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Evolution: Education and Outreach

CURRICULUM AND EDUCATION

A state-by-state comparison of middle school science standards on evolution in the United States

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Abstract

The focus of this study is a state-by-state comparison of middle school science standards on evolution in the United States. In 2009, Louise Mead and Anton Mates reviewed the high school science standards on evolution, giving each state a grade based on multiple factors including the number of times the word "evolution" is mentioned, the types of evolution covered, and the inclusion of creationist jargon (Mead and Mates in Evol Educ Outreach 2:359, 2009). Their study was a replication of an earlier one completed in 2000 by Lawrence Lerner and the Thomas B. Fordham Foundation (Lerner in Good science, bad science: teaching evolution in the states. Thomas Fordham Foundation, Washington, 2000). Mead and Mates indicated that, on average, the quality of the standards had increased over the decade between studies. This study concludes that this positive trend is now evident in the middle school science standards across the nation. We propose that early evolutionary education will be an excellent indicator of future acceptance of evolution across the United States and strongly encourage that evolution be introduced as the underlying theme of biology early in a student's academic career.

Keywords: Evolution, Natural selection, Curriculum, Standards, Next Generation Science Standards NGSS

Introduction

The middle school standards of a state can provide meaningful insight into the future of the general public's understanding of evolutionary science. While there is no way to determine exactly what kind of an impact high-quality science standards will have on the future literacy of students, state and national standards "provide a framework to which everything else is attached" (Lerner 2000). High-quality standards do not guarantee that evolution will be taught well, but educational standards are used by textbook and testing companies to develop educational materials, therefore driving instruction.

We propose that early evolutionary education will be an excellent indicator of future acceptance of evolution across the United States and strongly encourage that evolution be introduced as the underlying theme of biology as early as possible in a student's academic career.

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State and National Science Standards

There are number of strong reasons to have a classroom curriculum based on standards. Standards set clear learning goals for children. Teachers are trained in their district, using state or national standards as a common reference tool. Without standards, it would be difficult for a teacher to assess student understanding of his/her students when compared to other students. Standards also provide a rubric to determine which students are not meeting the learning goals set by the standards. Teachers can intervene with appropriate strategies to help these students meet the set expectations. In addition, standards provide school districts with a framework for the organization of course content and instruction. For example, standards are used to develop activities to deepen student understanding. There is no doubt that parents, who are clearly important stakeholders in their children's education, can also benefit from a familiarity with the instructional standards their children will be expected to achieve throughout a school year (Harris and Carr 1996).

As stated by the non-profit foundation Great Schools, "Without standards, districts and schools don't have goals to shoot for. By matching what is taught in the classroom to the standards in each subject area, students (and their parents and teachers) will know what teachers should be teaching, what students should be learning and what they will be tested on" (Great Schools 1999).

In addition, when it comes to evolution education, there are several more reasons that high-quality science standards are important. First, good standards "provide a critical resource for teachers who wish to teach evolution correctly." Second, high quality standards "provide important support for biology teachers facing protests from creationist students, parents, and administrators." And finally, "good state science standards can help to persuade administrators that the teaching of evolution is not a matter for political negotiations between parents and teachers but a clear educational necessity" (Mead and Mates 2009).

The process of developing and adopting new state standards varies from state to state. Usually, a committee of teachers, scientists, parents, and other stakeholders will be convened to write and review the standards. In many states, a period of public input is welcomed. When revising its math and language arts standards in 2013, for example, the Florida Department of Education welcomed public input through public meetings, a website with a comment form included, and an e-mail link for comments and questions (Florida Department of Education 2016). The national initiative that resulted in the Next Generation Science Standards has a permanent "Contact Us" link on its website for comments and questions (Next Generation Science Standards 2016).

The Next Generation Science Standards, NGSS

When it comes to middle school evolution standards, the NGSS are a great improvement over the science standards of several individual states. Therefore, it is important to discuss their inception and an explanation of how they are organized. In addition, as of the conducting of this review, September 28, 2016, 17 states have adopted the standards: Arkansas (so far only for middle school), California, Connecticut, Delaware, Hawaii, Illinois, Iowa, Kansas, Kentucky, Maryland, Michigan, Nevada, New Jersey, Oregon, Rhode Island, Vermont, Washington, and West Virginia, along with the District of Columbia (D.C.). As a result, the NGSS will very likely have a major impact on the teaching of evolution in this country.

The idea for the NGSS began in 2009, when a commission formed by the Carnegie Foundation concluded that "the nation's capacity to innovate for economic growth and the ability of American workers to thrive in the modern workforce depend on a broad foundation of math and science learning" (NGSS 2013).

The first step was the of development of *A Framework for K-12 Science Education*, this was managed by the National Research Council (NRC) of the National Academy of Sciences and funded by the Carnegie Foundation. The NRC put together a committee of 18 practicing scientists, Nobel laureates, cognitive scientists, science education researchers, and science education standards experts. The NRC also used design teams of scientists and education specialists in the fields of physical science, life science, earth/space science, and engineering to develop the *Framework*. To develop the *Framework*, they used the extensive research found in the fields of science teaching and learning and almost two decades of efforts to define the most foundational knowledge and skills for K-12 science and engineering.

The *Framework* provided a foundation for the NGSS by identifying the science all K-12 students should know and by drawing on research which highlighted how students learn science effectively. The final *Framework* was released in July of 2011.

The *Framework* was used as the foundation for the *Next Generation Science Standards* in a collaborative, state-led process that is managed by Achieve, an independent, nonpartisan, nonprofit education reform organization.

The development of the NGSS was a tremendous collaborative effort which included 26 US states, the National Research Council, the National Science Teachers Association, the American Association for the Advancement of Science, and Achieve.

The NGSS has three major categories, or dimensions. The first dimension is known as "Scientific and Engineering Practices." This dimension explains what scientists do with the knowledge they obtain through scientific inquiry. For example, students are expected to be able develop and use models, analyze and interpret data, and obtain, evaluate, and communicate information. The second NGSS dimension is called "Crosscutting Concepts." These are the overarching themes in all of the sciences. For example, patterns, energy and matter, and stability and change, just to name a few. Finally the third dimension is called the "Disciplinary Core Ideas." These are the big, important ideas found within or across the different areas of science. There are four Disciplinary Core Ideas under the Life sciences; one of them is "Biological Evolution: Unity and Diversity" (National Research Council 2013).

Evolution is elegantly described in the *Framework.*

Biological evolution: unity and diversity

Biological evolution explains both the unity and the diversity of species and provides a unifying principle for the history and diversity of life on Earth. Biological evolution is supported by extensive scientific evidence ranging from the fossil record to genetic relationships among species. Researchers continue to use new and different techniques, including DNA and protein sequence analyses, to test and further their understanding of evolutionary relationships. Evolution, which is continuous and ongoing, occurs when natural selection acts on the genetic variation in a population and changes the distribution of traits in that population gradually over multiple generations. Natural selection can act more rapidly after sudden changes in conditions, which can lead to the extinction of species. Through natural selection, traits that provide an individual with an advantage to best meet environmental challenges and reproduce are the ones most likely to be passed on to the next generation. Over multiple generations, this process can lead to the emergence of new species. Evolution thus explains both the similarities of genetic material across all species and the multitude of species existing in diverse conditions on earth—its biodiversity—which humans depend on for natural resources and other benefits to sustain themselves (National Research Council 2012).

In the middle school level of the Next Generation Science Standards, biological evolution: unity and diversity is divided into four sub-ideas: evidence of common ancestry and diversity, natural selection, adaptation, and biodiversity and humans.

LS4.A: evidence of common ancestry and diversity

- The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth.
- Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record, enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent.
- Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully-formed anatomy.

LS4.B: natural selection natural selection leads to the predominance of certain traits in a population, and the suppression of others.

- In *artificial* selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed onto offspring.

LS4.C: adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes.

ESS1.C: the history of planet earth.

- The geologic time scale interpreted from rock strata provides a way to organize earth's history. Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale.

Also included in the NGSS are "Performance Expectations," which describe what students at this level should be able to do once these standards have been mastered. These are as follows:

- MS-LS4-1. Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on earth under the assumption that natural laws operate today as in the past.
- MS-LS4-2. Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.
- MS-LS4-3. Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy.
- MS-LS4-4. Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment.
- MS-LS4-5. Gather and synthesize information about technologies that have changed the way humans influence the inheritance of desired traits in organisms.
- MS-LS4-6. Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time (National Research Council 2013).

Grading rubric

Before grading the national and state middle school science standards in the United States, we reviewed the high school science standards on evolution across the country. Those of higher quality were considered for their excellent content and clarity. The questions which naturally arose following this exercise were: What should the middle school standards on evolution include to help lay the foundation for a deeper study in high school and beyond? Do the Next Generation Middle School Standards on evolution meet these criteria? We answer them as follows:

First question: What should middle school standards on evolution include to help lay the foundation for a more in-depth study in high school and beyond?

- The idea that evolutionary theory is an important, underlying theme in biology.
- The concept of natural selection and the conditions necessary for natural selection to take place.
- The understanding that the evidence for evolution comes from multiple sources and sciences, including but not limited to paleontology, geology, genetics, artificial selection, and comparative anatomy.
- The concept that natural selection results in adaptations. Adaptations provide organisms with a greater chance of survival and successful reproduction.

Second question: Do the Next Generation Middle School Standards on evolution meet these criteria?

Because the Next Generation Science standards have been adopted by at least 17 states and are used as a model for the standards of many other states, it was essential to ask if the Next Generation Middle School Standards on evolution met these criteria. The NGSS middle school science standards on evolution are substantive, well-informed, and clearly stated. An excellent review of the Next Generation Science Standards was completed by the Fordham Institute in 2013. While finding the NGSS lacking in certain areas, such an absence of the mathematical concepts essential to scientific inquiry, the study concluded, "the standards addressing evolution are better organized and generally stronger than in many of the state standards that we have reviewed" (Gross et al. 2013).

However, one question should be addressed. The NGSS are divided into both sub-ideas and performance expectations. Which of these will be used by teachers as an assessment tool for their students? Because the NGSS are so substantial, assessments are bound to be based on the performance expectations alone. Nonetheless, the content found under the big ideas is valuable, and a considerable step up from most state standards. For this study, both sections were evaluated. It is important to note that if the Performance Expectations alone were used as a measurement, the NGSS would receive 7 points per our rubric, and a grade of C.

Explanation of rubric

Four independent raters reviewed the middle school science standards on evolution using the criteria described above. Their results were compared and discrepancies were corrected by additional reviews of the state standards until consensus was reached. Statistical tests for interrater reliability were not run because, as evidenced below, the data did not call for such rigorous testing. Each rater reviewed each state's middle school standard searching for the following criteria. See Appendix for a complete list of reviewed documents.

Is the term "evolution" used?

Some states do not use the term "evolution" at all in their middle school science standards but still address important aspects of evolutionary theory, such as natural selection. Evolution is still a controversial topic in many parts of the country. Addressing evolutionary concepts without using the term evolution is like sneaking the broccoli into a child's meal. Hopefully, (Tables 1, 2) with time, a child who has been unwittingly and repeatedly exposed to the taste of broccoli will not only accept broccoli but also realize the nutritional value it contains. Nonetheless, a point was given if this important term was included.

Is the concept of evolution clearly defined?

Defining evolution was given another point. The standards received this point if they gave a clear and accurate definition of evolution, something along the lines of: an explanation for both the change over time of living organisms and the current diversity of species on Earth.

Multiple lines of evidence for evolution are presented (fossils, homologous structures, genetics, artificial selection, etc.)

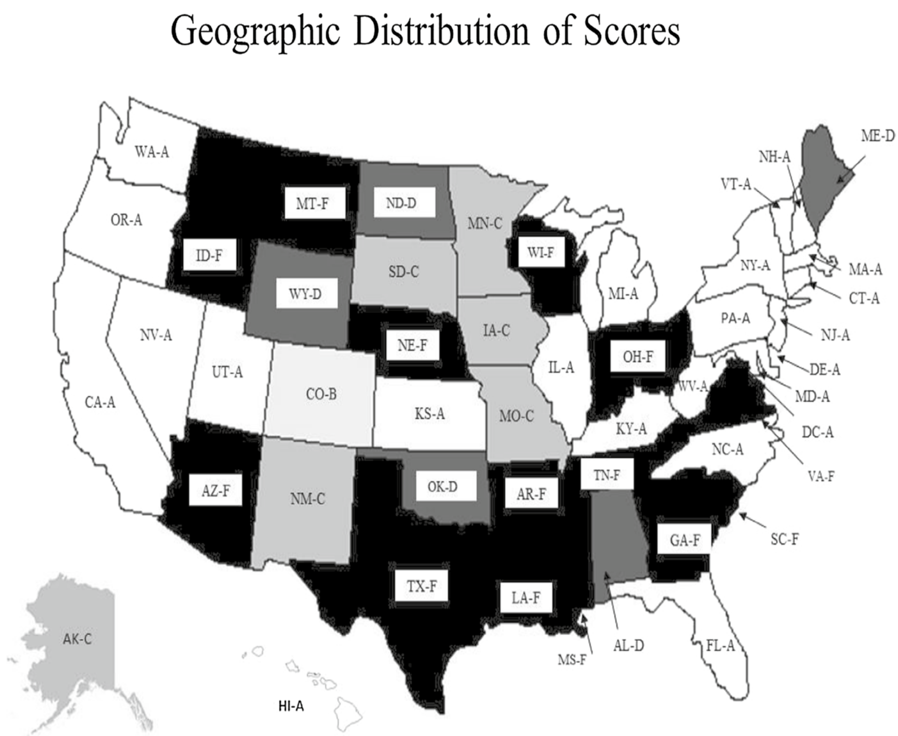
One of the strengths of evolution is the fact it is supported by so many fields of science. Points were awarded on the basis on how many lines of evidence were addressed in the standards. Many states were deficient in this category, relying on the fossil record as the only evidence for evolution.

Natural selection and adaptation

Points were awarded based on whether natural selection and adaptation were mentioned and/or clearly defined. The definition for natural selection included the differential survival and reproduction of individuals, or the change in heritable traits of a population over time. Adaptation was defined as a trait serving a current functional in an organism which evolved by means of natural selection.

Table 1 Grading scale

Total # of Points	Grade
9-10	A
8	B
7	C
6	D
≤5	F



Our rubric included the following point system:

Category 1	Category 2	Category 3	Category 4	Category 5	Total points
Is the term "evolution" used?	**Is the concept of evolution clearly defined?**	**Multiple lines of evidence for evolution are presented (fossils, homologous structures, genetics, artificial selection, etc.)**	**Natural selection Mentioned 1 point Defined 1 point**	**Adaptation Mentioned 1 point Defined 1 point**	
Maximum 1 point	Maximum 1 point	Maximum 4 points	Maximum 2 points	Maximum 2 points	10

Some important results are shown in Table 3.

Matters to consider

The grade breakdown of the states is the very opposite of a bell curve, an inverted bell curve. When it comes to state science standards for evolution education, it appears you are generally doing it right, or you're not.

New Hampshire

If a Grand Prize trophy for outstanding middle school evolution standards could be awarded, it would go to the state of New Hampshire. New Hampshire should not be commended just for its middle school standards on evolution. It starts incorporating evolution into the curriculum earlier than any other state, priming

Table 2 Results of state standards review

State	Category 1 Is the term "evolution" used?	Category 2 Is the concept of evolution clearly defined?	Category 3 Multiple lines of evidence for evolution are presented (fossils, homologous structures, genetics, artificial selection, etc.)	Category 4 Natural selection Mentioned 1 point Defined 1 point	Category 5 Adaptation Mentioned 1 point Defined 1 point	Total points	Letter grade
	Max 1 pt	Max 1 pts	Max 4 pts	Max 2 pts	Max 2 pts	10	
AL	0	0	3	2	1	6	D
AK	0	0	3	2	2	7	C
AZ	0	0	0	0	1	1	F
AR[b]	1	0	1	1	1	4	F
CA[a]	1	1	4	2	2	10	A
CO	1	1	2	2	2	8	B
CT[a]	1	1	4	2	2	10	A
DE[a]	1	1	4	2	2	10	A
DC[a]	1	1	4	2	2	10	A
FL	1	1	4	2	2	10	A
GA	1	1	1	2	0	5	F
HI[a]	1	1	4	2	2	10	A
ID	1	0	0	1	1	3	F
IL[a]	1	1	4	2	2	10	A
IN	0	0	2	1	1	4	F
IA[a]	0	1	4	2	0	7	C
KS[a]	1	1	4	2	2	10	A
KY[a]	1	1	4	2	2	10	A
LA	0	0	1	1	2	4	F
ME	1	1	2	1	1	6	D
MD[a]	1	1	4	2	2	10	A
MA	1	1	4	2	2	10	A
MI[a]	1	1	4	2	2	10	A
MN[b]	0	1	3	2	1	7	C
MS	0	1	1	1	2	5	F
MO	0	1	3	1	2	7	C
MT	1	1	0	1	0	3	F
NE	0	0	1	1	1	3	F
NV[a]	1	1	4	2	2	10	A
NH	1	1	4	2	2	10	A
NJ[a]	1	1	4	2	2	10	A
NM	1	1	1	2	2	7	C
NY	1	1	4	2	2	10	A
NC	1	1	4	2	2	7	10
ND	1	1	1	1	2	6	D
OH	1	1	1	1	1	5	F
OK	0	0	2	2	2	6	D
OR[a]	1	1	4	2	2	10	A
PA	1	1	4	2	2	10	A
RI[a]	1	1	4	2	2	10	A
SC	0	0	1	2	1	4	F
SD	1	1	2	2	1	7	C
TN	0	0	1	1	1	3	F

Table 2 continued

State	Category 1 Is the term "evolution" used?	Category 2 Is the concept of evolution clearly defined?	Category 3 Multiple lines of evidence for evolution are presented (fossils, homologous structures, genetics, artificial selection, etc.)	Category 4 Natural selection Mentioned 1 point Defined 1 point	Category 5 Adaptation Mentioned 1 point Defined 1 point	Total points	Letter grade
TX	0	0	1	1	0	2	F
UT	1	1	4	2	1	9	A
VT[a]	1	1	4	2	2	10	A
VA	0	1	1	1	1	4	F
WA[a]	1	1	4	2	2	10	A
WV[a]	1	1	4	2	2	10	A
WI	1	0	0	0	1	2	F
WY	1	1	0	2	2	6	D

[a] State has adopted the NGSS or is in the process of adopting NGSS (Arkansas and Iowa are adopting modified versions of the NGSS)

[b] State is planning to review their standards in 2017 or 2018

Table 3 Grade breakdown

Grade	Number of states
A	23
B	1
C	6
D	5
F	15

A—10 pts: California*, Connecticut*, Delaware*, Florida, Hawaii*, Illinois*, Kansas*, Kentucky*, Massachusetts, Maryland*, Michigan*, Nevada*, New Hampshire, New Jersey*, New York, North Carolina, Oregon*, Pennsylvania, Rhode Island*, Vermont*, Washington*, Washington DC*, West Virginia*

A—9 pts: Utah; B—Colorado; C—Alaska, Iowa*, Minnesota, Missouri, New Mexico, South Dakota; D—Alabama, Oklahoma, North Dakota, Maine, Wyoming; F—Total 15; F—5 pts: Georgia, Mississippi, Ohio; F—4 pts: Arkansas*, Indiana, Louisiana, South Carolina, Virginia; F—3 pts: Tennessee, Idaho, Montana, Nebraska; F—2 pts: Texas, Wisconsin; F—1 pt: Arizona; F—0 pts: none

the students for the middle school science standards addressed in this study. New Hampshire's kindergarten standard S:LS3:2:2.1 states, "Recognize that some plants and animals, which are alive today, are similar to living things which have become extinct, such as elephants and mammoths." The essential idea that evolution provides a framework for understanding all of life's common ancestry is introduced elegantly to 5-year-olds with simple, easy-to-understand observations. Three other states with early evolution education are Connecticut, Massachusetts, and Washington, which begin introducing simple concepts in their K-2 science standards. For example, Massachusetts kindergarten standard K-LS1-2(MA) states, "Recognize that all plants and animals grow and change over time."

Florida, New Hampshire, Massachusetts, North Carolina, Pennsylvania, and *Utah* are the only non-NGSS states with a grade of A.

Utah

The most improved award goes to the state of Utah. Its 2003 middle school science standards document would have received an F with the grading scale used in this study. Today, Utah is among the 23 states that received a grade of A. Utah also illustrates the point that a state does not need to adopt the NGSS in order to develop worthy standards. However, in this sense, Utah is one of the exceptions. Consider the data in Table 4.

Table 4 clearly illustrates that a student who happens to live in a state that has adopted the NGSS standards will—other things being equal—very likely receive a far better evolution education than one who resides in a non-NGSS state.

Arkansas, Iowa, and North Dakota

These three states were the hardest states to assess because will be implementing a modified version of NGSS. As it stands, their current state standards, assessed here, are mediocre at best.

Iowa: It appears that Iowa will be adopting a modified version of the NGSS after a review process which includes public comment.

Arkansas: Arkansas is in the process of modifying the NGSS and calling it the Arkansas K-12 Science Standards. Since this document is not yet available, their 2005 document was reviewed for this study. The available document, The 5–8 Learning Progressions and Standards

Table 4 Scores of non-NGSS states only

A	**6**
B	1
C	5
D	5
F	15

Overview, show a very positive change in the Arkansas standards. If adopted in July of 2017, Arkansas will also receive a score of A according to our rubric.

North Dakota: Greg Gallagher of the North Dakota Department of Public Instruction was reached for comment. He explained that the new standards draft was still under review and that the 2006 standards were still in implementation. If and when the 2014 draft standards are officially adopted, North Dakota would be modeling the NGSS framework and receive a score of 10, an A in this study. That will be the case if their modifications to the 2014 draft do not water down the evolution standards of the NGSS.

New Mexico

A very common feature of many state standards is the emphasis on fossils as evidence. The fossil record has been and continues to be crucial to the theory of evolution, but it is not the only kind of evidence for evolution. For example, the last two decades of genetic discoveries have substantially strengthened scientists' understanding of common ancestry and the tree of life. Very few states addressed genetics as evidence in their standards. New Mexico received the highest possible score for the other categories of the rubric, but since fossils were the only type of evidence mentioned for evolution, it lost three points and received an overall grade of C. This score brings to light some limitations to our rubric which we will discuss further in the conclusion.

Ohio

While Ohio received an overall grade of F with the rubric, it is worthy of mention that its lengthy standards document (344 pages) provided teachers with the best resources of any state document. For example, Understanding Evolution, a valuable website developed and maintained by the University of California Museum of Paleontology, is cited in the Ohio standards document. Ohio science teachers could certainly receive an entire evolution education through this valuable website. Although a few related concepts are mentioned, evolutionary science is truly not introduced until high school.

Florida and Pennsylvania

The two states with the most unique and teacher-accessible standards and resources are Florida and Pennsylvania. Teachers can set search parameters when entering the site- for example, "seventh grade" and "natural selection." The search will lead directly to the specific standards that need to be addressed and a very valuable list of ready-to-go lessons, videos, and lab activities. Both sites also have links to online websites such as PBS for additional classroom resources. Teachers can put together targeted lesson plans around the state standards since the creators of the state standard websites have done the legwork for them. We have mentioned that good standards do not necessarily translate into good classroom teaching. Offering teachers valuable lessons based on the state science standards is a productive way to help ensure that the standards make their way into a teacher's daily lesson plans. Any way a state's department of education facilitates the process from translating the standards document into actual classroom practice is helpful.

NGSS states

The states which have adopted the NGSS should all be applauded for providing their middle school science teachers with strong, clear evolution standards. However, it was often difficult to determine exactly when these states were fully implementing the NGSS in grades K-12. Some states clearly post their adoption and implementation timelines on their websites. Many states plan to be fully implementing the NGSS by 2020; other states do not have a set timeline posted on their websites. There is a big difference between simple adoption and implementation, which will take time. Implementation requires supporting teachers so they can make incremental an continuing changes to improve their classroom instruction. This includes providing teachers with professional development opportunities, resources, time to learn, physical classroom space, and lab materials which are aligned to supporting the NGSS vision.

Most of the NGSS states would have received much lower grades if their current standards had been judged instead of their newly adopted NGSS. To illustrate this point, the former standards of the NGSS states were graded using the rubric and the results can be found in Table 5. Only Washington DC would have received an A before NGSS adoption.

Table 5 What the NGSS states with a grade of A would have received if they had not adopted the NGSS

State	Category 1 Is the term "evolution" used?	Category 2 Is the concept of evolution clearly defined?	Category 3 Multiple lines of evidence for evolution are presented (fossils, homologous structures, genetics, artificial selection, etc.)	Category 4 Natural selection Mentioned 1 point Defined 1 point	Category 5 Adaptation Mentioned 1 point Defined 1 point	Total points	Letter grade
	Max 1 pt	Max 1 pts	Max 4 points	Max 2 pts	Max 2 pts	10	
CA	1	2	4	2	0[c]	8	B
CT	1[b]	0	0	0	0[c]	1	F
DE	1	0	1	2	2	6	D
DC	1	1	4	2	1	9	A
HI[a]							
IL[a]							
KS[a]							
KY[d]	0	0	1	0	1	2	F
MD	1	0	1	1	1	4	F
MN	1	0	3	1	0	5	F
NV	0	1	3	2	1	7	C
NJ	1	1	1	1	1	5	F
OR	1	0	1	1	0[c]	3	F
RI	1	0	3	1	1	6	D
VT[a]							
WA	1	1	4	0	2	8	B
WV	1	0	3	2	1	7	C

[a] Science standards before NGSS implantation could not be found

[b] The term evolution is introduced in K-2 science standards

[c] Adaptation was covered in elementary school, but was not part of the middle school evolution standards

[d] The term evolution was replaced with "biological change"

The high scores the states received were given under the assumption that they are committed to implementing the NGSS, as stated by their department of education websites. Because the NGSS are relatively new, these states were given the benefit of the doubt. As Eugenie C. Scott astutely observed, the NGSS present "science as both a body of knowledge and an evidence-based, model and theory building enterprise that continually extends, refines, and revises knowledge. Teachers are going to need some help in mastering this approach". With this insight in mind, a 4- or 5-year implementation plan is a reasonable proposition.

Conclusion

The improving quality of the middle school science standards on evolution is encouraging, especially when considering the contentious history of evolution education in the United States. The release of the Next Generation Science Standards in 2013 was an important step towards improving the evolution education of many American students.

Another study similar to this one is recommended in 5 years' time to determine if better standards have indeed translated into an improvement in classroom instruction. For such a study, an expanded rubric is recommended. Our rubric included five basic components and served as a starting point for future studies. The science standards of New Mexico elucidated the fact that our focus on the multiple lines of evidence for evolution could sell some states short, under representing the quality of their standards. An expanded rubric could award additional points if state standards included:

- How scientists use our understanding of natural selection to solve current issues (ex. Pesticide resistance)
- Science careers related to evolution
- Connections between the science of genetics and evolutionary biology (ex. Species relatedness in taxonomy/phylogeny)
- Human evolution
- Current examples of speciation

- The idea that evolution as the underlying theme of all of biology
- A focus on data collection and analysis when studying natural selection. (A future study can also measure the quality of a state's science inquiry standards. For example, very few state standards expected students to know the difference between hypothesis, theory, and law, a helpful distinction when addressing common misconceptions surrounding evolution).

Everyone interested in quality evolution education in this country should be encouraged to learn that half of the U.S. states are providing their science teachers with high quality middle school standards on evolution. However, despite a reason for optimism, the fact still exists that half of U.S. states have middle school science standards that were graded as average or below average for their treatment of evolution. The standards document for South Dakota provides an excellent reminder of the struggles the developers of science standards across the country still face today. In order to avoid public rebuke, the writers of South Dakota's science standards felt the need to state the following:

> *Through the public hearing process related to adoption of the South Dakota Science Standards, it is evident that there is particular sensitivity to two issues: climate change and evolution. The South Dakota Board of Education recognizes that parents are their children's first teachers, and that parents play a critical role in their children's formal education. The South Dakota Board of Education also recognizes that not all viewpoints can be covered in the science classroom. Therefore, the board recommends that parents engage their children in discussions regarding these important issues, in order that South Dakota students are able to analyze all forms of evidence and argument and draw their own conclusions.*

This capitulation to those opposed to evolution education brings to mind Andrew Petto's appeal for constant vigilance. He warns, "Anti-evolutionism is not a passing phenomenon, nor is it a matter of logic or integrity." His words should always be heeded; the need to maintain the integrity of our nation's K12 evolution education should never be underestimated (Petto and Godfrey 2008).

This insight reiterates the importance of high-quality evolution standards. Teachers and principals often turn to the state science standards as a means of defending what is being taught in the classroom. When teachers receive requests from parents to include creationism or intelligent design in their curriculum, they can respond, "Thanks for your suggestion, but the curriculum for the class is set by the district in conformity with the state's science education standards". That way, the teacher makes it clear that it's not going to happen, that it's not within the teacher's control, and that the teacher isn't going to address (or argue about) the actual content of the suggestion.

Eugenie C. Scott made an insightful comment when reviewing the results of the 2009 high school evolution standards study of Louise Mead and Anton Mates, "There is reason to be pleased by the progress over the last 10 years in the inclusion of evolution in state science education standards… there is considerable room for improvement, but we should be optimistic that teachers, scientists, and others who care about science education will continue—as science standards continue to be periodically revised—to work for the appropriate inclusion of evolution in state science education standards" (Scott 2004).

Remember that this is a study of *middle school* standards. Just a few years ago such a review would have been superfluous, since most states were not even adequately covering evolution in high school. As states begin to train their teachers in the proper implementation of NGSS, students at younger and younger ages will exposed to the unifying concepts of common ancestry and relatedness. There is reason to hope that these students will begin to realize that "there is grandeur in this view of life."

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Competing interests

The authors declare that they have no competing interests.

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