instructors were accused of saying that 'Africans were closer to ape ancestors because they were still in Africa'[4]. Paradoxically, some students of the 'Africa in the World' course interpreted the adaptations of humans and their origins in Africa to mean that '…the "out of Africa" thesis was an indication that the only "pure race" was the "black man" and that "all other races" were derivatives'[4].

In order for South African democracy to function effectively, our citizenry needs to be able to celebrate social, political and biological diversity, with mutual respect and the understanding that all people, as human beings, have equal social and political rights.[1] In addition, South Africans should be able to analyse information critically, respect the evidence when forming their opinions and be willing to change their minds when presented with new and valid information.[1]

Accepting evolution

Research has shown that the views, opinions and attitudes that teachers have about a subject affect their curricular and instructional decisions. On the one hand, teachers might spend less time on a subject they do not care about, or go as far as to ignore it entirely if they feel strongly.[11] Students, on the other hand, might avoid learning about subjects they disagree with or find uninteresting.[8]

The Measure of Acceptance of the Theory of Evolution Instrument (MATE) is a well-known and often-used validated Likert-scale survey that assesses the acceptance of evolutionary theory, originally among teachers and later among students.[22] The MATE has since been updated by Cavallo and McCall[23], who added items to evaluate learner perceptions of the theory.

Mpeta and colleagues[19] used the updated MATE to assess the acceptance of evolution among Grade-12 Life Sciences students in the Vhembe District of the Limpopo Province. They found that, although most of the respondents in their sample subscribed to some form of religious worldview, almost half of the students accepted the theory of evolution as scientifically valid.[19] However, some students experienced a hazardous or even insurmountable border crossing; so opposed were they to evolution that they had no interest in learning about it. Other learners stated that their faith had weakened since learning about evolution. These results are similar to those of Anderson[18] who found that fundamentalist Christians might have trouble learning about evolution because the facts of evolution contradict their doctrine.

Chinsamy and Plaganyi[15] investigated the success of a first-year course in evolution (16 lectures, 94 students) at the University of Cape Town using a before-and-after questionnaire. Many students in their study found the evolution content interesting but were concerned with how the theory would challenge their religious views. Although an overall increase in student understanding of evolution was noted, the researchers found no statistically significant change in the acceptance of evolution.

Recommendations

In terms of recommendations for improving texts associated with teaching and learning evolution, the categorisation used by Tshuma and Sanders[14] is useful. The following list synthesises the problems identified and recommendations given in order to amend inaccurate and misleading texts in evolution education.[5,14,17]

Manifest errors:

- **Inaccuracies:** Scientific facts and terminology need to be accurate and up to date and should not include *manifest errors* (obvious and easily detectable inaccuracies).[5,14,17]
- **Not pointing out common misconceptions:** Textbooks should include a section about the misconceptions commonly associated with the mechanics of evolution and about evolution as it is seen by society.[14]

Latent errors:

- **Language errors:** Facts and processes need to be explained in scientific language, with few or no latent errors. The text should make accommodations where such errors might occur, by explaining the meaning of the terms in the correct context. Focus should be given to language differences when translating explanations into a different language might lead to latent errors.[17] Teachers should:
  - Be aware of **paradoxical jargon or risk terms** (words with more than one meaning – one everyday and one scientific, such as adapt, theory, fitness), where the scientific meaning is meant, but the everyday meaning might be used for interpretation, leading to latent errors.[14,17]
  - Avoid **metaphors** (figures of speech that use non-literal terms to represent comparable concepts), because they are open to multiple interpretations.[14]
  - Avoid **euphemisms** (milder alternatives to words that might be considered offensive), because learners might not realise that the euphemism is being used instead of another term. The word evolution is often avoided altogether, in favour of terms like 'change' and 'develop'. Learners do not realise they are learning about evolution at all, which contributes to concept fragmentation.[14,17]

- **Inadequate and poorly worded explanations:** Inadequate explanations occur when a key text lacks the information necessary for full understanding of a concept.[14,17]
- **Fragmentation:** Curriculum fragmentation should be kept to a minimum and the concepts needed to understand evolution need to be covered holistically. Evolution by natural selection should be taught as a single concept and not obscured by fragmentation in order to cultivate acceptance and foster political correctness.[5,14,17] Fragmentation includes:
  - **Not facilitating the consilience of inductions:** Learners should be taught how to form logical links between seemingly disparate topics such as geology and embryology, in order to prevent the creation of true errors (where learners integrate scientific facts into their own schema incorrectly, thereby forming misconceptions that are difficult to overcome).[5]
- **Inadequate sequencing:** The facts and concepts involved in evolution by natural selection should be covered in a logical format in such a way that learners can form meaningful links between concepts.[5,14,17]

Teacher content knowledge:

- Specific courses in evolution and the nature of science should be a requirement with supplementary training for teachers not previously exposed to the theory.
- Detailed instructional material should be made available to all teachers. This material should be prepared by professionals with knowledge about evolution and its misconceptions and good instructional practices for its teaching.
- Teachers should be knowledgeable about common misconceptions and logical fallacies, in order to filter learning material and diagnose misconceptions held by students.

Discussion of controversial issues:

- Teachers should be trained in how to facilitate discussion around controversial issues, particularly with the values of democracy in mind.
- Discussion has been proposed as an effective way of teaching the skills necessary to conduct a fair and informed debate and as a way to deal with issues of conflict.[1,11] A well-facilitated discussion is also beneficial to encourage students to engage with the content and to create an exciting, interactive and supportive learning environment.[15]
- Students are more accepting of facts than of processes, and improving the reasoning ability of students might improve their ability to grasp the processes involved in evolution.[15]

Conclusions

Evolution is a vital component of scientific literacy. It provides an explanatory framework in which to understand the complexity and diversity of life on earth and the relationships between organisms, populations and species. The theory is a powerful unifying theme that links concepts from different fields of science from biology to geology. There are various practical applications of evolutionary theory to human life, notably advancements in medicine to combat constantly evolving pathogens and understanding human diversity.[5,20]

Understanding evolution, especially human evolution, is essential to South Africa's growing democracy.[1] Controversial subjects, if taught correctly, instil upon learners the knowledge and skills they need to conduct fair, logical and democratically sound arguments. Understanding human variation is also the first step to respecting the heterogeneous nature of South African society, and can be achieved by designing and implementing proper educational strategies.[2]

A lack of scientific literacy – through choice or chance – allows for the continuation of racial stereotypes and deprives everyone of the knowledge and mechanisms of thought to counter these misperceptions.[4]

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Authors' contributions

C.S.: Conceptualisation; methodology; writing – initial draft; writing – revisions. E.N.L.: Student supervision; writing – revisions.

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