

Summary of the AAPT Response to the January 2013 Draft  
Next Generation Science Standards

American Association of Physics Teachers  
February 1, 2013

### **Executive Summary**

On January 28, 2013, the American Association of Physics Teachers (AAPT) convened a group of fourteen physicists, physics teachers, and educational specialists to review and comment on the January 2013 draft of the Next Generation Science Standards (NGSS). The group was disappointed with that draft of NGSS and found that significant editorial changes, if not a whole new formulation, will be needed before AAPT and the broader science community can support that document as the basis for national K-12 science education standards. There are several major difficulties with the current NGSS: (1) The NGSS Student Performance Expectations are built on the articulation of Science and Engineering Practices and on Disciplinary Core Ideas as articulated in the National Research Council report *A Framework for K-12 Science Education*. Although we applaud the link between practices and core ideas, *A Framework* has several statements of disciplinary core ideas that are unclear and some that are scientifically inaccurate. Unfortunately, NGSS has inherited those flawed statements. (2) We argued in our May 2012 response to the first draft of NGSS that it is a strategic error of enormous magnitude to associate only one of the science and engineering practices with one disciplinary core idea. As a matter of science standards, students should be expected to be able to perform any of the practices with any of the disciplinary core ideas. We are in essence urging that NGSS not define precisely which practice would be assessed with which disciplinary core idea. Teachers may want to assess one cluster of practices in their classrooms, others might be assessed by district or state tests, and yet others by nationally normed assessments. The performance standards should be separated from the details of the assessment tools, which should build on, but should not dictate, performance expectations. (3) The wording of many of the NGSS performance expectations is confusing to the point that it is not clear what students are actually supposed to do. (4) The science content of the current form of NGSS contains so many errors that most science teachers and scientists will doubt the credibility of the entire enterprise. In what follows, we cite evidence from NGSS to support these conclusions, we give examples of how to reconstruct the performance expectations that make them more understandable as well as being scientifically correct, and we propose what AAPT will do in conjunction with other teachers, science educators, scientists and scientific societies to produce documents that can be used to move forward the nationwide science standards effort.

## I. Introduction

In this section, we present some general comments about the Next Generation Science Standards (NGSS), based on the discussions at a meeting on January 28, 2013 of experienced high school physics teachers and representatives from the American Association of Physics Teachers, the American Physical Society, the American Institute of Physics, the National Society of Black Physicists, and the American Institute of Research. Five of the participants are currently teaching high school, two are university faculty members, three are disciplinary society staff members and two are retired physics teachers. Others are a National Science Digital Library editor, science fellows in the federal government, a teacher-in-residence at a university physics department, and one who works in large-scale assessment. Seven of the participants have their highest post-secondary degrees in physics, and seven in science education. Three currently are teaching high school physics, seven had taught high school physics in the past, one taught other disciplines, and two have never taught at the high school level. Other K-12 teaching experience represented in the group included middle school and high school mathematics and language arts, high school earth and space science, high school biology, and middle school mathematics and science. About one-third of the participants had experience with science standards reviews at the state level and most had experience with science standards review at the federal level.

The AAPT group reviewed AAPT's May 2012 document, commenting on the first draft of NGSS released in May 2012. (See [http://www.aapt.org/Resources/policy/NGSS\\_draft.cfm](http://www.aapt.org/Resources/policy/NGSS_draft.cfm) for a summary of AAPT's response to the first draft.) That review is omitted from this summary. However, many of the issues raised in that review continue to exist in the second draft of NGSS.

The group then commented on two of the appendices that were added to the January 2013 release of NGSS.

Appendix J of the January 2013 draft of NGSS provides an outline of three models of course progressions that would support NGSS. The AAPT group believes that Model 3 is just a restatement of the standard biology-chemistry-physics sequence. The only change is the articulation of performance expectations (which, of course, is a good thing) but otherwise very little would change from current practice. In particular, we were struck by the gross imbalance among the number of disciplinary core ideas associated with biology as compared to chemistry and physics. Is that a reflection of the state of biology understanding, which currently has fewer general principles (compared to physics and chemistry)?

Appendix D makes an attempt to come to grips with equity and diversity issues. Perhaps that is the best one can do when discussing student performance expectations, but at some point those advocating for *A Framework* and NGSS will have to address these important and serious implementation issues.

## II. General Comments January 2013

We now provide some general comments on the second draft of NGSS.

A. Minimum Standards. We emphasize again that the NGSS document should state very

clearly that the performance standards put forward in the document are minimum standards. This caveat is included in the second draft but it is rather subdued. Teachers can and should go beyond these performance expectations for most students. Students expecting to pursue STEM-related majors or careers will need more depth.

- B. Use of Language. Why are some Performance Expectations (PEs) so murky?
1. There is still a lack of consistency of language in the science and engineering practices, and in the performance expectations (PEs) , e.g., the use of the term model, using carry out vs. conduct, and many other small inconsistencies that make it hard to interpret what students will need to know and be able to do.
  2. We suggest rewrites of PEs by a small group of writers who are disciplinary experts, working together to ensure consistency of language and usage across the levels and domains.
  3. Clarify and simplify language (models, etc). One performance expectation states that students should “*Demonstrate understanding to evaluate.*” Does that mean simply “evaluate” or is there something more subtle going on?
  4. Given that developing and using conceptual and mathematical explanatory models is central to science, we suggest that pulling together the various kinds of modeling activities that students are expected to do into a short, coherent description would be useful for a broader audience. Appendix F and A *Framework* provide more elaborate descriptions of these terms. Something shorter would be very helpful.
- C. Language of the Standards vs. Language for Students. We suggest that the language of the standards, which are written for adults to use, should be scientifically accurate. It is appropriate in the standards to use the language of science, since the audience for the NGSS document consists of teachers, science supervisors, scientists, engineers and curriculum developers. Clarification statements can contain definitions and limits on the language use expected of students. For students there should be a progression of technical language and terms. For example, “motion energy” may be appropriate for elementary school, but by middle school, the term kinetic energy should be introduced – use of that term paves the way for high school students to understand usage of terms like kinematics and kinetic friction.
- D. Electric Circuits. We are concerned that there seem to be almost no standards relating to electric circuits. We recognize that lacuna was inherited from A *Framework*. However, electrical technology is pervasive in today’s world both in both everyday home life and cutting-edge technology. Batteries, bulbs, motors, switches and modern high capacity capacitors provide an excellent area of study where students can construct devices and build simple qualitative and quantitative models of the behavior of electric circuits. Activities that emphasize construction, measurement, and modification of circuits could work well at the middle school level and high school level using the engineering practices. Circuits also provide very nice examples of conservation of energy and conservation of electrical charge. We think that some PE’s should be developed in the structure of matter and energy sections that more specifically deal with electric circuits in both middle and high school standards.

- E. Modern Physics. We do not see any treatment of ideas of quantum physics, beyond the idea that the behavior of light can be described by both particle and wave models (HS-PS4-e). We think students should develop at least some qualitative concepts about quantum ideas. A PE under the category of obtaining, evaluating and communicating information about quantum physics might be an appropriate addition to encourage exposure to these ideas.
- F. Science Errors in DCIs and PEs. There are still a number of glaring errors in statements of the science in some of the PEs and in some of the statements of the DCIs on which they are based. It is imperative that errors in the science be fixed, or there will be members of the scientific community who will reject the formulation of the standards on that basis.
- G. Integrating Engineering Practices. The engineering practices have now been integrated and spread among the performance expectations rather than treated as a separate strand. Pedagogically that can be helpful, but it may be a burden on teachers who are not familiar with engineering design, particularly at the elementary level, and may be an additional, overwhelming challenge for resources in schools. Project-based activities are frequently done in schools, but it is not clear that they really integrate all aspects of engineering and design. Giving more and better-defined examples in the clarification statements might help. We also see the need for stronger professional development for teachers if they are to integrate engineering practices into their classrooms.
- H. Qualitative versus Quantitative. By middle school, students have sufficient competence with numbers that we can expect them to draw conclusions from quantitative data and to support scientific arguments both qualitatively and quantitatively. We find an under-emphasis on using quantitative techniques and also a lack of emphasis on construction and interpretation of graphs at middle school and high school levels. Graphical presentation of information is ubiquitous in society, cutting across many professions and occupations. We want students to be able to deal with both qualitative, graphical and age-appropriate quantitative information and models. Compared with the Common Core State Standards for Mathematics at middle school level, the Physical Science PEs undervalue the use of mathematics in science.
- I. Appendix J. In the very short turn-around time available for comment on the revised standards, Appendix J has generated a variety of reactions and questions. The Physics First movement is concerned that Model 3 specifies a sequence of Biology, Chemistry, and Physics. It is not at all clear whether Model 3 assumes that the domain-based courses as described by the PE lists in Model 3 would be taught in that specific order or whether the break-out is merely by content. If the overall intent of *A Framework* and NGSS is to make a significant change to the content arrangement of science teaching as in Models 1 and 2, some discussants suggested leaving out Model 3. There are also two fundamental concerns: (1) the large amount of Earth and Space Science PEs will make it difficult to organize physics domain courses that deal with the additional topics that will be expected

for college preparatory courses and (2) there seems to be a large imbalance between the number of PEs for Biology compared with the numbers for Chemistry and Physics.

#### K. Some additional specific comments

1. Many of the discussants felt that leaving out scientific computing was a major weakness of *A Framework*. We don't expect students to be expert programmers, but all students should be familiar with the range of tools available for simulations, data gathering, and data visualization.
2. Several discussants urged having Performance Expectations dealing with laboratory and field work safety.
3. The entire group was surprised to find that the periodic table of the elements does not appear until high school. The periodic table presents one of those grand organizing principles that cut across all STEM disciplines and can be appreciated with growing levels of sophistication from upper elementary grades and onward.
4. Several of the discussants recommended that science and society issues should use local examples, not just bland generic issues, to heighten student engagement.
5. Several discussants were worried that the phrasing of many of the performance expectations involving engineering practices seems to say that we can engineer our way out of any problem.

### III. Equity and Diversity Issues

We were pleased to find that the NGSS authors have addressed some implementation issues, particularly those involving equity and diversity, in Appendix D. One of our discussion participants, the president of a society of minority scientists, noted that many minority schools do not have resources to make these changes, and that different parental involvement means that other opportunities for science engagement such as after-school activities will be needed, including a systematic effort to engage national lab resources, colleges and universities and business/industry resources, as well as other organizations such as NASCAR and NASA. For NGSS to be successful, more than teachers and students need to be involved.

To implement properly the performance expectations and to ensure that students have adequate learning environments beyond the classroom to respond correctly to the many challenges foreseen in implementing the new standards, the promoters of NGSS should also reach out to national physics societies (such as the American Association of Physics Teachers, American Physical Society and the like), including minority physics societies (e.g., National Society of Black Physicists), national laboratories (e.g., Jefferson Lab and Brookhaven National Lab), two- and four-year colleges, and after school programs (e.g., Girls Inc.). These institutions have in combination enormous untapped resources and materials along with highly qualified scientists that could leverage the in-class training of students.

### IV. Conclusion

As mentioned previously, the AAPT group is profoundly disappointed with the current formulation of NGSS and we believe that in fact, that formulation undermines the national science education standards effort. AAPT, however, is a strong supporter of the science

education standards effort, so we believe that it is important for AAPT to take steps to move that program forward. Below we list steps that AAPT will take (many in collaboration with other professional societies, state and local organizations, teachers, college and university faculty, and practicing scientists):

1. Develop a teachers' guide to NGSS physical sciences performance expectations (in conjunction with the American Chemical Society and earth science organizations).
2. Provide a thorough review of *A Framework* physical science and NGSS, perhaps formulating alternative documents. This will be a one or two-year process, but it must be done.
3. Provide resources at the physics National Digital Science Library site ComPADRE.org such as lesson plans, example curricula, laboratories, and simulations matched with NGSS PE's.
4. Create professional development opportunities in support of the new standards (via AAPT/Physics Teaching Resource Agents peer-led professional development program):
  - a. Align current professional development materials with the NGSS.
  - b. Incorporate engineering design into resource materials.
  - c. Connect with chemistry, math, and physical sciences to organize joint professional development opportunities.
  - d. Create electronic professional development as well as face-to-face professional development programs.
  - e. Create materials to support physical sciences teaching at the elementary level.
  - f. Modify and extend current materials for teaching pre-service elementary and middle school teachers ("Powerful Ideas in Physical Science") to align with the NGSS.
5. Provide opportunities for K-12 teachers to partner with physicists through electronic mechanisms like "Adopt A Physicist" that the Society of Physics Students currently oversees. Furthermore, provide training for physicists interested in working with K-12 teachers.
6. Keep AAPT members and the physics education community informed about the development of the NGSS, the roll out of the final version, and the implementation by state partners. AAPT has many mechanisms to do this such as
  - a. Including information in eNNOUNCER, AAPT's monthly electronic newsletter.
  - b. Connecting with regional Sections, which can disseminate information to local physics teachers.
  - c. Providing information at Section and national meetings about the NGSS and the ways that AAPT can support physics teachers teaching to the new standards

In addition, AAPT is prepared, as mentioned previously, to develop collaborative efforts with groups in chemistry, biology, and earth sciences to produce a refined version of *A Framework* to repair misleading or incorrect science statements and to modify the list of the disciplinary core ideas to include some areas that have proven to be important pedagogically but are not now part of *A Framework* and to reframe others that either received too little or too much attention. We then plan to develop an expanded set of student performance expectations, less closely tied to the practicalities of developing state-wide or nation-wide assessment tools. In essence, we believe that as a first approximation all science and engineering practices apply to all disciplinary core

ideas, while recognizing that the scope of widely-used assessments may need to focus on a relatively small number of practices to be associated with each disciplinary core idea.