Next Generation Science Standards and the Physics Education Research Community

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Abstract. The Next Generation Science Standards (NGSS) are currently under development involving a multi-state collaboration. The NGSS are structured around core ideas in each discipline, cross-cutting concepts, and science and engineering practices. These standards will direct future state wide assessments and therefore K-12 science and physics instruction. Experience has shown that standards and the corresponding assessments can bring about both positive change and unintended consequences in K-12 physics education, is affected by the preparation of teachers, curricular materials available, and methods of assessment. This paper explores the impact of standards and assessment, changes that will need to happen for successful implementation of NGSS, discuss to what extent the educational goals of the PER community align with those of the NGSS and how the PER community could influence the process.

Keywords: Next Generation Science Standards, Physics Education Research, educational reform.
PACS: 01.40 eg, 01.40 ek, 01.40 Fk, 01.40 gb, 01.40 gf, 01.40 jc, 01.40 jh

INTRODUCTION

The Next Generation Science Standards (NGSS) is a collaborative effort to develop new state-level standards for K-12 science education. The goal is "that by the end of 12th grade, *all* students have some appreciation of the beauty and wonder of science; possesses sufficient knowledge of science and engineering to engage in public discussions on related issues; are careful consumers of scientific and technological information related to their everyday lives; are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering and technology."[1] (Emphasis in the original.) NGSS builds on previous standards and research on learning and it follows the recent wide adoption of the Common Core Standards in Mathematics and Literacy. It is being carried out in a two stage process; the development of the conceptual framework by the National Research Council, and the writing of the standards themselves, organized by the non-profit educational foundation Achieve, Inc. [2] As of June 2012, feedback on draft standards has been

Scientific & Engineering Practices

- Asking questions (for science) and defining problems (for engineering)
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations (for science) and designing solutions (for engineering)
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

Core Ideas

Physical Science
PS 1: Matter and its interactions
PS 2: Motion and stability: Forces and interactions
PS 3: Energy
PS 4: Waves and their applications in technologies for information transfer

Engineering, Technology, and the Applications of Science
ETS 1: Engineering design
ETS 2: Links among engineering, technology, science, and society

Crosscutting Concepts

- Patterns
- Cause and effect: Mechanism and explanation
- Scale, proportion, and quantity
- Systems and system models
- Energy and matter: Flows, cycles, and conservation
- Structure and function
- Stability and change

FIGURE 1. The three dimensions of the Next Generation Framework showing core ideas in Physical Science and Engineering. Taken from Ref. 1.

collected from various sources and a review of revised standards is expected in Fall 2012.

The *Framework* identifies three dimensions of scientific understanding: Scientific and Engineering Practices, Cross Cutting Concepts, and Disciplinary Core Ideas. They are organized so that each performance item contains a practice, a core idea and a cross-cutting concept.

College Readiness

There exists a significant gap between high school and post secondary instructors in what students need to be ready for college. In a curriculum survey carried out by ACT, Inc. it was found that high school and college science teachers had very different beliefs about whether state graduation requirements effectively prepare students for college (see Fig. 2). The same survey also found that while secondary science teachers ranked ten process skills and ten foundational concepts as the most important things for being ready for college level work, high school teachers ranked none of the process skills in the top twenty.[3] This is understandable as “too often, [current state science] standards are long lists of detailed and disconnected facts.”[4].

The NGSS development process is specifically addressing these issues. The interwoven dimensions of the NGSS are intended to ensure that process skills and cross-disciplinary connections are valued as much as content topics. Also a two-day national panel from all the Lead States (including the author) was assembled in Jun 2012 to specifically look at college and career readiness in the draft standards.

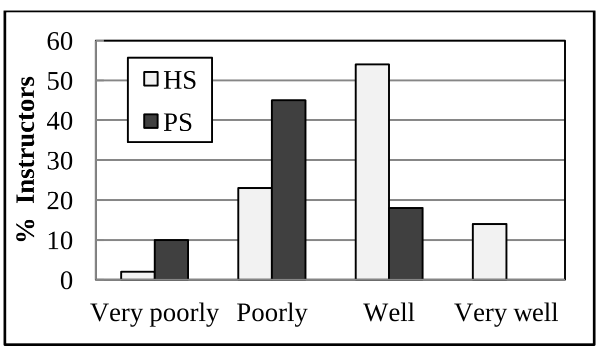

FIGURE 2. View of high school (HS) and post-secondary (PS) science instructors on how well they believe their state high school graduation requirements prepare students for college. (Data from Ref. 10.)

Interaction With the PER Community

So far the NGSS effort has had limited involvement of the Physics Education Research (PER) community. David Hammer was among the experts consulted by the *Framework* committee,[5] and feedback on drafts the *Framework* and standards was provided by panels assembled by AAPT, APS and AIP.[6] The author and two other members of the PER community were present in college and career readiness panel.

In spite of this, the vision of the *Framework* is broadly consistent with that of the PER community. The committee sought to base decisions on research and evidence,[7] the *Framework* emphasizes deep understanding over breadth of coverage, wants students engaged in the learning process, identifies the importance of previous understanding and misconceptions, and seeks the development of expert-like practices.[8] While there may be specific points of disagreement, the author believes that the general vision of NGSS is aligned with that of PER.

POTENTIAL IMPACT OF NGSS

There are currently 26 states serving as Lead State Partners who will seriously consider adoption of NGSS.[9] It is likely states not currently participating will eventually adopt NGSS as occurred with the Common Core Standards, which have now been adopted by 45 states and the District of Columbus.[10]

However, “the framework and subsequent standards will not lead to improvements in K-12 science education unless the other components of the system—curriculum, instruction, professional development, and assessment—change so that they are aligned with the framework’s vision.”[11]

Two highly respected and experienced science teachers in the area were interviewed to provide a teacher perspective to this work. Susan Yusk has seventeen years of teaching at the elementary level and is currently a fourth grade science and math teacher at W.R. McNeill Elementary in Bowling Green, Ky. Kenny Lee has taught for eighteen years and is currently the science department chair and physics teacher at Warren Central High School, also in Bowling Green. Selected statements from these interviews were organized and woven together with text to discuss potential impacts of NGSS and opportunities to assist good implementation of the standards.

Changes In What Is Taught When

NGSS will require changes in emphasis on topics, add new elements, and shift where things are taught. Teachers will need to be prepared for this. The structure with core disciplinary ideas, practices and cross-cutting concepts seeks to focus teaching and learning of science to go deeper on the fundamental elements while reducing the number of topics covered.

A significant change in physical sciences is the designation of Waves as a core idea. Typical college physics instruction tends to not treat waves as a major organizing concept the way energy or forces are, often rushing through mechanical waves towards the end of the first semester and electromagnetic waves towards the end of the second semester. Susan Yusk observed, "in the fourth grade science there is a lot of emphasis on waves and how waves affect our lives….. I'm going to have to do some studying. I'm going to have to get some more materials. I'm going to probably have to find some experts in the field to come also."

Another area is that "the new standards have an emphasis on engineering, which is good." (KL) "We are going to see a greater emphasis on technology and design and understanding specifics, especially the physical science" (SY) which "will be a benefit in the long run." (KL) However, "in the short run, teachers are concerned about, 'How does that work? How are we going to assess it, see if it is taught?'" (KL)

NGSS has a potential to affect college level science instruction. Unlike mathematics and literacy, there is no widely used definition of college readiness in science, so the use of developmental or remedial science courses is rare and some college level science courses assume little or no science background. The question has been raised as to whether there should be standard expectations of college readiness, and if the NGSS will define that. This could have profound implications for college level physics. For example, the current draft indicates students should master conceptual understanding of Newton's laws by middle school and be able to apply them quantitatively in simple situations by high school.[12] Should this happen relatively widely, much of what PER has done on addressing student difficulties introductory physics would no longer be needed for regular college level physics classrooms, only K-12 and remedial classes. The Arizona State Modeling project has shown that high school students are capable of becoming Newtonian thinkers.[13]

Type of Instruction Needed

NGSS is also different because the performance objectives "not only have the specific concept, but they have the processes they want the kids to be involved in to understand them. We didn't have that before." (SY) These practices focus on students doing science and overlap with what is often meant by inquiry teaching, though that particular word is not used because it has come to be used in many different ways.[14] An increased emphasis on inquiry/practices will be a challenge, as "a lot of teachers … know what discovery learning is, they just don't know how to put it together. " (SY)

NGSS envisions the core ideas, practices and concepts as things that will be built up from early elementary school. For example, the draft standards released in May has second graders investigating Pushes and Pulls, third grades looking at the Interaction of Forces, middle school students developing conceptual understanding of Newton's laws, and high school students applying them quantitatively.[12] This structure assumes that teachers down to the elementary level are prepared to teach these topics, but Yusk observed that "a lot of teachers do not feel comfortable with physical science."

Support and Resources Needed

In-service teachers will need to "get some professional development so that we know what is expected of us." (KL) Yusk stated "It would be important for professionals in the field, maybe find some materials or maybe teach us, have some professional development opportunities, to help us figure out how we can teach those concepts to the kids. It can be a little overwhelming." SY

NGSS will require rethinking of pre-service teacher preparation. "University professions who understand the properties of light, how sound travels … how energy is transferred from one form of matter to another can, maybe, not only explain that but show teachers how they can explain that to their children through experiments, through hands-on activities, through other guided discovery tasks." (SY)

Teachers will need new curricula and resources as "textbooks are not, basically, lined up to what these new standards are at all…. It is going to cause teachers to have to go out, find information on their own, find resources that will better educate their students." (SY)

Assessment

"It is great to have an excellent set of standards, but if you don't have a way to evaluate it, how do you know it is being taught and being learned?" (KL) Results of state accountability testing are a significant driver of instructional priorities. For example, in Kentucky "at the fourth grade in the elementary level they are tested, and we are tested on earth, life and physical sciences" (SY) so "a lot of times the subject where the concepts are going to be tested is where it is emphasized. For example, I think there is a lot of emphasis on science at fourth grade and may not as much in fifth grade because it is not tested…. I've seen that at other schools." (SY)

Developing assessments for the type of performances the standards call for will be a challenge. "Previously the science standards were assessed using multiple choice and a few extended responses. Well, multiple choice is fine if you can remember … what are the characteristics of a vertebrae, what does sound travel fastest through. But if these new standards are based on the processes, the new assessments also need to have an aspect to them that will assess how kids think, how they can apply what they have learned, not just remembering what their science teacher told them." (SY) Kenny Lee also asked "that the scores teachers and students get back are transparent enough so teachers can see where they are doing well, where their students are not doing well."

It should be noted that there are currently two large scale collaborations involved in developing assessment systems for the Common Core Standards in Math and Literacy.[15] This is an important precedent, although no guarantee that such an effort will happen with science.

OPPORTUNITIES FOR DEFINING THE FUTURE OF PHYSICS INSTRUCTION

The development and implementation of NGSS will require a large scale effort in curriculum, instruction, professional development and assessment. This presents both a need for expertise that is present in the PER community and an opportunity for the community to influence the future of instruction in physics and physical science. Some specific areas based on the previous discussion would include:

- Ensure that the final standards are, as much as possible, clear and based on sound research.
- Teacher preparation and development, particularly in practices of science and at the elementary level where the foundations for the concepts are expected to be developed.
- Curricular materials and associated professional development in new areas of emphasis, such as waves and engineering.
- Assessments that measure thinking skills and student abilities in practices as well as content.
- Work together to create better alignment of K-12 education and college instruction.

None of these ideas are brand new; members of the PER community have been doing quality work in these areas for many years. However, it is the belief of the author that an intentional, organized response by the community would be valuable in maximizing the influence of what we know about best practices in physics instruction. First, there is a limited time frame. The final opportunities for feedback on the standards will happen this fall with the final standards expected to be released in spring 2013. Soon after that, efforts in developing curricula, changing instructional practices, teacher development activities and assessment approaches will commence. PER will have a greater influence if it is significantly involved when changes first start rather than after other approaches have been developed. Second, strategic alliances will need to be developed with like minded groups in AAPT, NSTA and others. Third, there are other efforts underway to orient direction of the PER community, AP exams, teacher preparation and other institutional efforts.

It is the opinion of the author that the development and implementation of the NGSS presents a special opportunity for the PER community to help shape the future of physics instruction in both K-12 and secondary levels. It is broadly aligned with the values of this community and open to receiving assistance from groups such as the PER community.

ACKNOWLEDGMENTS

The author would like to thank Susan Yusk and Kenny Lee for their willingness to share their perspectives on this important matter.

REFERENCES

1. National Research Council, *A Framework for K-12 Science Education,* Washington, D.C., National Academy Press, 2012, p. 1.
2. Ibid., p. 8, 19.
3. ACT, *ACT National Curriculum Survey 2009*, Iowa City, Iowa, ACT, Inc., 2009, http://act.org/research/policymakers/pdf/NationalCurriculumSurvey2009.pdf.
4. NRC, *Framework*, p. 10.
5. NRC, *Framework*, p. xii.
6. Ibid., p. 344.
7. NRC, *Framework*, pp. 2, 15.
8. Ibid., pp. 1, 25.
9. Next Generation Science Standards, *Lead State Partners*, 2012, http://www.nextgenscience.org/lead-state-partners
10. Common Core State Standards, *In the States*, 2012, http://www.corestandards.org/in-the-states
11. NRC, *Framework*, pp. 19-20.
12. Achieve, Inc., *Next Generation Science Standards (May 2012 draft)*, 2012
13. M. Wells, D. Hestenes, and G. Swackhamer, *Am. J. Phys.* **63**, (1995) 606-619
14. NRC, *Framework*, p. 45,
15. K-12 Center at ETS, *Coming Together to Raise Achievement: New Assessments for the Common Core State Standards*, Education Testing Service, 2011 (revised), http://www.k12center.org/rsc/pdf/Assessments_for_the _Common_Core_Standards.pdf