Review of Texas State Board of Education
Texas Essential Knowledge and Skills, Science, Grades K-12

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In late September, I was approached by Barbara Cargill of the Texas State Board of Education to serve as a reviewer for the Texas Essential Skills and Knowledge (TEKS) for science, grades K-12. In this report, I will address each of the questions in the review format provided by the Texas Education Agency (TEA). While my training is primarily in biology, I will address all areas that I examined. I will first provide comments on the introductions to the various sections of the science TEKS, and then address the specific questions requested by the TEA.

Grades K-5

General Comments on the Introductions

The various sections of the science TEKS generally begin with an introduction that provides 1) a summary of both the skills to be learned and the knowledge to be gained; 2) usually a definition of science; 3) a statement about "systems"; and 4) a general statement about the process of science, including the changing nature of investigations, methods, and the models produced. The introductions to grades K-5 are inconsistent. For example:

- While grades K & 3 are expected to communicate their findings (at a kindergarten level, I suppose), in the introductions for 1st, 2nd, 4th & 5th grades, there are no such general requirements. An additional level of inconsistency is seen in that 4th and 5th graders are required to communicate their findings in other standards.
- K, 1st, 3rd and 4th graders are to ask questions, whereas 2nd & 5th graders are not. However, inquiry is specifically found in the knowledge and skills sections for all grades.
- K, 1st, & 2nd have a clear definition of science that shows the limits of science ("students…. should know that science may not answer all questions"), but 3rd, 4th & 5th graders do not. This is unfortunate, since a critical skill (and not one addressed at any grade level) is knowing when a question can be answered by science, and when it cannot.
- All grades, except 4th, have general language relating to systems (which appears to be so vague that I question its usefulness).

In general, the K-2 grade introductions were consistent in form, summarizing the increasing levels of both knowledge and skills to be gained by students. However, that consistent form was lost beginning in grade 3. I would recommend that all introductions consist of:
1) a statement describing the skills learned (measuring, asking & answering questions, use of instruments and communication tools such as graphs, etc.);
2) a statement summarizing knowledge gained;
3) a statement on the nature of science & its limitations;
4) a statement on systems; and
5) a statement on investigations models, and their changing correspondence to reality.

Specific Comments on the Introductions

Grade 3, (a) (4):

- The comment on systems is now prefaced with an unrelated short definition of science ("science is a way of learning about the natural world").
- There appears to be an editing error ("Students should know understand a whole in terms of its components") – two verbs in a row makes the sentence grammatically incorrect and unintelligible. I recommend removing "know" and placing the entire, previously used definition of science as a separate paragraph.

Grade 5, (a) (2):

- I recommend removing the additional "in": ("Within in the living environment");
- More importantly, the statement on adaptations is tautological: adaptations **are,** by definition, traits that improve the survival of a member of a species. Change this to "… adaptations are traits that improve the survival of members of a species."

Grade 5, (a) (2), (3), (4):

- **"**Within the physical environment" and "Within the natural environment" are unnecessary and false distinctions. The "natural environment" includes a lot. I recommend starting all statements with, "Students learn…"

Answers to Specific Questions

1) Do the TEKS ensure that scientific concepts are presented in an accurate and factual manner?

In this section, I found no errors of fact in the scientific concepts presented. As noted above, the introductions for Grade 5 had problems with tautologies in introducing the concept of adaptations, and it also had a puzzling distinction between the "physical" and the "natural." However, I found the body of the TEKS factually accurate.

2) Is a complete and logical development of scientific concepts for each grade level or course followed?

The concepts develop logically, with each grade's concepts building upon previous knowledge. This applies to both the concepts learned and the reasoning and skills to be gained. There is a gradual increase in the tools used and the sophistication of the investigations. The one exception was that 4^{th} graders learn about adaptations [Grade 4: (b) (10) (E)], but the term appears to be one that 5^{th} graders are to learn [Grade 5: (a) (2)].

3) Have the correct science vocabulary and terminology been used?

In this section, I have found correct and age-appropriate vocabulary and terminology used.

While this does not apply to the knowledge and skills sections themselves, the language used to describe systems in the introduction [(a) (4) for grades K-3 and (a) (5) for grade 5] would be hopelessly vague to all but the most indoctrinated educrat. The concept of a system is a powerful one, but it is not clearly communicated in the statements in the introduction.

4) Are the science process skill statements written at the appropriate grade level or course?

In general, these are appropriate. Most of the problems lay in (b) (3), "The student knows that information and critical thinking are used in scientific problem solving."

For example, Kindergarten, (b)(3) (A) requires students to "identify and explain a problem, such as the impact of littering on the playground, and propose a solution in his/her own words."

While littering is a problem, I think we could come up with a problem that's more scientific, rather than social. To a kindergartener, littering is a moral issue — it's BAD. Since they're just identifying and explaining the problem, perhaps the example could be ways to save water (an issue in Texas), or ways to cut down on garbage (an issue everywhere). The same can be said of the "finding a home for a class pet" problem in first grade [Grade 1 (b)(3)(A)]. A more scientific problem and solution can be used as an illustration.

I would also choose a different illustration for Grade 2 (b)(3)(A). Lack of water is not a problem in a habitat, unless we decide it's a problem (El Paso is just El Paso — only when people get involved is it a habitat that "lacks water"). If you want the habitat to lack water, make it an artificial habitat, such as a garden.

The (b)(3)(A) expectation (which relates to critical thinking and scientific problem solving) increases appropriately with age. Beginning in Grade 3, students are expected to "justify an explanation, argument, or conclusions using student generated data" [Grade 3 (b)(3)(A)]. This is a worthy goal. I would recommend that you add language that explicitly develops students' skills at recognizing good arguments and rejecting inadequate ones. Since the exact same goal is used in Grade 4, perhaps further development could be achieved in Grade 4.

I note that Grade 5 has kept the original language in previous TEKS, [(b)(3)(A): "analyze, review, and critique scientific explanations, including hypotheses and theories, as to their strengths and weaknesses using scientific evidence and information"]. I believe that this is a <u>critical skill</u> for students beginning in the 5^{th} grade, and should be incorporated in ALL the science TEKS in future grades. Texas students will spend their lives as citizens evaluating science claims that affect them. It is vital that they learn to think and decide for themselves in these areas.

(b)(3)(C): The last expectation in section 3 is often about knowing the contributions of scientists. The expectation of identifying scientists has very little direct connection with "the knowledge that information and critical thinking are used in scientific problem solving" [(b)(3)]. Granted, the stories that you could tell about some scientists provide wonderful illustrations of good thinking and hard work producing results. A better use of selected scientists would be to illustrate how their thinking and reasoning resulted in the discoveries that they made. Jacques Cousteau, Jane Goodall, and Thomas Edison are important people to know, but their stories need to be clearly related to the skills and knowledge of that grade level.

Let me add that I did an informal survey of 8 Ph.D. Biologists, Geologists, and Geographers of the individuals listed. None had heard of Maria Mitchell or Alejandro Acevedo-Gutierrez.

Also,, it should be noted that, unlike other grades, 5th graders are not currently expected to know any scientists.

Additionally, calculators are introduced as appropriate scientific tools in 3rd grade [(b)(4)(A)]. My personal opinion (I also consulted with Dr. Ted Cox, our science education instructor at UW-Superior, who agreed) is that 3rd grade is too early for calculator use; they are still becoming competent in basic math at that age. Dr. Cox confirmed that students do not become competent in basic math until at least 6th grade. My opinion is formed by years of working with college students who are the victims of early introduction to calculators, and as a result have no sense of an appropriate answer; if the calculator says 2+2 = 5, they believe it (a slight exaggeration). I constantly see student answers where they make a mistake on the calculator, it gives an absurd answer, and their math skills are such that they are unable to recognize the fact that they just gave an absurd answer. I would delay calculator use until 5th grade, at the earliest. In addition, the calculator is not listed for 4th grade.

Finally, I applaud the fact that, beginning in the 4th grade, Texas students are expected to use environmentally appropriate and ethical practices in their investigations. However, I am curious as to who is to supply their ethical training.

5) Are the science concept/content statements grade-level appropriate?

These relate to both knowledge and skills. There is a clear progression in both knowledge and skills in the content areas (matter and energy, force, motion, and energy, organisms and environment) that is age-appropriate.

6) Do the Science TEKS have Student Expectations (SEs) that are aligned with the knowledge and skills statements?

The SEs are, in almost all cases, fully aligned with the knowledge and skills that they demonstrate. Again, I would question the wording on Grade 3 (b)(3)(D):

"(D) represent the natural world using models such as volcanoes or sun/earth/moon, and identify their limitations including size/scale and properties/materials."

This SE focuses on representing the natural world; the knowledge and skill in this case is primarily in understanding the limits of models. It would be worded better to emphasize the importance of recognizing the limitations of models. The construction of models is also a skill emphasized later in (b)(7), Earth and Space.

7) Are the Student Expectations clear and specific?

I found them quite clear and specific.

Review of Middle School Science TEKS, Grades 6-8

As I did for the K-5 review, I will first address the introductions and then address the individual questions in the TEA review format.

General Comments on the Introductions

The format for the introductions to the middle school science TEKS is different than either the K-5 TEKS or the individual courses in grades 9-12. This section makes use of "strands," which are essentially summaries of what is to be learned about scientific investigations and reasoning, plus the major content areas of Matter and Energy, Force, Motion and Energy, Earth & Space, and Organisms and the Environment. If the TEA is seeking consistency in format, then I would recommend that these be revised, and that each section given a separate number: i.e., Scientific investigations and reasoning becomes (a)(3), Matter and Energy becomes (a)(4), etc.

All of the introductions indicate that science in that grade will focus (at least 50%) on physical (6), life (7), or earth & space science (8), with the remainder of instruction using the "lens of …" to examine science processes and concepts. While this is a worthy goal, I found that to be most nearly true for grade 7, life sciences, and somewhat true for grade 8. I could not see the "lens of physical science" in 6th grade employed in the organisms and the environment portion, except (perhaps, and this is a stretch) for where it related to ecology. For the sake of accuracy, perhaps this statement should be toned down a bit.

All Scientific Investigations and Reasoning strands [(a)(3)(A)] include a statement about "rules of evidence." I find no place where students exclude evidence based on breaking the "rules of evidence," nor any indication that they are discussed. The statement seems to be more of a legal concept than a scientific statement. The only thing that personally comes to mind is proper calibration of instruments and good controls and adequate numbers of replicates in experimental design. I would eliminate that phrase.

The distinction between descriptive and experimental investigations is a good one in [(a)(3)(A)(ii)], and I appreciate its inclusion in the introduction.

All the TEKS have, in their introduction, a statement about the inability of science to answer all questions. At some point will there be an attempt to have students actually NAME some of those questions? A common statement is that while science may tell us what we **can** do, it doesn't address what we **ought** to do. It can tell us that we can make hydrogen bombs, and hybrid cars, and human embryos in a test tube, but it doesn't tell us whether we ought to do such things. A huge problem in ethics is the problem of scientists speaking, not as scientists, but as amateur ethicists, answering questions on which they have no more moral authority than anyone else. The place to bring this up is the science classroom, when such questions arise naturally in the course of describing what we can do in science.

Specific Comments on the Introductions

Grade 6,(a)(3)(E):

- I would recommend that students learn the concept of the Domain as well as that of the Kingdom in 6th grade, and add a bit more taxonomy in the 7th grade. 6th graders know about bacteria (or at least germs), and we can tell them that they are SO different that we group them all by themselves, and everything else we also group together.

- There's a typo in Grade 6(a)(3)(A)(iii): "questions can by answered" should be "questions can be answered." This same typo is repeated in the intro to grade 7, but not in grade 8.

In Grade 7, the numbering system is off; there are two (a)(3)(A)s, Scientific investigations and reasoning, and Matter and energy, and no (a)(3)(D).

For the second (a)(3)(A), the sentence, "Much of this energy is cycled as organic matter," makes no sense. Energy flows, matter cycles. When organic matter cycles, it cycles from organic forms (such as us) to inorganic forms (such as CO_2, N_2, H_2S, water, etc).

I really like Grade 7 (a)(3)(C), highlighting the characteristics of earth that allow life. In general, the Grade 7 strands integrate the physical sciences concepts (matter and energy, force, motion, and energy, earth & space science) much better into the year-long theme of biology than do the other grades. However, biology is by nature integrative, which made this task easier for the writers.

Grade 7 (a)(3)(E)(i):
"Students understand the relationship between living organisms and their environment. Different environments support different living organisms that are adapted uniquely to that region of the Earth. Organisms are living systems that maintain equilibrium with that environment that may be disrupted by internal and external stimuli. External stimuli can be due to human activity or the environment. Successful organisms can reestablish a balance through different processes such as a feedback mechanism or succession."

There are several areas that I would change:
(1) As anyone who has dealt with exotic species knows, organisms may be adapted to a region, but not uniquely.

(2) Eliminate the word "equilibrium" in the document. Organisms are, perhaps in balance, or in a steady state, but not in equilibrium. The term we use for a cell that is in equilibrium with its environment is DEAD. Organisms are FAR from equilibrium.

(3) Succession is an ecological, not an organismal, concept. Environments recover due to succession, but not organisms.

Grade 7 (a)(3)(E)(ii) "Changes in traits that are observed in a population can occur over many generations through the process of natural selection."

This gives the impression that the changes that occur in a population are **only** due to natural selection. There are many other forces at work, which are beyond 7th grade: genetic drift and immigration are two that come to mind. Attributing everything to natural selection is a common tendency. I would modify the language as follows:

"Changes in traits sometimes occur in a population over many generations. One of the ways this change can occur is through the process of natural selection."

Grade 7 (a)(3)(E)(iii): "All living organisms are made up of smaller units called cells. **All** cells use energy, get rid of wastes and contain genetic material for reproduction." (emphasis added)

This statement is not correct because not **all** cells reproduce. We are full of cells — terminally differentiated skin cells, nerve cells, etc. — that don't reproduce. I recommend removing "**All,**" for the sake of accuracy.

Section (a)(3)(E)(iii) also seems to neglect plants, even though they have systems as well. While the human body serves as a model for all sorts of animals, students are not given a chance to appreciate that there is hierarchical organization in plants as well. A brief mention of plants here, as well as in later sections of the TEKS, would be appropriate.

Answers to Specific Questions

1) Do the TEKS ensure that scientific concepts are presented in an accurate and factual manner?

In general, the concepts presented are accurate and factual. I have some concerns in regards to this concept:

Grade 6 (b)(12): "Organisms and environments. All organisms are classified into Kingdoms.Organisms within the Kingdoms share similar structures, which allow them to respond to the living and nonliving parts of their ecosystem. The student is expected to:

(A) identify the basic characteristics of organisms in the currently recognized Kingdoms;

(B) analyze how structure relates to function in the classification of living organisms;"

Our best understanding of classification is that, above the level of Kingdom is the Domain, and the Domain is a more fundamental division of living organisms. 6thgraders may not need to define the three Domains (they probably don't know enough to appreciate the difference between the Archaea and the Bacteria). But 6th graders do know about "germs" (bacteria, for the most part), and can understand that bacteria are profoundly different than other organisms. It might be necessary to move some content from 7th grade (where the nucleus is first introduced) to 6th grade, but I would rather they learn things properly, albeit at a lower level, than to learn about biology incorrectly for the sake of simplicity. They would already have to know basic bacterial characteristics to meet SE (A) above, and it would be only a small bit of added work to separate bacteria off by themselves.

Regarding (B) above, it is not clear what students are expected to learn. Relating structure to function is a major part of science; at the Kingdom/Domain level, we focus on structures that are important enough to unify all organisms that have that structure, and distinguish them from the rest. Such distinguishing characteristics include possession of a nucleus (eukaryotes), the presence of chitin in cell walls (fungi), or differentiated cell types (plants and animals). While all of these parts function, some of these differences are simply differences. The cell walls of both plants and fungi have similar functions; it is a quite advanced topic to ask why fungi have chitin and plants cellulose in their cell walls, but this is what appears to be asked. I would either eliminate the expectation, or change Grade 6 (b)(12)(B) to the following:

"identify the function of the major structures that are used to place organisms in a particular kingdom."

I also consulted with Dr. Kurt Schmude, (our entomology instructor) who thought that Grade 6 (b)(12)(B) was a profound question that might be addressed at a graduate level. To require "analyzing how structure relates to function *in the classification of living things"* is not a skill that can be expected of 6^{th} graders.

Grade 7, (b)(11): "**Organisms and environments.** The student knows that populations and species demonstrate a variety of life and acquire many of their unique traits through gradual processes over many generations. The student is expected to:"

I strongly object to this TEKS requirement. Can we really "know" that populations acquire many of their unique traits through gradual processes over many generations? I would submit that, except for examples of small-scale change, we know nothing of the sort. For all the interesting unique traits (such as photosynthesis, or sex, or flight in mammals), we are completely clueless as to any sort of clear path or gradual process. Most of these features appear suddenly in the fossil record. We simply have a made a large extrapolation from the very small things that we can observe, such as what can be done with artificial breeding or selection in bacteria. The language invites students to "know" things that are simply speculation and extrapolation. While I have nothing against speculation and extrapolation, it should not be confused with knowledge.

In this regard, SE (b)(11)(C) is good. The changes in genetic traits that are observed and demonstrated, along with the results of selective breeding, will be of the normal, modest sort that selection (either natural or artificial) is capable of producing.

(b)(11)(D): This SE again mixes speculation with observation. Maybe hummingbirds did evolve from other birds to take advantage of tubular flowers. However, all we really have is an observation (hummingbirds feed off tubular flowers) and a tendency to view this observation through an evolutionary lens (hummingbirds must have co-evolved with tubular flowers). My understanding of hummingbird evolution is that, until 2004, the earliest fossils were only thousands of years old, but that a discovery in Germany (where there are no current hummingbirds) pushed the date back 30 million years — and the 30 million year old hummingbirds were recognizable as hummingbirds (albeit somewhat more primitive). We don't really have the sort of evidence that would support this claim; but we simply don't have any other way to view it as occurring. My strong preference would be to tone down the language, perhaps changing it to:

> (A) "describe the characteristics of two species that **are thought to have adapted** to one another through generations such as humming birds and tubular flowers or the Yucca moth and Yucca plant."

It's important to understand what is at stake here. If we want a citizenry that thinks and evaluates the claims of science, we need to be very careful not to present things that we *think* are true as things we *know* are true. Very rapidly, speculations become "facts." Students should not be left thinking, "I heard it in school, so it must be true."

Additionally, it should be noted that "hummingbird" is one word.

Grade 7, (b)(12): "complementary" is misspelled. The writers apparently know the difference between "complimentary" and "complementary" because they use the word correctly in (b)(12)(E).

Grade 7, (b)(13): See comments above on the use of the word "equilibrium" [7 (a)(3)(E)].

2) Is a complete and logical development of scientific concepts for each grade level or course followed?

The scientific concepts are as complete and logical as can be expected, considering the fact that each grade has a particular focus. In Matter and Energy, for instance, 6th graders are introduced to the concept of chemical change and the forming of compounds; this is expanded and related to life processes in the 7th grade, with the periodic table and atoms formally introduced in the 8th grade. There will always be more that could be learned on these subjects, but they develop logically in each grade, with new knowledge being added at each level.

3) Have the correct science vocabulary and terminology been used?

In general, yes. See my comments on "equilibrium."

4) Are the science process skill statements written at the appropriate grade level of course?

Again, I would recommend that the language for (b)(3)(A) from Grade 5 be included for all grades:

> "analyze, review, and critique scientific explanations, including hypotheses and theories, as to their strengths and weaknesses using scientific evidence and information;"

This is a broader statement, allowing a more critical analysis; it does not exclude student-generated data, but does allow for the discussion of real scientific controversy.

In my informal survey of 8 Ph.D. biologists, geographers, and geologists (the members of my department here at UW-Superior), I found only vague recognition among 1 or 2 faculty of William M. Jackson, Alfred Wegener, Warren Washington, Mario Molina, and Barbara McClintock. I am quite familiar with Barbara McClintock's work, but I would be hard-pressed to explain transposable elements in maize, and her work on that, to 7th graders, particularly since they are just learning about genes, and learning that they can sometimes be mobile might be confusing.

In general, stories of scientists are quite good at conveying science. Thus, the scientists that we choose to talk about should tell stories about discoveries that are related to the concepts and content covered at that grade level. In general, I found that to be true for the ones that I recognized.

For (b)(2), Science investigations and reasoning, the (SI) system, is introduced without definition in 6th grade; it is not defined until 7th grade.

5) Are the science concept / content statements grade-level appropriate?

The science concepts show a gradual increase in the depth and complexity of coverage that is appropriate. I have discussed under question 1 my concerns about the accuracy of some of these areas.

6) Do the Science TEKS have Student Expectations (SEs) that are aligned with the knowledge and skills statements?

In general, I found this to be true. The one exception was Grade 6, (b)(10):

> **Earth and space**. The student understands the cyclical nature of Earth systems. The student is expected to:
>
> (A) classify rocks a metamorphic, igneous, and sedimentary based on the processes that create them;
>
> (B) investigate how differences in pressure and heat effect air movement; and
>
> (C) describe the role of heat energy in weather-related phenomena including thunderstorms, tornadoes, and hurricanes.

While the geological cycle can be inferred from (A), the connections of (B) and (C) to cycles need to be clearer.

7) Are the Student Expectations (SEs) clear and specific?

Yes.

Review of TEKS High School Science, Grades 9-12.

Since the TEKS high school science includes nine different courses, each will be reviewed separately. However, I will provide some general comments on the introductions to each of these courses before examining them individually. Since my training is primarily in biology, I will have limited comments on some of the more specialized courses offered.

Before delving too deeply into my analysis of the TEKS for Grades 9-12, I want to note a gross inconsistency: The TEKS purport to endorse critical thinking; however, the strongest indicator in the standards which calls for students to "analyze, review, and critique scientific explanations, including hypotheses and theories, as to their strengths and weaknesses using scientific evidence and information" is found only in certain subjects covered by the TEKS for high school science (Astronomy and Chemistry). Why this inconsistency exists, I have no idea; it's not as if only astronomers and chemists need critical thinking. But this inconsistency must be rectified. I will address this in much greater detail below, but if we are to teach students how to think like scientists, we must apply the most effective requirements for critical thinking in all subject areas, not just a select few.

General Comments on the Introductions

I would like to reiterate three of my comments from the middle school TEKS. First, I commend the explicit statement found in (b)(2) for most courses that students "should know that science may not answer all questions." As I stated earlier, students should have a good idea about what science can address and cannot address. As I discuss below, Biology and ESS provide answers to some of the questions that science does not address; however, these TEKS do so in such a way as to devalue questions that can't be answered by science, and at the same time promote scientism. Secondly, I would again recommend that (c)(3)(A) for each course include the language from 5th grade, encouraging critical analysis and evaluation of scientific theories and hypotheses and examining them for their strengths and weaknesses. Finally, I would again ask about the source for the ethics in the "ethical practices" for (c)(1).

With the exception of the Earth and Space Science course, the introductions to these courses consist of four statements: 1) a statement about the scope of the course; 2) a definition of science, including its limitations; 3) a statement about systems; and 4) a statement about investigations. This form is used for the Integrated Physics and Chemistry (IPC), Chemistry, Physics, and Astronomy. Three other courses (Biology, Aquatic Science, and Earth and Space Science) have added statements about the nature of science, which for some reason were not combined with either the definition of science or the statement about investigations. All are apparently derived from a 2008 National Academy of Sciences report. The aquatic science statement is the shortest, adding a brief statement about science allowing predictions to be made about natural phenomena and the importance of testable explanations. The statements in Biology and Earth and Space Science are longer and specifically exclude from science "purported forces" that are outside of nature ("If scientific explanations are based on purported forces that are outside of nature, scientists have no way of testing those explanations"). This is a curious statement, since I doubt if the authors would consider an explanation based on "purported forces that are outside of nature" to be a *scientific* explanation. In any case, the statement reeks of *scientism:* the philosophy that the only explanations that count are those that rely on nature. I say this because the word "purported" implies a *claimed* or *alleged* force outside of nature; the clear implication is that one cannot have a solid basis of claiming that such forces exist, and thus such an explanation is not only nonscientific, but is likely false. The statement implies that "we" (i.e., all us "educated people") all "know" there are no forces outside of nature. It is also an unnecessary statement, since throughout these TEKS science has been defined as learning about the *natural* world. This language about "purported forces" should be removed.

The extra statements in Biology and ESS probably detract more than they add; they imply a contempt for other ways of knowing that will only serve to enhance the conflict between science and other disciplines. I would agree that adding a statement on science being built upon testable hypotheses would be useful to add to the fourth paragraph [(b)(4): "Investigations are used to learn about the natural world…"] However, such a statement is far better added to the existing ones on the nature of science.

In addition, I find it ironic that it is in biology that the authority of the state is most used to suppress inquiry. [Biology, (b)(5): "Many theories in science are so well established that no new evidence is likely to alter them substantially."] I suspect that this is deliberately placed to suppress critical inquiry into biological evolution, a theory that upwards of 50% of the population suspects as being flawed. If the TEA is dissatisfied with this state of affairs, it will not be helped by suppressing inquiry into areas where students have doubts.

I would add two more suggestions to the introductions to these courses. The middle school TEKS emphasized the difference between **descriptive** and **experimental** investigations. These are important themes that should not be lost on high school students. I would urge that similar language be incorporated into all the course TEKS.

Secondly, there is a significant difference in the way that the historical sciences (geology, paleontology, and much of evolutionary biology) and other field sciences (such as field ecology and wildlife biology) learn about the world as compared to the way experimental sciences (such as cell biology, chemistry, and physics) learn about the world. My experience as a member of a Department of Biology and Earth Sciences has made me acutely aware (and appreciative) of the different approaches to learning that are used by these various disciplines. An understanding and appreciation of the different "ways of knowing" in science would help to produce a better informed citizenry, able to appreciate those times when our understanding of the natural world changes due to new research. It would be to everyone's benefit if the TEA encouraged a culture in which, when taught new material, students react by asking "how do we know?" Such questioning would produce better students, better teachers, better schools, and better citizens.

Review for Integrated Physics and Chemistry (IPC)

1) Do the TEKS ensure that scientific concepts are presented in an accurate and factual manner?

The concepts presented come from both physics and chemistry. They are concepts that will lead to both an understanding of the physical world and prepare students for more advanced courses. I found them to be accurate and factual.

2) Is a complete and logical development of scientific concepts for each grade level or course followed?

As stated above, this course teaches important concepts in both physics and chemistry, with basic coverage of force, motion, energy, and matter. Each of these topics is important in and of itself, and they also connect to each other; force, motion, and energy in particular are difficult to understand apart from each other.

3) Have the correct science vocabulary and terminology been used?

I found no errors in the vocabulary or terminology used.

4) Are the science process skill statements written at the appropriate grade level or course?

I would again note my strong preference for including language related to strengths and weaknesses of scientific explanations in (c)(3)(A).

There is also a typo in (c)(2)(A), as it should read "implement **investigative** procedures," and in (c)(3)(D) which should read "research **and** describe the history of physics, chemistry, etc." Also, this is a pretty broad goal; you may want to list some scientists, as was done in prior sections.

5) Are the science concept/content statements grade-level appropriate?

This course would typically be taken in the 9th grade. I note that velocity is introduced to students in the 8th grade, distinguished from simple speed, yet it is not taught in IPC. If students learn about velocity in the 8th grade, it should be reviewed in 9th grade IPC.

There is also a typo in (c)(4)(D), "noting **that** the relationship is"

I also appreciate that there are a number of areas where students address real-world issues related to the course, using real-world examples of applications of force, energy, and motion, and critiquing advantages & disadvantages of various energy sources. These will help make the courses more enjoyable and relevant.

6) Do the Science TEKS have Student Expectations (SEs) that are aligned with the knowledge and skills statements?

Yes.

7) Are the Student Expectations (SEs) clear and specific?

Yes.

Review of Biology

Please see my general comments on the introductions to the TEKS for my comments about (b)(5).

1) Do the TEKS ensure that scientific concepts are presented in an accurate and factual manner?

(c)(6)(B): The genetic code, while almost universal, is not completely universal.

(c)(7): The student knows evolutionary theory is an explanation for the diversity of life.

It is good to see that this concept is not presented as dogmatically as it could be (thankfully, evolution is only *an* explanation). However, the usual phrasing includes complexity as well (evolutionary theory is an explanation for the diversity *and complexity* of life). Please see my comments below regarding the SEs for this concept.

As a microbiologist who has conducted scientific research that implies there are limits to the Darwinian mechanism of mutation and selection, I believe that modern evolutionary theory can be subjected to serious scientific criticisms. For this reason, this indicator would be an appropriate place to implement a standard that requires students to "analyze, review, and critique scientific explanations, including hypotheses and theories, as to their strengths and weaknesses using scientific evidence and information."

(c)(8): There is no mention in the taxonomy concept of Domains. The three-Domain system is the most accepted today (archaea, bacteria, and eukarya). Also, the terms archaebacteria and eubacteria are no longer used, having been replaced by archaea and bacteria.

(c)(11): As I indicated in my review of the 7th grade TEKS, [Grade 7 (a)(3)(E)], Eliminate the word "equilibrium" in the document. Organisms are, perhaps in balance, or in a steady state, or maintaining homeostasis, but they are not in equilibrium. The term we use for a cell that is in equilibrium with its environment is *dead*. Organisms are FAR from equilibrium.

2) Is a complete and logical development of scientific concepts for each grade level or course followed?

Yes. The science concepts go from cell to ecosystem, which is the typical and logical way biology is presented.

I do note that there is no discussion of the origin of life. This could be placed in either (c)(4) (which focuses on cells, but without discussing their origins), or in (c)(7) (evolutionary theory). A proper discussion would include a consideration of the assumptions that underlie origin of life research, the components of the most primitive cell, evidence for the earliest forms of life, and a discussion of such theories as the RNA world theory, clay matrices as catalysts for formation of biologically relevant polymers, panspermia, etc. Concept (c)(8) in the Earth and Space Science course has some relevant language, although I would modify it as I suggest above. Given the controversy facing many leading origin of life theories, this would be an ideal instance to implement a standard that requires students to “analyze, review, and critique scientific explanations, including hypotheses and theories, as to their strengths and weaknesses using scientific evidence and information.”

In addition, there is no discussion of the life history of the earth. As part of the evolutionary theory concept, students should have an understanding of some of the major life events as we understand them, such as the appearance of the first cells, first eukaryotic cells, Cambrian explosion, dinosaurs, a sense of when humans appeared, etc. I find nothing in either the middle school or high school courses (with the exception of the Earth and Space Science course) that addresses these topics.

3) Have the correct science vocabulary and terminology been used?

For (c)(11), replace “equilibrium” with “homeostasis.” See my comments from question 1) above.

4) Are the science process skill statements written at the appropriate grade level or course?

Yes. I would again indicate my strong preference that (c)(3)(A) be strengthened by language that allows students to examine the “strengths and weaknesses” of the explanations examined. This is vital to helping students to learn to approach the biological sciences like real scientists.

Also, (c)(3)(C) Includes no discussion of careers, and there is surprisingly no mention of the rich history of science and the people involved. What happened to knowing about Darwin and Pasteur?

5) Are the science concept/content statements grade-level appropriate?

In general, they were appropriate. I have already expressed my concerns about indoctrination rather than education in the area of evolutionary theory [(c)(7)] in 1) above and in 6) below. In addition, for (c)(6)(G), high school biology students can go beyond simply “recognizing the significance of meiosis to sexual reproduction”; they are capable of understanding the bulk of the details of this very important process, which is key to recognizing its significance.

6) Do the Science TEKS have Student Expectations (SEs) that are aligned with the knowledge and skills statements?

In general, the SEs align very well with the knowledge and skills statements.

One of my concerns relates to the SEs for (c)(7). The Student Expectations for (c)(7) (“The student knows evolutionary theory is an explanation for the diversity of life.”) leave the student with little opportunity to critically examine the standard neo-Darwinian story. I would certainly endorse having students learn all of the evidence and concepts presented; I would also endorse having them learn more, because many of those same evidences also speak against this theory. Will they learn that Darwin considered the fossil record the gravest objection to his theory? Will they learn that distinguished scientists such as Carl Woese (discoverer of the Archaea) and Ford Doolittle no longer believe in the existence of a Last Universal Common Ancestor? Will they learn the discouraging limits to what can be experimentally achieved by selection? I fear that these standards will lead to indoctrination, not education.

I would recommend modifying the SEs as follows (changes are in bold):

(A) **Critically examine the** evidence of common ancestry among groups that is provided by the fossil record, biogeography, and homologies including anatomical, molecular, physiological, behavioral and developmental;

(B) **Critically assess the ability of** natural selection to produce change in populations; recognize the types of changes that have been documented through field observation and experimental evolution studies.

(C) describe the elements of natural selection including inherited variation, the potential of a population to produce more offspring than can survive, and a finite supply of environmental resources resulting in differential reproductive success;

(D) **Critically evaluate** the significance of natural selection to adaptation, and to the diversity of species; and give examples of natural selection contributing to adaptation and diversity, and

(E) **Critically analyze** the results of other evolutionary mechanisms including genetic drift, gene flow, mutation, and recombination.

These additions will allow students to practice critical thinking skills in line with the TEKS requirement that they should investigate the “strengths and weaknesses” of scientific theories.

7) Are the Student Expectations (SEs) clear and specific?

The SEs are clear and specific. I have noted my recommendations for certain changes, which will, if implemented, improve them.

Review of Chemistry

Comments on the Introduction

The proposed TEKS for Chemistry use a very standard introduction. I did note that the proposed TEKS change "learning about the natural world" to "**knowing** about the natural world" in (b)(2). In this regard,
I would recommend returning the language to "learning" because such language better reflects the scientific values of tentativeness and humility. I am also puzzled by the difference in the wording from physics, which includes statements about hypotheses as well. I would think that both chemistry and physics could have the same definition of science.

1) Do the TEKS ensure that scientific concepts are presented in an accurate and factual manner?

The TEKS cover the basics of chemistry; I found no errors in the concepts presented.

2) Is a complete and logical development of scientific concepts for each grade level or course followed?

The Science concepts show a logical development from the characteristics of matter, to the atomic theory, to balancing chemical equations, and finally to energy calculations. I appreciate the inclusion of key experiments in the discussion of atomic theory — --this will enrich the course.

3) Have the correct science vocabulary and terminology been used?

Yes.

4) Are the science process skill statements written at the appropriate grade level or course?

Yes. I particularly appreciate the (c)(3)(A) and the inclusion of critiquing both strengths and weaknesses of theories. Chemistry is an excellent place to show how key experiments allow us to accept or reject certain views of matter. For the sake of consistency and in order to maintain a high standard of teaching students about critical thinking, I again reiterate my strong recommendation that this language be included in the standards for each science subject, not just chemistry.

5) Are the science concept/content statements grade-level appropriate?

The Science concepts are appropriate for a high school chemistry course. I did note that there is no mention of hydrogen bonds in the discussion of bonding. Inclusion would allow the course to address the biological relevance of bonding.

6) Do the Science TEKS have Student Expectations (SEs) that are aligned with the knowledge and skills statements?

Yes.

7) Are the Student Expectations (SEs) clear and specific?

Yes.

Review of Physics

General Comments

I find the introduction to physics to be well-written. I would use the physics definition of science, again replacing the word “knowing” with “learning” to reflect the scientific values of tentativeness and humility.

1) Do the TEKS ensure that scientific concepts are presented in an accurate and factual manner?

I found no flaws in the scientific concepts.

2) Is a complete and logical development of scientific concepts for each grade level or course followed?

The course follows the classical development of the ideas of physics, and they are presented in a logical manner.

3) Have the correct science vocabulary and terminology been used?

Yes.

4) Are the science process skill statements written at the appropriate grade level or course?

Yes. I would again recommend that (c)(3)(A) use the language used in chemistry that requires students to “analyze, review, and critique scientific explanations, including hypotheses and theories, as to their strengths and weaknesses using scientific evidence and information.” This will implement a consistent high standard of teaching students critical thinking skills throughout the entire high school TEKS. I particularly appreciate the emphasis on use of scientific notation and SI units in measuring and recording data.

5) Are the science concept/content statements grade-level appropriate?

Yes. This is appropriate content for juniors or seniors taking physics.

6) Do the Science TEKS have Student Expectations (SEs) that are aligned with the knowledge and skills statements?

Yes.

7) Are the Student Expectations (SEs) clear and specific?

Yes.

Review of Environmental Systems

General Comments on the Introduction

The introduction uses the standard 4 paragraphs found in many of these introductions. They add a very appropriate 5th paragraph [(b)(5)]. Environmental Systems is a multi-disciplinary field involving both science and public policy. Distinguishing between the facts involved and the ethical/social decisions utilizing scientific data is a key point.

1) Do the TEKS ensure that scientific concepts are presented in an accurate and factual manner?

I found no flaws in the scientific concepts.

2) Is a complete and logical development of scientific concepts for each grade level or course followed?

The course appears to have a strong basic science component. Once students have that foundation, the course then addresses a number of environmental issues. This would seem to be the proper order for addressing these topics.

3) Have the correct science vocabulary and terminology been used?

Yes.

4) Are the science process skill statements written at the appropriate grade level or course?

I would again note my support for a (c)(3)(A) statement that allows students to evaluate on the basis of strengths and weaknesses. This is particularly important for EnvSys, since environmental issues have so many pro/con issues to address, and we can only make progress as a scientific society if we train citizens who can think critically and thereby understand these issues. I do note that students are expected to “analyze” or “examine” often in the course. Explicitly encouraging an evaluation of both the strengths and weaknesses of both policies and data will make for a better course.

5) Are the science concept/content statements grade-level appropriate?

The Science concepts should be within the capabilities of Texas high school students.

6) Do the Science TEKS have Student Expectations (SEs) that are aligned with the knowledge and skills statements?

Yes.

7) Are the Student Expectations (SEs) clear and specific?
Yes.

Review of Aquatic Science

General Comments

The introduction seems adequate.

1) Do the TEKS ensure that scientific concepts are presented in an accurate and factual manner?

I found no flaws in the scientific concepts. The language used in (c)(12), which covers human impacts upon aquatic environments, appears to leave no room for positive benefits from aquaculture. It would be important that a “pro/con” approach to human activities be employed in the teaching of this concept.

2) Is a complete and logical development of scientific concepts for each grade level or course followed?

The course lays a foundation of basic hydrogeology and limnology and uses that as the basis for a long-term study on aquatic environments. This is an excellent approach to Aquatic Science.

3) Have the correct science vocabulary and terminology been used?

Yes.

4) Are the science process skill statements written at the appropriate grade level or course?

I would again note my strong support for a (c)(3)(A) statement that allows students to evaluate on the basis of “strengths and weaknesses.” This is particularly important for Aquatic Science, since environmental issues have so many pro/con issues to address. It is vital that the TEKS uphold a strong commitment to teaching students critical thinking in each subject area. Teaching students to “analyze, review, and critique scientific explanations, including hypotheses and theories, as to their strengths and weaknesses using scientific evidence and information” will uniquely accomplish this goal.

5) Are the science concept/content statements grade-level appropriate?

The Science concepts should be within the capabilities of Texas high school students.

6) Do the Science TEKS have Student Expectations (SEs) that are aligned with the knowledge and skills statements?

Yes.

7) Are the Student Expectations (SEs) clear and specific?

Yes.

Review of Astronomy

General Comments on the Introduction
The introduction uses the standard 4 paragraphs and is quite adequate. Since the subject is astronomy, perhaps "Science is a way of learning about the natural *world"* is a bit restrictive [(b)(2)].

1) Do the TEKS ensure that scientific concepts are presented in an accurate and factual manner?

I found no flaws in the scientific concepts.

2) Is a complete and logical development of scientific concepts for each grade level or course followed?

The course builds on what students already know about the sky, provides lifelong skills in observing the sky, and then goes into cosmology, which seems logical.

3) Have the correct science vocabulary and terminology been used?

Yes.

4) Are the science process skill statements written at the appropriate grade level or course?

I appreciate the use in (c)(3)(A) of expectation that students will analyze hypotheses and theories as to their strengths and weaknesses. Having this standard in astronomy, however, is not enough to guarantee that students learn to think critically across a broad range of scientific disciplines. For the sake of consistency, the standard that students should "analyze, review, and critique scientific explanations, using including hypotheses and theories, as to their strengths and weaknesses" should be included in each subject area.

I also note that students are not expected to know any key astronomers, which would be appropriate.

5) Are the science concept/content statements grade-level appropriate?

The Science concepts should be within the capabilities of Texas high school students.

6) Do the Science TEKS have Student Expectations (SEs) that are aligned with the knowledge and skills statements?

Yes.

7) Are the Student Expectations (SEs) clear and specific?

Yes.

Review of Earth and Space Science

General Comments

This section appears to describe a challenging course that will attract the better high school students. I would love to take this course! It appears to combine rigor with relevance.

Comments on the Introduction

The introduction is more like the ones in the middle school science, with a detailed description of topics covered and its use of "strands," major themes that are found as students study about Earth in space and time, the solid earth, and fluid earth. This results in the introduction providing a more detailed account of the major themes for the course.

As I have discussed in my general review of the introductions to all the courses (see p. 11 above), there is language about "purported forces that our outside of nature" that appears to be an attempt to impose a philosophical viewpoint by denigrating those who do not accept philosophical naturalism. While it is important to emphasize that science deals with the *natural* world, this can be done without implying that nature is all there is. My strong recommendation is to eliminate the ideological bias from (b)(5), reintroducing a definition of science [such as is found in (b)(2) in all other courses], and adding to that definition the language of (b)(5) from Aquatic Sciences:

"Science uses observational evidence to make predictions of natural phenomena and to construct testable explanations. Scientific explanations are open to testing under different conditions, over time, and by independent scientific researchers."

1) Do the TEKS ensure that scientific concepts are presented in an accurate and factual manner?

Tentativeness, humility, and skepticism are core scientific values. Many of the science concepts in this course deal with the distant past: formation of the universe, the Sun, planets, etc. While I have no objection whatsoever to teaching students about concepts like the nebular-planetesimal-protoplanet model, and I have no reason to doubt the accuracy of that model, it should be presented as a model, and our best understanding of what happened in the past. As such, I believe that a bit more humility might be warranted when teaching students how to think scientifically about events that took place billions of years ago.

One of my concerns is that students aren't given a sense of how certain we are of scientific claims. Students are told that the earth accreted from a stellar nebula "as explained by the nebular-planetesimal-protoplanet model" or "DNA is the only genetic material" or "eating eggs will clog your arteries," and they are told to think that. Because "science says" these statements, our degree of certainty about all of them is the same. And students will, in their lifetimes, be told things that are "true" that are then reversed. A classic for those of us over 40 is what "science told us" about butter and eggs. Both were "bad for us" in the 1960s but have recently been rehabilitated. It does not take too many of these instances before students and citizens become cynical about **all** the pronouncements of science. To reflect the scientific values of humility, tentativeness, and skepticism, I would offer a modification to (c)(5) as follows:

"The student knows that the currently accepted theory for the formation of our solar system is the nebular-planetesimal-protoplanet model, in which the stars, planets, and minor bodies of a stellar system accrete from stellar nebula."

I would recommend that (c)(4),(5), and (10) be modified to give students a sense of the tentativeness that should be found in all scientific statements about reality.

2) Is a complete and logical development of scientific concepts for each grade level or course followed?

This is a very ambitious course; it is twice as long as any of the other TEKS. However, the concepts follow a logical flow from the history of the universe to current weather and climate patterns.

3) Have the correct science vocabulary and terminology been used?

Yes.

4) Are the science process skill statements written at the appropriate grade level or course?

I would again recommend that the (c)(3)(A) statement found in Chemistry and Astronomy be used so that there is a strong requirement that students learn critical thinking skills.

5) Are the science concept/content statements grade-level appropriate?

The Science concepts should be within the capabilities of Texas high school students.

6) Do the Science TEKS have Student Expectations (SEs) that are aligned with the knowledge and skills statements?

Yes.

7) Are the Student Expectations (SEs) clear and specific?

Yes.

Review of Engineering Design and Problem Solving

General comments.
This course appears to meet a need for giving students experience and training in engineering. The prerequisites will mean that the students enrolled will almost all be seniors. They may need to consider co-enrollment in one of the science courses that is a prerequisite. Local schools will have much leeway in the projects that will be developed, which, assuming that rigor is maintained, will mean students will benefit from the local talents of their instructors.

I also note that social and ethical implications of technological development is mentioned in the introduction, and that a discussion of the codes of conduct of engineers is included in (c)(4). Perhaps this could be expanded to include examples of engineers behaving both ethically and unethically, and the social and personal consequences.

1) Do the TEKS ensure that scientific concepts are presented in an accurate and factual manner?

The knowledge and skills are not divided into processes and concepts, for the knowledge and skills include mixtures of both. However, they appear accurate and factual.

2) Is a complete and logical development of scientific concepts for each grade level or course followed?

Yes. Students receive an introduction to engineering, while solving an engineering problem; they then learn to present and defend the results. A broader, more open-ended problem is then addressed, and finally students learn about managing engineering projects.

3) Have the correct science vocabulary and terminology been used?

Yes.

4) Are the science process skill statements written at the appropriate grade level or course?

Yes.

5) Are the science concept/content statements grade-level appropriate?

This is an ambitious course, but should be achievable by senior high school students.

6) Do the Science TEKS have Student Expectations (SEs) that are aligned with the knowledge and skills statements?

Yes.

7) Are the Student Expectations (SEs) clear and specific?
Yes.