Thinking About Standards

by Kelly M. Deters and Henry W. Heikkinen

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The basic foci of chemistry teaching in schools have remained unchanged since chemistry became a secondary school course in the early 1800s. These constant concerns are encompassed by just three questions:

- What should students know, understand, and be able to do?
- How will they get there?
- How will we know if they actually attained these goals?

Although those questions have remained unchanged, the particular answers offered at a particular time depend on what is known and valued about chemistry, learning, instruction, assessment, and technology, as well as prevailing views about societal priorities and the purposes of schooling.

Two sets of comprehensive national guidelines were developed in the 1990s that provide contemporary answers to those three questions:

- *National Science Education Standards* (NSES)—produced under the aegis of the National Research Council (NRC, 1996); and
- *Benchmarks for Science Literacy*—developed by Project 2061 of the American Association for the Advancement of Science (AAAS, 1993).

These documents have influenced and energized science education reform planning, policies, and action at national, state, and school district levels since their publication over a decade ago, as well as addressed the three questions posed earlier:

- *What should students know, understand, and be able to do?* NSES content standards and Project 2061 benchmarks provide answers in terms of fundamental concepts and skills to be learned by every student.
- *How will they get there?* NSES science teaching standards and Project 2061 tools and blueprints offer criteria for effective instruction and curricula. NSES program and system standards also identify external support needed to create and sustain standards-based science instruction in classrooms.
- *How will we know whether they have reached the goals?* NSES assessment standards and Project 2061's assessment blueprints provide guidance for monitoring student progress in attaining standards-based goals and suggestions about how such assessment data can inform and guide instruction.

David Armer, USNCO

Consistent with the national standards-based agenda, we can clarify the actual goal of chemistry education today: The ultimate goal of chemistry education reform efforts is *not* to improve the quality of classroom instruction, develop better textbooks or teaching units, implement better laboratory activities, or use more authentic assessments. Nor is the goal to implement new instructional methods, encourage group work, or even to use "hands-on" experiences. While these approaches certainly possess merit, their value is as a *means* to a common, well-focused *end* or goal: *improved student learning of central facts, ideas, and skills of chemistry*.

From a standards-based perspective, the sole "quality claim" that counts for *any* instructional technique is that it should clearly contribute to students' improved science learning. Instructional strategies are all *means* to an *end*, not ends in themselves. In other words, content standards express the learning *ends*, and not the *means* by which they may be reached.

Now that learning goals in science for all K–12 students have been established nationally (with related state and local efforts completed), what do "standards" imply for improving science (and thus chemistry) teaching and learning? Educators, parents, and community leaders have developed their own understanding about implications of this standards-based agenda. Unfortunately, those well-intentioned efforts have generated some unfocused, misleading notions. Those common misconceptions about standards-based science education are sufficiently pervasive to justify their attention here, as they may influence how ideas discussed later in this book are understood and interpreted.

Standards vs. Content Standards

"Implementing standards" is sometimes narrowly understood to imply that the K–12 science curriculum faithfully supports student learning defined by *content* standards. However, NSES insists that *all five* additional science-standard categories, carefully described by the NSES document (NRC, 1996), must be addressed: *science teaching* (instructional) standards (discussed in this book in chapters 4, 13–15), *professional development* standards (discussed in chapter 10), *assessment* standards (discussed in chapter 11), K–12 *program* standards, and school *system* standards. Content standards are merely an initial direction-setting step toward comprehensive standards-based reforms. Clearly, that decade-old NSES document remains highly relevant today; it certainly should not be dismissed as "yesterday's news."

Standards-Based vs. Standardized

These sound-alike terms cause mischief and confusion, since *standards-based* vaguely resembles *standardized*. The latter term, often associated with traditional school testing, carries historic baggage of rigid, fact-based, low-level test items. By contrast, classroom assessments designed to probe student learning of material defined by content standards (*standards-based*) ensure that these important student learning goals are validly assessed.

Content Standards vs. Curricula

Content standards do not specify particular science courses or curricula; they just map ideas and skills that all students—over their K–12 schooling—should know, understand, and be able to do (AAAS, 2001). Learning *ends* (content standards) are distinct from instructional *means* used to reach them. Specifying a journey's destination doesn't imply any particular travel route or mode of transportation. NSES address both standards-based *ends* (content standards), as well as standards-based *means* (teaching standards, assessment standards, etc.).

Content standards have roughly the same relationship to a school's curriculum as nutritional standards have to a particular diet or cuisine. People don't consume nutritional standards; they consume well-prepared meals, ensuring that desired nutritional standards are met. Nutritional standards can certainly guide the design of various diets and can help evaluate their quality, but they don't dictate or define a particular sequence of meals. (How many people elect to consume their entire daily allotment of dairy products within one meal?) Likewise, strictly speaking, schools do not *teach* (or even *implement*) content standards, but rather, schools plan, implement, and deliver sequences of instruction (curricula) to help students attain those learning goals.

Diversity vs. Unity

Despite one common set of nutritional standards, there are many cuisines, most of which meet those standards. In fact, people prize variety among their dining experiences. Similarly, content standards don't mandate particular science courses or science curricula. Many pathways exist to learning goals defined by content standards (NRC, 1999*a*, *b*). Students learn more effectively when curricula are adapted to their interests and to their instructor's interests and strengths, which vary across schools, school districts, states, or the nation. Thus, curricular flexibility should be encouraged across all levels (e.g., no mandated topic sequence within any particular courses, or predefined classroom or laboratory activities).

Where's the Chemistry?

Chemistry ideas and skills appear within *all* eight NSES content standards categories (Unifying Concepts/Processes in Science, Science as Inquiry, Physical Science, Life Science, Earth/Space Science, Science and Technology, Science in Personal/Social Perspectives, and History/Nature of Science). It is quite correct that the word *chemistry* does not appear in either the table of contents or index of *Benchmarks for Science Literacy* or *National Science Education Standards* (AAAS, 1993; NRC, 1996); however, it may be reassuring to chemistry teachers that the terms *biology*, *physics*, *geology*, or *astronomy* do not appear there, either.

The absence of these familiar science-content organizers should not trigger alarm. It does not deprecate the usefulness of those collective nouns as titles or organizers of school science courses. Rather, this observation serves as an additional reminder about *means* vs. *ends*. These documents *do not* describe courses or curricula; they just map intended science facts, ideas, and skills that all students—over their K–12 studies—should know, understand, and be able to do.

However, all central facts, ideas, and skills of chemistry are mapped collectively within *eight* categories of NSES content standards. That simply acknowledges and highlights chemistry as a "central science," with its applications and implications across all branches of natural science. Thus, one should not expect chemistry topics to appear only within Physical Science content standards (discussed in this book in chapters 5 through 9).

NSES content standards, while presented within particular categories, do *not* imply how school teaching units, courses, or curricula should be organized. Confusion on this point can be clarified, once again, by distinguishing means and ends: Just as specifying a journey's destination does not imply any particular route or mode of transportation, specifying and organizing learning *ends* (content standards, benchmarks) are distinctly different from the instructional *means* (curricula, courses) designed to reach them.

Discipline-Based vs. Interdisciplinary

Consistent with the previous point, NSES content standards understandably remain silent on merits of either discipline-based or interdisciplinary/integrated approaches to curriculum design. However, content standards ensure that cross-disciplinary or integrated discussions about science-course design can occur without any threat of "watering down" or omitting valued chemistry content for all students. Well-defined content standards ensure that all intended student science learning will remain on the curriculum-design table.

Some vs. All

When chemistry teachers are asked to align their courses with NSES, they frequently respond, "I already teach that, and more." However, aligning instruction with NSES requires more than just ensuring that chemistry courses address relevant content standards. The NSES content standards apply to *all* students, not just to those currently enrolled in chemistry (even if that's a majority of students). This carries major implications for high school science course design. How will students not electing to enroll in biology, chemistry, and physics courses still meet the standards? What alternative courses or sequences will be made available to the *rest* of students? And how will these courses meet other requirements, such as state graduation requirements or Regents Board or college entrance requirements?

In brief, content standards delineate what should be *learned* by all students, not just what should be *taught* by teachers or offered in elective courses. Courses and assessments should ensure that standards-based content is *learned* by *all* students, not just by those students completing courses "covering" that content.

Can vs. Should

Upon reflecting on the notion that content standards require that *all* students should learn that content, some experienced teachers may respond, "not all students can do that!" However, secondary school content standards do not necessarily describe what students *can currently do*, but what they *should be able to do,* following a K–8 standards-based science curriculum. If NSES were fully implemented in 1996 when it was first published, the juniors of 2007 would have possessed the knowledge and skills of a comprehensive standards-based science program. So, are we there yet? Most teachers would certainly agree that we are not. Why not?

An unexpected side effect of the initial cycle of No Child Left Behind (NCLB) legislation was that while schools directly focused funding and activities to enhance student performance in mathematics and reading, many schools relegated science education to the back burner. This placed teachers and students at a science-learning deficit; NCLB-mandated science assessments will be possibly linked to school accreditation and perhaps to Annual Yearly Progress indicators. But even if schools *had* revamped their science programs in 1996, time is still required to develop curricula, gather resources, provide in-service teacher support, evaluate progress, and adjust instructional programs. What can high school teachers do to fill a science-background gap among their current students, while they await standards-based students to enter their schools?

9–12 vs. K–12

If high school teachers want to ensure that students arrive fully prepared to meet secondary-school content standards, then they should envision a *K–12* science program rather than just a 9–12 science program. High school science teachers can meld their content knowledge with K–8 teachers' pedagogical and developmental knowledge (discussed in this book in chapter 14), with guidance from content standards, to establish a sound, vertical science curriculum. Such a curriculum should be cohesive—not envisioned as discrete instructional "layers," but as a purposeful development of ideas and skills mapped over students' 13 school years (AAAS, 2001).

Chemistry-related content standards should not be "saved up" for high school chemistry classes but should be *supported and developed over students' entire school experience*. Standards-based reforms imply that high school teachers, ideally, should confer with K–8 teachers to bolster their confidence about science content and best practices, including inquiry-focused, standards-based, developmentally appropriate science for students. Secondary school teachers can encourage integrating science with other content areas (such as mathematics, reading, writing, and other modes of communicating) to help prevent K–8 teachers from abandoning science in favor of strengthening other curricular areas. Care must be taken, however, to ensure that science stands as a valued curriculum in its own right and that other studies are linked to the science curriculum rather than, for example, merely selecting science-related prose for reading instruction and concluding that students have therefore encountered enough science. Science instruction should be championed and supported by a district's science curriculum coordinator or resource person. This admittedly is an ideal expectation—school districts may not yet possess needed time or resources to implement such standards-based "vertical thinking."

Mike Ciesielski

Floors vs. Ceilings

The focus on standards being met by *all* students and remediation for students not prepared to meet secondary school content standards provokes concern that students will be held back, and the richness and opportunities of more rigorous science courses will disappear in favor of more homogeneous instruction. However, content standards define the *floor*, not the *ceiling*. Content standards do not limit possibilities for students able to achieve more, they merely specify the *minimum for all students*. A "science for all" vision does not in any way preclude or discourage additional science-learning opportunities, enrichment, and course options for students motivated and capable of pursuing them.

Inquiry vs. Content

Historically, science teachers (and those who prepare, support, and supervise them) have often debated whether classroom emphasis should be placed on students' development of inquiry skills or on their assimilation of science content. This is a false dichotomy, according to the NSES (NRC, 1996, 2000), which defines inquiry *as content,* rather than merely as an instructional strategy to address "real content." Considered as content, inquiry encompasses both student understanding *about* scientific inquiry and the skills needed to *do* inquiry (NRC, 2000).

Hands-on vs. Inquiry

Some science teachers mistakenly assume that implementing inquiry in science classrooms necessarily means that students are busily engaged in numerous activities and with laboratory work. Although hands-on work is necessary and valuable in all science courses, it does *not* ensure that students are engaged in inquiry. NSES (NRC, 2000) considers inquiry as purposeful student activity, driven by *asking questions of nature*. Modeling scientific investigations through prescribed laboratory procedures is *not* congruent with students designing and conducting their own investigations. Students cannot learn to *plan and complete their own inquiries* without first gaining needed practice. By contrast, they can also participate in classroom inquiry without engaging in chemistry laboratory work—students can seek data or gather information from literature, case studies, or the Internet, and share, evaluate, debate, and generate ideas with their classmates. Thus, inquiry learning is *not* necessarily equivalent to conventional, hands-on laboratory activities (discussed in this book in chapter 4).

Summary and Conclusion

Many instructors believed that standards-based education would answer many questions about how to best teach science to students. The standards provide a framework to answer questions concerning what students should know, how they will get there, and how we will know when they've attained those learning goals. Content standards, teaching standards, and assessment standards have set minimum expectations for all students.

However, standards-based frameworks pose additional questions for teachers, schools, and districts. Because content standards define the ends, rather than the means, schools must now decide how they will attain those desired learning goals.

Once misconceptions are dispelled concerning what standards-based education actually implies, stakeholders can begin to address more challenging issues. High school science educators should consider, among other questions: (1) Are their educational settings congruent with all standards or just content standards? (2) What particular courses and sequences should be implemented to ensure that all students have opportunities to learn science in terms of all standards? (3) What standards-based curricula should they select or design, assuming that the curriculum should be based on a K–12 development of student ideas and skills? (4) How should standards-based science curricula address the science-background gap, while awaiting the arrival of students possessing complete K–8 standards-based science knowledge and skills?

Many strategies can be devised to address these questions, depending on particular districts, schools, and teachers. This book offers suggestions and provides examples for implementing all NSES standards within the context of chemistry instruction. It's up to individual schools to weigh suggestions and examples for implementing comprehensive, well-thought-through plans for meeting science standards by *all* students.

One way to explore the challenges and tasks ahead is to reflect on what teachers and school administrators should "know, understand, and be able to do" about implications of standards, whether those standards focus on chemistry or other valued science learning. That's what this book is all about!

Recommended Readings

National Research Council (NRC). *Designing Mathematics or Science Curriculum Programs: A Guide for Using Mathematics and Science Education Standards;* National Academy Press: Washington, DC, 1999*a*. Suggestions for translating mathematics and science standards into classroom instructional materials.