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CURRICULUM AND EDUCATION ARTICLE

Assessing "The Framework" for Kindergarten Through Fifth Grade Biological Evolution

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The Framework

The National Science Education Standards (National Research Council 1996) was one of the most influential documents in the history of United States (U.S.) science education and guided science educators for well over a decade (Carin et al. 2005). In early 2010, experts in education and science came together to develop a new document that identified "the key scientific practices, concepts and ideas that all students should learn by the time they complete high school" (National Academies 2011). In July of 2011, this document entitled, "A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas"[1] (National Research Council 2011), was released (National Academies 2011).

"A key purpose for the framework is to serve as the basis for new science education standards" (National Academies 2011). The framework is also meant to be utilized by science education curriculum and assessment developers, preservice teacher programs, and those that construct professional development materials—district and state science supervisors and those that work in informal science education settings (National Academies 2011). "The framework lays out broadly the core ideas and practices that students should learn, and the standards will build upon that foundation, explaining in detail what students should learn at various grade levels" (National Academies 2011). Now that the framework has been completed, the development of the new standards (i.e., Next Generation Science Standards [Achieve Inc. 2011]) will be led by a group of states coordinated by Achieve Inc. (2011), a nonprofit education organization (National Academies 2011). "The release of the Next Generation Science Standards is expected in Fall 2012, with public drafts available in winter 2011/12 and summer of 2012" (Achieve Inc. 2011). When the standards are complete, states will voluntarily adopt the standards to "guide science education in their public schools" (National Academies 2011).

Kindergarten Through Fifth Grade Biological Evolution Content in the Framework

The framework presents science content in physical sciences, life sciences, Earth and space sciences, and engineering and technology. Under each major scientific area (e.g., life sciences) the content is divided into grade categories. These categories are "By the end of grade 2" (average age, 8 years old); "By the end of grade 5" (average age, 11 years old); "By the end of grade 8" (average age, 14 years old); and "By the end of grade 12" (average age, 18 years old). The categories denote the science content students should learn by the end of a given grade (National Research Council 2011).

The vast majority of the biological evolution content is presented in the life science area (National Research Council 2011, p. 6–15 to 6–21) with a minimal amount occurring in the Earth science area (National Research Council 2011, p. 7–6 and 7–14). Biological evolution and/or mechanisms of biological evolution (e.g., natural

[1] Henceforth referred to as the framework. Note that "A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas" can be download for free at http://www.nap.edu/catalog.php?record_id=13165.

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selection) are presented in both the "By the end of grade 8" and "By the end of grade 12" categories in the life science area. Foundational concepts that *can* be built upon to understand specific biological evolution concepts are presented in the "By the end of grade 2" and the "By the end of grade 5" categories, but there are *no* references to biological evolution or any mechanisms of biological evolution in *either* of these elementary categories (National Research Council 2011, p. 6–15 to 6–21).

For example, in the "LS4.A: Evidence of Common Ancestry and Diversity" section (National Research Council 2011, p. 6–16) in the "By the end of grade 2" category it is stated that "Some kinds of plants and animals that once lived on Earth (e.g., dinosaurs) are no longer found anywhere, although others now living (e.g., lizards) resemble them in some ways" and in the "By the end of grade 5" category it is stated that "Fossils can be compared with one another and to living organisms according to their similarities and differences." These are examples of foundational concepts that *can* be built upon to understand specific biological evolution concepts (e.g., common ancestry) but these are *not* biological evolution concepts. This same trend is observed in the other three life science sections (i.e., LS4.B: Natural Selection; LS4.C: Adaptation; LS4.D: Biodiversity and Humans [National Research Council 2011, p. 6–17 to 6–19]) and the two Earth science sections (i.e., ESS1.C: The History of Planet Earth [National Research Council 2011, p. 7–6]; ESS2.E: Biogeology [National Research Council 2011, p. 7–14]) that address biological evolution. In conclusion, when assessing the framework as a whole, *no* biological evolution content exists at the kindergarten through fifth grade level.

Other Biological Evolution Issues of Concern in the Framework

Three other biological evolution issues of concern are also present in the framework that are worthy of mention. First, under the "LS4.A: Evidence of Common Ancestry and Diversity" section in the "By the end of grade 2" category it is stated "Some kinds of plants and animals that once lived on Earth (e.g., dinosaurs) are no longer found anywhere, although others now living (e.g., lizards) resemble them in some ways" (National Research Council 2011, p. 6–16). This statement is incorrect. Birds are avian dinosaurs and they are extant. Second, there is no mention of genetic drift anywhere in the framework even though genetic drift is one of the basic mechanisms of biological evolution. High school students (i.e., in the "By the end of grade 12" category) should have the opportunity to learn about genetic drift to fully understand biological evolution. Third, there is no mention anywhere in the framework of human biological evolution. *Homo sapiens* are a product of biological evolution. Students should learn, in their kindergarten through twelfth grade educational experience, about how our species arose and the mechanisms that have produced humans.

As a side note, it should also be pointed out that in the "LS4.D: Biodiversity and Humans" section (National Research Council 2011, p. 6–19) in the "By the end of grade 12" category the current anthropogenic impacts of human activity (e.g., Millennium Ecosystem Assessment 2005; Tripati et al. 2009; World Wide Fund for Nature 2010) is mentioned and the current great mass extinction (e.g., Jackson 2008; Wake and Vredenburg 2008; Zalasiewicz et al. 2010) is hinted at.

The framework states "But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. These problems have the potential to cause a major wave of biological extinctions—as many species or populations of a given species, unable to survive in changed environments, die out—and the effects may be harmful to humans and other living things" (National Research Council 2011, p. 6–19).

This addition is applauded but, considering the gravity of the global environmental situation, students should be exposed to this content at all grade levels to become active participants in reducing our current level of degradation of the biosphere (Wagler 2011a) and to understand how human activity is impacting biological evolution (Wagler 2011b).

Why Should Elementary Students Learn about Biological Evolution?

Biological evolution produces all species (i.e., speciation) and changes them over time. As such, it is the central unifying theme of the biological sciences (Dobzhansky 1973; Gould 1999). If we are to *fully* understand *anything* about *any* species, we must first know how it was produced (i.e., via biological evolution), how it has changed (i.e., via biological evolution), and how it is currently being changed (i.e., via biological evolution). This fact applies to all of biology education whether it is an elementary student learning about a spider in a deciduous forest, a middle school student learning about amphibian genes, or a high school student learning about human DNA polymerase. The knowledgeable and highly esteemed evolutionary biologist Theodosius Dobzhansky illustrated this concept best when he said "Seen in the light of evolution, biology is, perhaps, intellectually the most satisfying and inspiring science. Without that light it becomes a pile of sundry facts–some of them interesting or curious but making no meaningful picture as a whole" (Dobzhansky 1973, p. 129). When elemen-

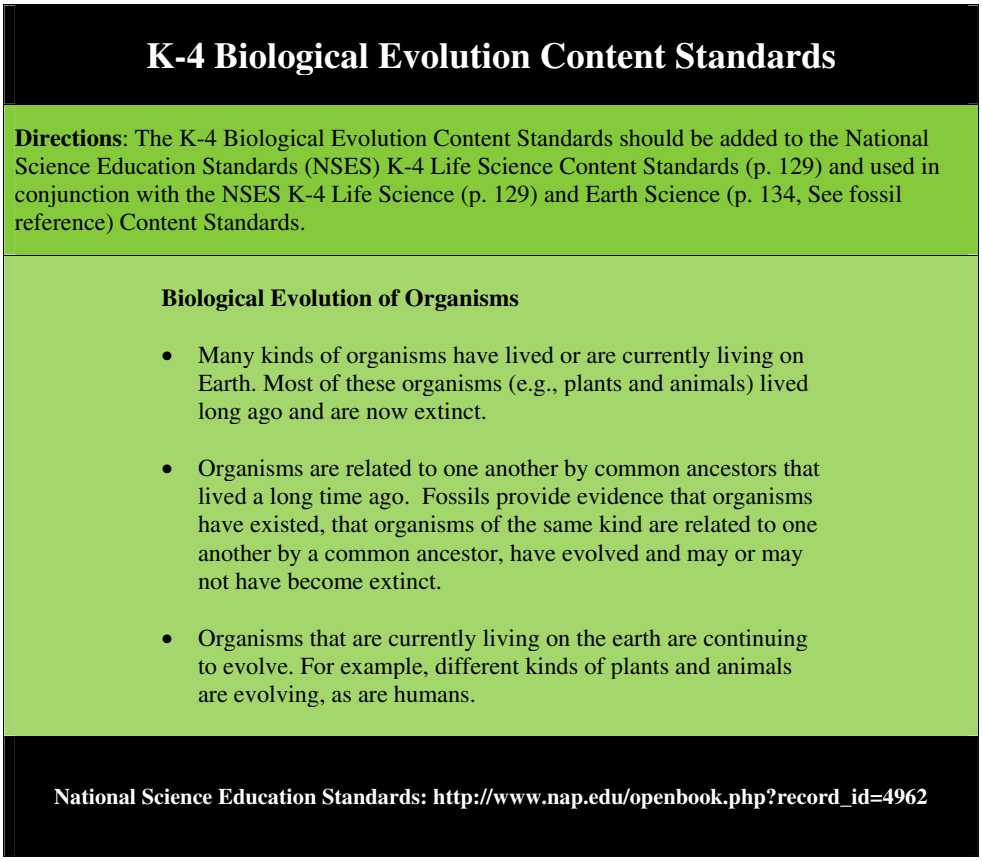

Fig. 1 K-4 Biological Evolution Content Standards. Note that Fig. 1 has been modified and reproduced with permission from Wagler (2010)

tary students do not *learn* about biological evolution along with other biology content they miss the *complete* picture of all past and present life because biological evolution produced this life. This lack of exposure to evolution in the elementary grades impacts students' educational success when they are introduced, in middle school and high school, to the complex interactions of organisms and environments since biological evolution is an indivisible component of these interactions. As a result, the students' overall long-term biological development (i.e., knowledge and application of that knowledge) is impacted by the lack of biological evolution knowledge that was not presented in their elementary classroom.

The Cognitive Readiness of Young Children to Learn Biological Evolution

Past beliefs doubting young children's ability to think abstractly, sometimes used as an argument for not teaching biological evolution to children, have been shown to be unfounded (e.g., Carey 1985; Gelman and Baillargeon 1983; Gelman and Kalish 2005; Keil et al. 1998; Metz 1995; Nadelson et al. 2009[2]; National Research Council 2007; Toyama 2000). "Contrary to conceptions of development held 30 or 40 years ago, young children can think both concretely and abstractly" (National Research Council 2007, p. 3). Young children "are able to reason in ways that provide a foundation for scientific thinking, including potential precursors of modeling, designing experiments, and reasoning about theory and evidence" (National Research Council 2007, p. 81). This is the case, whether that theory is the theory of gravity or the theory of biological evolution. Furthermore, recent research has shown that when third graders are taught the biological evolutionary origins and biological evolution of nonhuman and human animals, they begin to incorporate this knowledge into their responses about speciation (Berti et al. 2010).

[2] For further research related to the cognitive readiness of elementary children and their ability to participate in classroom activities [i.e., biological evolution] that may require abstract thought see Nadelson et al. (2009).

Teaching Biological Evolution in Elementary School

Recently, supporting materials have emerged from both science educators and science education researchers encouraging the teaching of biological evolution at the elementary level in U.S. schools. These materials include (but are not limited to) elementary biological evolution education research (e.g., Au et al. 2008; Nadelson et al. 2009; Prinou et al. 2011; Solomon and Johnson 2000; Venville and Donovan 2007), research-based position papers calling for the teaching of evolution in elementary schools (Hermann 2011), elementary biological evolution education resources (e.g., Understanding Evolution 2011), and elementary biological evolution education curricula (e.g., Chanet and Lusignan 2009; Eldredge and Eldredge 2009; Understanding Evolution 2011).

Furthermore, because the National Science Education Standards (NRC 1996) did not provide national biological evolution content standards for kindergarten through fourth grade, biological evolution content standards were developed that could be used in conjunction with the National Science Education Standards K-4 life science and K-4 earth science content standards (NRC 1996) (see Fig. 1). For a full review of the K-4 biological evolution content standards including examples of integration activities using the K-4 biological evolution content standards and supplemental teacher information for the K-4 biological evolution content standards, see Wagler 2010.

A Respectful Request

Considering the future influence the Next Generation Science Standards will have on local schools, school districts, state departments of education, national curriculum groups, and many other entities, the author respectfully requests that the developers of the Next Generation Science Standards:

1. Assess the complete body of indirect and direct research associated with the cognitive readiness of young children to learn biological evolution and
2. Based on this assessment, utilize the presented elementary biological evolution supporting materials (and others) to develop kindergarten through fifth grade biological evolution content standards for the Next Generation Science Standards.

Conclusion

Young children possess the cognitive abilities necessary to learn biological evolution while in elementary school (e.g., Berti et al. 2010; Carey 1985; Gelman and Baillargeon 1983; Gelman and Kalish 2005; Keil et al. 1998; Metz 1995; Nadelson et al. 2009; National Research Council 2007; Toyama 2000). Many elementary biological evolution education supporting materials exist that can assist the developers of the Next Generation Science Standards in developing kindergarten through fifth grade biological evolution content standards for the Next Generation Science Standards (e.g., Au et al. 2008; Chanet and Lusignan 2009; Eldredge and Eldredge 2009; Hermann 2011; Nadelson et al. 2009; Prinou et al. 2011; Solomon and Johnson 2000; Understanding Evolution 2011; Venville and Donovan 2007; Wagler 2010). The recommendation from the framework, as the basis for the Next Generation Science Standards, is to not teach biological evolution to kindergarten through fifth grade students in the U.S. Instead, the framework recommends that the first time U.S. students learn biological evolution content is in sixth grade. Let us hope that the developers of the Next Generation Science Standards will consider the author's respectful request. If kindergarten through fifth grade biological evolution content standards are not included in the Next Generation Science Standards, U.S. elementary children may very well experience firsthand Theodosius Dobzhansky's claim that "nothing in biology makes sense *except* in the light of evolution" (Dobzhansky 1973, p. 125).

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