The Globalization of Science Education

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Abstract: Standards-based science education, with its emphasis on monitoring and accountability, is rapidly becoming a key part of the globalization of science education. Standards-based testing within countries is increasingly being used to determine the effectiveness of a country’s educational system, and international testing programs such as Programme for International Student Assessment (PISA) and Trends in Mathematics and Science Study (TIMSS) enable countries to compare their students to a common standard and to compete among themselves for top scores. The raising of standards and the competition among countries is driven in part by a belief that economic success depends on a citizenry that is knowledgeable about science and technology. This article considers the question of whether it is possible and prudent to begin conversations about what an international standards document for global citizenship in science education might look like. It examines current practices in a range of countries to show both the areas of international agreement and the significant differences that exist. It concludes with a recommendation that such conversations should begin, with the goal of creating a document that lays out the knowledge and competencies that international citizens should have but yet that gives space to individual countries to pursue goals that are unique to their own setting. © 2011 Wiley Periodicals, Inc. J Res Sci Teach 48: 567–591, 2011

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In an increasingly globalized world that is interdependent and competitive in terms of both economic productivity and educational attainment, there has been a steady movement toward standards-based science education. Many countries are making either new or renewed efforts to set higher standards for student learning outcomes so they will not be left behind in that global competition. In part, this trend is motivated by international comparisons of students’ performance on science assessments, combined with the belief that the economic well-being of a nation is related to its educational success, especially in technical fields. There is also a belief that greater specification of student learning goals and accountability through assessment of those learning goals will lead to improved learning. Although there is some resistance to this paradigm at the local level, there generally seems to be uncritical acceptance among policymakers globally (Carter, 2005).

One of the most significant drivers of this movement worldwide, because it has brought the comparative success of students around the world to light, are the reports of student performance on international tests such as the Programme for International Student Assessment (PISA), and the Trends in Mathematics and Science Study (TIMSS). PISA was created by the Organization for Economic Cooperation and Development (OECD) and first
administered in 1997. The test is administered every 3 years in reading, mathematics, and science. It is taken by students at age 15, near the end of compulsory education in most countries, during which time students have typically followed a broad common curriculum. In 2006, science literacy was the major domain tested; in 2009, reading literacy; and in 2012, the focus will be on mathematics. Fifty-seven countries participated in PISA in 2006, and 67 participated in 2009. TIMSS is an international assessment of the mathematics and science knowledge of fourth- and eighth-grade students around the world and was developed by the International Association for the Evaluation of Educational Achievement. TIMSS was first administered in 1995 and is given every 4 years. Forty-eight countries participated in 2007.

As will be described in greater detail later in the article, PISA and TIMSS differ in that TIMSS focuses more on students’ curricular knowledge, whereas PISA focuses on students’ ability to use science knowledge in real-world applications. Both PISA and TIMSS were created with the expectation that results would help policymakers think about the expectations they have for their students and consider ways to improve the level of science learning in their respective countries. At the same time, both PISA and TIMSS provide the opportunity for increased accountability, surveillance, and regulation within countries (Apple, 1999, 2000; Carter, 2005).

These international tests are having an impact on how countries view science education. For example, in the book, Making it Comparable: Standards in Science Education (Waddington, Nentwig, & Schanze, 2007), which deals with the development of science standards in a group of countries from various parts of the world, but primarily from northern Europe, half of the countries explicitly mentioned the results of TIMSS or PISA in discussions of their country’s approach to science standards. In response to the TIMSS and PISA results, many of these countries are developing more highly specified student outcome statements as a way to improve science learning and scores on those tests.

In this article, I address how international testing and the frameworks that accompany those tests are influencing discussions about science education in participating countries. In particular, the article raises the question of whether, given the work that has been accomplished by the international assessment programs, it would be productive to begin a conversation about creating common international standards and accompanying assessments that build on what has already been done. The time may also be ripe for such an endeavor given the nature of the problems that confront us globally. As citizens of the world, there are science-based issues that affect us all, and understanding the science that underlies those issues is critical for effective global citizenship. Could such common international standards be developed that would identify the most important science knowledge and skills for global citizens to have, and at the same time enable each individual country to interpret how its science education should be organized and delivered? Although most discussions about standards currently take place at the level of how to improve scores on international tests generally, at some point, given the considerable differences between the existing tests, countries will have to decide if following the lead of one or the other of these testing programs takes them in the direction they want to go.

To answer the question of whether such an effort at international standards development might be productive, this article will examine the various ways that countries around the world currently view the use of content standards and standards-based assessments. As will be discussed in this article, individual countries have their own unique educational histories and cultural values that affect what they want their students to learn in science and how they want to assess that knowledge, but there are also commonalities that could form the basis for an international standards setting endeavor. The article lays out some of the ways in which
countries currently agree and differ in their views of standards and assessment. The expectation is that this analysis will demonstrate to most readers that discussions about common international standards could be productive, but also that there are significant obstacles due to the differing views that countries hold toward standards setting and assessment. The discussion that follows focuses on the expectations that countries set for their students during the period of compulsory education, not with the high school years when disciplinary study tends to dominate science programs around the world.

There are two primary sources of data used in this article, both of which analyze how standards are being used in a variety of countries to describe expectations for students. One is a set of reports from a conference on international science standards held at the University of Kiel, Germany in 2007 and synthesized in the publication *Making it Comparable: Standards in Science Education* (Waddington et al., 2007). Experts from 15 countries discussed the development and introduction of science content standards in the educational systems of their own countries. Representatives from 11 European countries, including Austria, Denmark, England, Finland, France, Germany, Netherlands, Portugal, Scotland, Sweden, and Switzerland were joined by representatives from Australia, Israel, Chinese Taipei, and the United States. Some of these countries had previous experience with science content standards over a relatively long period of time, and others were just beginning the process of development and implementation.

The second source of data is the international science benchmarking report prepared in the United States by Achieve, Inc., *Taking the Lead in Science Education: Forging Next-Generation Science Standards* (Achieve Inc., 2010). The Achieve report is a study of the differences and similarities between science standards in 10 countries where students typically perform well on international tests: Canada (Ontario), Chinese Taipei, England, Finland, Hong Kong, Hungary, Ireland, Japan, Singapore, and South Korea. The Achieve study was conducted because U.S. policymakers believe the next generation of standards and assessments in science in the United States should be internationally benchmarked to the standards of high performing countries. In part, the Achieve study is an attempt to identify the commonalities among those international standards that could inform the current efforts to develop a framework for what is anticipated to become the next generation of science standards in the United States.

Because so little has been written about how science standards are used in individual countries, we are fortunate to have these compilations available to us. Both of them include a significant number of countries and a careful description of the use of standards in those countries. In all, 22 countries are included. But, those countries cannot be considered representative of the entire international community. For example, no countries from South America or Africa are present. And much of Asia is not represented. Because not all parts of the world are included, there is only so much that can be concluded from the reports. And, because many of the countries that are included have somewhat similar educational traditions (many from Europe) and have made a commitment to standards setting at some level, a truly international vision of science education is probably of even greater challenge than a review of the available data will suggest.

Why a Global View of Science Education?

Currently, the results of international testing are affecting how countries view their science education programs, particularly in countries where students did less well than expected or hoped for on the tests. In some countries there is a general call to create higher standards; in others the approach is to match educational programs to the framework that is guiding the development of the international assessments. Countries are paying attention to international

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comparisons because no country wants to be marginalized in a world where all parts of the
global society are so interconnected. This competition is energizing efforts to improve educa-
tion in the individual countries.

Although much of the effort to improve science education vis-à-vis other countries is cast
in terms of an economic competitiveness argument, there is also a globalization of science
that is occurring, which involves a greater degree of collaboration and cooperation among
countries. This, too, should inform the nature of the science education enterprise as well as
what students learn in science. In 2010, the U.S. National Science Foundation (NSF) included
a companion to their annual Science and Engineering Indicators Report titled Globalization
of Science and Engineering Research (NSF, 2010). The report demonstrates the tremendous
growth in investments in science and engineering around the world that are being used as a
vehicle for economic growth. The report recognizes that the globalization of science and
engineering research also holds great promise for the advancement of scientific knowledge
and for international collaboration, not just competition. Also in the United States, the theme
of the 2012 annual meeting of the American Association for the Advancement of Science
(AAAS) will be “Flattening the World: Building the 21st Century Global Knowledge
Society.” About this, AAAS says:

The issues that face us are many: climate change, energy, agriculture, health, water,
biodiversity and ecosystems, population growth, and economic development. The 2012
program will focus on the complex challenges of the 21st century that are both global
in their scope and profoundly interconnected as well as ways to tackle them on a global
scale through international, multidisciplinary efforts. (AAAS, 2011)

Another dimension of the globalization of science is science diplomacy (Lord &
Turekian, 2007). Science diplomacy involves the use of joint scientific efforts to create a spirit
of cooperation and shared purpose among countries that can contribute to a stable and secure
international community.

As the theme of the 2012 AAAS annual meeting makes clear, there are many science-
related, societal issues that affect the entire planet and on which individual countries can
collaborate. It is not my purpose to recommend at this time which of those issues would be
most appropriate to focus on in an international standards document. The most obvious candi-
dates are such things as global climate change, energy resource development and use, food
production and distribution, and human health and disease. In an interdependent world, we
are all affected by developments in these critical areas because failure to act wisely can lead
to social instability anywhere in the world. Science and technology provide opportunities to
find solutions to global problems, and the search for and training of technical talent should be
an international effort. The bottom line is that science is an essential part of our lives, and it
is a lever for economic development and international security. Scientific knowledge and an
appreciation for the benefits and limits of science that affect us as interconnected citizens of
the world should be part of the education of all worldwide. The question that I will address
in this article is how likely is it that the disparate countries of the world could come together on
what that knowledge is and how it should be described and tested.

What Is the Model That Countries Are Currently Moving Toward?

In the next section of the article, I examine the commonalities and differences in how
countries are viewing science content standards. This is intended to provide a better sense
of whether educational leaders from these various countries could settle on a common

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international model that would have a reasonable likelihood of being implemented successfully. I begin by characterizing the changes that are currently taking place with respect to standards setting around the world on which there is considerable agreement. There are two major trends: The first is the effort to create more precisely defined outcome statements regarding student learning, along with assessments to measure those outcomes. In countries where responsibility for standards setting had previously been left to individual states (Switzerland, Australia, Germany, the United States, among others) efforts to specify outcomes is being combined with efforts to create common national standards and common national assessments. The second trend is toward a more holistic and integrated interpretation of learning goals for students, using broad competency models to describe expected student outcomes instead of discrete knowledge and skill statements that curriculum developers and teachers are then expected to organize into coherent learning experiences for students.

Outcome Standards

Stating educational standards in terms of student outcomes is a relatively new experience for many countries. A number of countries, particularly European countries, had previously focused on the quality of educational inputs in their standards setting. Inputs included such things as the curriculum, instructional materials, and pedagogical strategies. In Germany, for example, prior to 2003, teachers in the 16 federal states were given guidance on what to teach through each state’s own course syllabus (Scheck & Parchmann, 2007), which gave direction to teachers on which topics to teach but not on the student outcomes to achieve. Now, the German Standards of Education are specified in the form of common outcome standards to be used by all 16 of the federal states, although each federal state still has responsibility for implementation.

This move toward clearly defined student outcomes has been described by some as a shift from the German/Nordic didactic tradition towards the Anglo American curriculum tradition (Westbury, 1999). According to Dolin (2007), in didactic oriented classrooms, teachers “autonomously interpret and translate the curriculum to make it fit to the specific class and the specific students...” (p. 80). In the Anglo American curriculum tradition, a much greater emphasis is placed on specifying performance outcomes and on accountability through student testing, which gives teachers more limited responsibility to interpret the goals of education.

The United States has long focused on outcome measures in education rather than on input or process measures. This emphasis began in the early 20th century as large-scale standardized testing became popular, but the approach was articulated most notably with the publication in 1949 of Ralph Tyler’s Basic Principles of Curriculum and Instruction (Tyler, 1949). Tyler’s goal oriented approach, with a clear link between educational goals and student assessment, continued to define American education throughout the 20th century. The approach was given new support with the publication in 1983 of A Nation at Risk (U.S. Department of Education, 1983), which supported the development of clearly stated educational goals and student assessments to measure progress toward those goals. This was soon followed by the publication of two national standards documents in science, Benchmarks for Science Literacy (AAAS, 1993) and the National Research Council’s (NRC) National Science Education Standards (NRC, 1996), which identified what all students should know to achieve science literacy and which were presented as content recommendations to policymakers.

In addition to focusing attention on foundational concepts rather than on lists of facts and principles to memorize, the U.S. national standards also brought attention to the importance of students becoming critical consumers of science by understanding the nature of science
and the scientific enterprise, on cross-cutting themes relevant across all domains of science, and on historical episodes in science. Some critics saw the U.S. standards as a repackaging of the reforms of the 50s and 60s because of their focus on canonical science knowledge rather than on more socially relevant themes (Carter, 2008; Fensham, 1992, 1997; Hurd, 2001), but most saw the value in having for the first time clear statements of a broad range of learning goals for students. What is not disputed, however, is the extent of the reach that these documents and others like them have had in influencing science education policy around the world. According to Carter (2005), “Project 2061 and the National Science Education Standards … through their international dissemination, have, in effect, crystallized the directions for the curricula and teaching reform agendas for science education globally” (p. 567).

Today, in the United States, there is a new effort underway to take the next step in the identification of learning goals for students in science by creating common standards that the 50 states can voluntarily choose to follow. A similar effort to establish common core standards has already been completed in mathematics and English language arts, and most states have volunteered to use these common core standards (Common Core, 2010). Common core initiatives represent an attempt to bring more consistency to what students across the United States are learning in these subjects. The approach also gives policymakers greater control over what is taught and greater opportunities to monitor aspects of the system, including students, teachers, and schools. It is not yet known how successful the common core initiative will be, given the long history of local control and teacher autonomy in the United States. Different parts of the country, having different traditions of local control over education, will most likely respond differently as they adjust to a system in which what is taught will be controlled much more centrally than ever before.

Internationally, the trend toward specification, commonality, and accountability through student assessment is not without its critics, especially in countries that have a long history of stating educational goals broadly, or in countries that have a history of teacher autonomy and limited emphasis on assessment, particularly for elementary and middle school students. For example, writing about the situation in Denmark, Dolin says:

It is obviously a good idea to enhance the evaluation culture in the classroom. But there is a danger that more emphasis on summative assessment could be at the expense of some of the present good and productive sides of science education … In meetings with science teachers throughout Denmark, you hear how the test examples, recently published on the internet, makes them put more emphasis on the content areas covered by the test, and change their focus toward facts and the measurable. (Dolin, 2007, p. 80)

In Finland, too, there has been resistance to too rigid an emphasis on outcomes-driven education.

Flexibility and diversity have been main guiding lines in implementation of the national framework curriculum and assessment at the school level. Especially important in Finland has been the devolution of decision power and responsibility at the local level. (Lavonen, 2007, p. 114)

Competency Models

A second international trend in science education standards development has been to describe student outcomes in terms of what are referred to as “competency models.” This is

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especially evident among European countries. An article by Weinert (2001) provides the most often cited definition of “competency.” According to Weinert, competencies are the “cognitive abilities and skills possessed by or able to be learned by individuals that enable them to solve particular problems, as well as the motivational, volitional and social readiness and capacity to utilize the solution successfully and responsibly in variable situations” (Weinert, 2001, cited in Weiglhofer, 2007, p. 63). A competency model takes a holistic and integrated approach to science knowledge. It includes conceptual understanding in various areas of science, the ability to recognize applications of relevant science ideas, and the disposition to use science ideas to explain natural phenomena.

PISA used a competency model in its 2006 science framework (OECD, 2006). In the PISA assessment framework, science competencies are the abilities and motivations to use scientific knowledge in the solution of real-world problems. PISA identifies three competencies: the capacity to identify scientific issues, to explain phenomena scientifically, and to use scientific evidence in the context of real-world situations (OECD, 2006). On the 2006 test, these three competencies are assessed in the context of problem-based scenarios having to do with health, natural resources, the environment, natural and human-induced hazards, and the frontiers of science and technology (OECD, 2006, p. 36). Each scenario is described for students, and then students are asked a series of questions meant to elicit the competencies. For example, one set of questions is centered on the formation of the Grand Canyon. Regarding the competence of explaining phenomena scientifically, students are expected to know that the breakdown of the rocks of the canyon can be explained by water freezing and expanding in cracks in the rocks. Students are also expected to know that the fossils that are observed in the limestone layer of marine animals are found there because an ocean that was once covering the land in that location later receded. To test the competence regarding the identification of scientific issues, students are expected to know that a scientific investigation could be used to determine how much erosion is caused by the use of the walking tracks, but that the question of whether the park is as beautiful today as it was 100 years ago could not be answered by means of a scientific investigation. In another scenario, students are asked questions about marble statues in Greece that are being eaten away by acid rain. To test their ability to use scientific evidence, students are given a graph showing the increase in carbon dioxide emissions since 1860 and another one showing the average temperature of Earth’s atmosphere since 1860. Students are expected to use the evidence provided in those two graphs to justify a claim that there is a relationship between the increase in carbon dioxide and atmospheric temperature.

The structure and intent of the PISA assessments contrast with most traditional definition- and fact-based science tests and with the structure and intent of the TIMSS assessments, where most items test a single fact about science or the nature of science from the different subject areas of the school curriculum. Other items test applications of students’ knowledge. For example, the TIMSS eighth-grade released items from 1999 to 2003 (U.S. Department of Education, Institute for Education Sciences, n.d.) test why the moon shines, the characteristics of mammals, the definition of a tissue, what happens to animals when they hibernate, which particles are in the nucleus of an atom, why the moon changes shape, the function of red blood cells, and how to calculate density. In terms of application of knowledge, students are expected to know that liquid in a container with a greater surface area will evaporate more quickly than liquid in a container with a smaller surface area, to compare the efficiency of two machines for pumping water based on the amount of water pumped and the amount of energy needed to run the machine, and to determine speed from a graph of distance versus time. In addition, some of the items expect students to use various reasoning abilities to solve
more complex problems related to the science content. When seen next to each other, the difference between a competency model of assessment and one based on testing students’ knowledge of the curriculum is quite striking.

A number of countries have developed their own competency models that are similar to the PISA model. In Denmark, for example, at the secondary level, the competency model includes:

- An empirical competence: the ability to observe, describe, experiment, measure, etc.
- A representation competence: the ability to represent the phenomenon in different ways (graphs, figures, pictures, etc.) and to shift between the representations.
- A modeling competence: the ability to reduce complexity, determine causalities, build and use different kinds of models, etc.
- A perspective competence: the ability to put science into perspective, to reflect on the role of science in society, to assess scientific knowledge in relation to other knowledge, etc. (Dolin, 2007, pp. 76–77).

Germany has established a complex multi-dimensional competency model. Langlet (2007) offers “thinking in terms of evolution” as an example of what the subject matter competence looks like. The “thinking in terms of evolution” competence is supported at the highest level by knowledge of basic concepts (reproduction, variation and adaptation, and history and genealogy). At the next level of specificity, the evolution competence is supported by additional statements referred to as “dimensions.” Dimension 1, for example, says: Differences in reproduction lead to differences in adaptation. Dimension 2 says: Variation in organisms leads to adaptation. Dimension 3 says: Adaptation depends on ecology (p. 168). This subject matter competence includes a set of interrelated and supporting science ideas that create a coherent mental model, which then enables one to think through a range of problems involving evolution.

Portugal uses a concept of competence based on a definition by Perrenoud (1997). According to Perrenoud, competence is “the integration of knowledge and skills developed in complex learning situations.” The notion is one of “wide-ranging competence, comprising knowledge, capacities and attitudes, which may be considered as knowledge in action or in use” (Perrenoud, 1997, cited in Galvão, Reis, Freire, & Oliveira, 2007, p. 239). The Portuguese National Curriculum identifies specific competencies that students should have by the end of compulsory education. These include reasoning; communication; attitudes; and knowledge (including substantive, methodological, and epistemological knowledge). For each of these competencies, the expected student outcomes are described in combination with examples of the types of learning experiences that students should have. For example, substantive knowledge is developed through “the analysis and discussion of evidence or problematic situations.” Methodological knowledge is “experienced by carrying out bibliographic research, observation, experiments, individually or in groups, assessing the results obtained, planning and carrying out research [and] designing and interpreting graphs based on statistical and mathematical data.” Epistemological knowledge involves “analysis and discussion based on the reports of scientific discoveries, which should highlight successes and failures, the persistence and working patterns of different scientists and societal influences in science” (Galvão et al., 2007, p. 240).

Finally, in Chinese Taipei, educators speak of “cultivating students with competences that they can carry with them for a lifetime” (Chiu, 2007, p. 304).

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“Competence” is a broad concept that involves the application of science knowledge to real-world problems involving science and technology and the capacity and disposition to use that knowledge. It can be a difficult concept to operationalize, and, as an outcome goal it can be difficult to measure, but the idea of competency is having a very significant influence on how countries around the world are defining their learning expectations in science for students.

How Different Are the Various Countries in Their Approach to Standards Setting?

If disparate countries, with various educational traditions and values, are to come together around a common set of learning goals for students that have a reasonable chance of being implemented successfully, it is important to know the ways in which the countries differ as well as the ways they are similar. Some of these differences have already been suggested, and in the next section of the article, I will provide more detail about these similarities and differences. The examples used here are drawn largely from northern European countries plus the United States, Israel, Chinese Taipei, and Australia that took part in the conference held in Kiel, Germany in 2007 and reported on in the conference report, Making it Comparable: Standards in Science Education (Waddington et al., 2007). It is not surprising that differences of opinion around standards setting would be particularly evident in the European countries, given that the standards-based approach challenges long-held intellectual traditions of many European countries, which give considerable responsibility to the classroom teacher to make decisions about what students are to learn and how that learning will be assessed. The tradition of Bildung (liberal education), which assumes that the classroom teacher has the competence to interpret the norms, values, and traditions of the society and transmit them in a way that will transform the character of the youth is deeply rooted in the consciousness of many European educators. The contrast between that approach and a more top-down managerial approach common among Anglo-Saxon countries was summarized well by Westbury (1995) in the book Didaktik and/or Curriculum. Although there are certainly additional points of departure among countries around the world besides this, the European case is useful as an example of the kinds of intellectual traditions that can influence efforts to achieve common ground.

Specificity

In some countries, the introduction of standards means greater specificity in how student outcomes are stated. For example, in Germany, in response to students’ unsatisfactory performance on PISA, the German federal education ministers decided to develop common national education standards and assessment procedures, first in German and second language study and math, and then in 2003 in the various science areas. In addition to creating standards that specified what was to be learned rather than specifying what was to be taught, the standards were also developed to be national as opposed to regional in scope (Schecker & Parchmann, 2007). This meant abandoning the tradition under which the 16 federal states had previously had independent control of curriculum and assessment, and instead giving control to the central German education authority. Switzerland is another country that recently began to develop common standards in the cantons of each of its four language regions. In 2004, the ministers of education decided to develop student performance standards, similar to what had been developed in Germany. And, as in Germany, the decision was motivated by unsatisfactory performance by Swiss students on PISA.

But not all European countries see value in highly specified and centralized achievement standards. This is particularly true with respect to educational goals at the compulsory level in countries that historically have been guided by goal statements for students that are

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expressed in broad, general terms. For example, according to Dolin (2007, p. 73), in the Danish *folkeskole* "most teachers have focused on the human development of the students and on the social functioning of the class, in order to build a strong foundation for the academic performance of the students—and thus (according to critics) give a low priority to subject specific knowledge.” Consistent with this tradition, even though there was dissatisfaction with student performance on PISA and a number of efforts were initiated to improve the educational system, as of 2007 the country had not chosen to implement a program of highly specified standards. Instead, education continued to be directed by broad goals focused on the development of individual students’ productive participation in society.

In Finland, too, the goals of education are stated in broad terms. For example, government documents state that “the main objective of education in comprehensive schools is to support students’ growth towards humanity and ethically responsible membership of society, and to provide them with the knowledge and skills necessary in life. Moreover, the instruction should promote equality in society and the students’ abilities to participate in education and to otherwise develop themselves during their lives” (Basic Education Act 628, 1998, cited in Lavonen, 2007, p. 104). The central government establishes these broad educational goals and then specifies what students should know and be able to do at the end of various grade bands. But the more specific expectations, too, leave considerable room for interpretation. For example, by the end of grades 7–9, students are expected to “recognize phenomena related to the flow and storage of heat in nature and know how to interpret those phenomena.” They should also “know how to prepare small-scale research reports, to present results with the help of tables and graphs, for example, and to interpret those results” (Lavonen, 2007, pp. 120–121).

In Scotland, there is a move to reduce the level of specification. According to Bryce (2007), A *Curriculum for Excellence* (Scottish Executive, 2006) is a recent initiative by the Scottish government that acknowledges that the curriculum of the compulsory school has been “over-specified; is cluttered and needs some simplification” and that schools need more flexibility. Bryce says this “is not a move against standards or specification per se, but it is a concession that too much has not been wholly effective, particularly when the full range of pupil abilities are taken into account” (p. 257). Similar efforts to reduce the level of specification also have been taking place in the Netherlands (Driessen, 2007).

England, too, has moved toward reduced specification of content. According to Millar (2007), the revision of the Key Stage 4 National Curriculum that came into effect in 2006 “greatly reduced the amount of detail in the specification of content” (p. 89). The four attainment targets used since 1991 were collapsed into two components: Breadth of Study and How Science Works. Breadth of Study has four strands: Organisms and Health; Chemical and Material Behaviour; Energy, Electricity and Radiations; and Earth and Environment. For Energy, Electricity and Radiations, what is specified is that the students’ study of science should include the following:

- Energy transfers can be measured and their efficiency calculated, which is important in considering economic costs and environmental effects of energy use.
- Electrical power is readily transferred and controlled, and can be used in a range of different situations.
- Radiations, including ionizing radiations, can transfer energy.
- Radiations in the form of waves can be used for communication. (Qualifications and Curriculum Authority, 2005, cited in Millar, 2007, p. 89.)
In summary, content specification is a significant issue when contemplating the development of content standards in science. There is a belief among many policymakers that greater specification gives educational leaders greater control over student learning because it reduces variability and minimizes misinterpretation of intended meanings. This means that there is greater likelihood that students will be taught (and will learn) those things that the society has deemed most important for successful participation in a global economy. It also increases accountability and surveillance through standardized assessment. But this is a difficult course to take for countries that have a long tradition of flexibility in interpreting the goals of education.

Assessment

A system of national assessments typically accompanies the creation of national standards. Some believe that standards are meaningless without assessments that measure what the standards say is important. Often, to policymakers, the primary reason for creating standards is to provide a framework for accountability monitoring. Assessment becomes the means for holding students, teachers, and schools responsible for the expected student outcomes that are specified in the standards. Throughout the world, there are many approaches to assessment, and countries vary in the extent to which assessments are used for accountability purposes. Given how intimately connected standards and assessment are, any discussion of international standards needs to also consider the differences in how assessment is viewed.

At one extreme are the countries without a strong tradition of centralized assessment but yet have performed well on international tests. In those countries, there is relatively little political pressure to increase the level of accountability through testing. In Finland, where student scores are near the top on international tests, there is little interest in increasing accountability through assessment. According to Lavonen (2007), “flexibility and diversity” have guided the implementation of the national curriculum framework and assessment. In Finland there is a “culture of trust” with respect to teachers, and a sense of professionalism among teachers for “judging what is best for students and reporting on progress of their learning” (p. 114).

In Sweden, there are no mandatory national tests in science, and Swedish students have done acceptably well on international science tests. Students are tested at the national level in Swedish, English, and mathematics, but not in science. Instead, assessment of students’ knowledge in science is the responsibility of individual teachers. At the national level, Sweden describes the competencies that students are to achieve (e.g., modeling, reasoning, communications, and concept understanding), and teachers are provided with a bank of test items that they can use for constructing tests. Items that meet certain quality standards are included in the test bank, and the items are categorized according to the competency that they measure (Stromdahl, 2007).

Other countries without a strong tradition of national testing, however, are under political pressure to increase their emphasis on assessment. In Denmark, for example, because of lower than expected performance of Danish students on PISA 2000, the government took part in a review of its compulsory schools (OECD, 2004). A key suggestion of the reviewers was to “build a stronger basis of student assessment and school evaluation” (Dolin, 2007, p. 73). In response, the government began a process of introducing more tests into the system. But, because Denmark does not have a strong tradition of assessment, the move toward greater accountability through student assessment has been controversial. As Dolin says: “It is important to stress that the folkeskole is not (or rather has traditionally not been) an examination-oriented school ... It is the class teacher (deep in the Danish school tradition)
who has the main responsibility for monitoring and supporting the academic and social development of the pupils. School failure is an almost non-existing phenomenon in the folkeskole” (Dolin, 2007, p. 72). There is also some concern now that the increased focus on assessment is encouraging teachers to “teach for the exams instead of teaching and assessing for learning” (p. 80). Also, in Switzerland, where too many students reached only the lowest level on PISA, performance standards and assessments have been developed to provide outcome monitoring. But, according to Labudde (2007): “Switzerland has absolutely no tradition in centralized assessments, neither on the national nor cantonal or school level” (p. 290). Therefore, the proposed assessment of standards will be low stakes and based on a representative sample of the students. The stated intention of the tests is to monitor the educational system and provide feedback, not to make judgments about students or teachers. However, “some Swiss teachers still fear and oppose the development and assessment of standards” (Labudde, 2007, p. 290).

Germany has had similar concerns about student performance on international tests. As in Denmark and Switzerland, historically there had not been an emphasis on systematically examining student outcomes in Germany, and assessment was handled separately by teachers in the individual federal states. But the response by educators in Germany to performance standards and increased assessment seems to have been more positive than it was in either Denmark or Switzerland. In response to the results of international testing, Germany instituted a national testing program to increase the level of accountability. According to Rupp and Vock (2007), “it is now more widely accepted in the German educational community that the outcomes of school education processes have to be evaluated through periodic assessments of students’ competencies, which represents an explicit focus on objectively measurable results of classroom teaching” (p. 174).

The Netherlands is a country that did have a system of national testing for some time, but has recently found the testing to have adverse effects on teaching and learning. In 2002, an Exploratory Committee on Chemical Education mapped out the problems encountered in chemistry education in the Netherlands (which apply to biology and physics as well). The committee concluded that the exam requirements for chemistry are “a constraining strait-jacket.” The committee felt that practical assignments and personal research received too little attention and that “the examination program makes it impossible to have extramural activities such as an introductory visit to a university, a school for vocational education, a laboratory or a company.” In addition, “teachers spend too much time preparing their students for the national tests.” They “copy questions from former national exams instead of developing questions, which are congruent to the learning, classroom activities and teaching” (Exploratory Committee on Chemical Education, 2003, cited in Driessen, 2007, p. 233).

Local Teacher Autonomy

Countries also differ in the extent to which their educational systems are under the control of the national government or under local control, either at the state or school level. This issue is often closely related to the issue of specificity, discussed above. Typically, the more broadly learning goals or content standards are stated, the more freedom teachers are given to interpret them in the context of their own local situations. For example, in Denmark, it is the classroom teacher who has primary responsibility for the academic and social development of the students. Teachers are given only broad-based guidance about what to teach. In biology, for example, according to Dolin (2007), “students must acquire knowledge about living organisms and the surrounding nature, the environment and health, and applications of
biology—with emphasis on the understanding of connections.” The teaching “must take the students’ own experiences, investigations, and understanding as a point of departure, and it must enhance their joy of nature and willingness to engage in biology and biological problems.” Teaching should also “develop the students’ responsibility towards nature and provide a basis for attitude and action to environmental problems” (pp. 75–76). Within those parameters, teachers decide on the experiences students will have.

Finland has a similar approach to education. According to Lavenon (2007) the Finnish National Core Curriculum for Basic Education (National Board of Education, 2004) gives schools and teachers the freedom to choose learning materials and teaching methods. In addition, there is no national pre-evaluation of curriculum materials that teachers create. Teachers are “valued as experts in curriculum development, teaching and in assessment at all levels.” A culture of trust assumes that teachers, along with head teachers, principals, and parents “know how to provide the best possible education for children and young people” (Lavenon, 2007, p. 102).

Sweden also takes the approach that teachers should have the responsibility to interpret the broad goals of the national syllabi. According to Stromdahl (2007), “The syllabi are designed to make clear what all pupils should learn, at the same time as they provide great scope for teachers and pupils to organize their work, choose their own materials and working methods” (p. 265).

In some countries where there had been a history of centralized control of education, there has more recently been a transfer of authority to local schools and teachers. In Chinese Taipei, one of only four non-European countries who participated in the Kiel conference (Waddington et al., 2007), there has been a move toward greater openness and decentralization in the educational system. In 1998, guidelines were created to replace standards as part of a process of educational reform (Ministry of Education, 1998). The reforms emphasized “societal and personal needs” over national needs, multiple versions of textbooks over a national version of textbooks, a competence approach over a content orientation, a general education over an elite education, and a social relevance approach over “an academic rationalism approach” (Chiu, 2007, pp. 307–308). According to Chiu (2007), as a result of the implementation of these guidelines, which provided only qualitative descriptions of content knowledge, teachers had the responsibility to design teaching materials for their own classes in accordance with the rationale, goals, and core competencies in those guidelines.

A similar trend toward school and teacher control is taking place in the Netherlands. A new structure for the first 2 years of secondary schools was implemented in 2006. According to Driessen (2007), since the reforms of 2006, schools became more autonomous and “could organize their own structure and content of these first two years of basic secondary education” (p. 223). Teachers are also encouraged “to substitute some chapters in the textbook about the applications of science with investigation projects based on contemporary science” (p. 234).

In Germany, on the other hand, with the recent development of national standards and assessments that are common across the 16 states, greater control now rests with the federal government. But the standards are written flexibly, and teachers in the 16 states still have responsibility for implementing those standards. According to Langlet (2007), this could have both positive and negative consequences: “While teachers generally appreciate the flexibility in the way that the standards have been written, there is a danger that this could lead to different, and perhaps erroneous, interpretations with respect to basic concepts, competences and levels of achievement” (p. 165).
In England, there are statutory requirements concerning what teachers should teach, but no specification of student outcomes. Even so, many teachers believe they do not have enough freedom to decide either what they should teach or how to teach it. In part this is because of a non-statutory “scheme of work” that was developed to provide additional guidance to teachers. According to Millar (2007), “these detailed schemes, intended as illustrations and to help improve practice in weaker schools and departments, have had a significant constraining effect on practice—and have strengthened the already widespread view of teachers that their job is to ‘deliver’ a curriculum designed and specified by someone else, rather than to be thoughtful professionals with a view on what they should be teaching as well as on how to teach it” (p. 90).

In France, the State is responsible for course syllabi, which are specified for each grade level and each disciplinary area and are mandatory for the whole country. The State also publishes official instructions and comments regarding the syllabi. According to Malleus (2007), prior to 2005 changes in the syllabi were generally “content-oriented and top-down driven, giving teachers little chance to be listened to and giving them almost no time to reflect on their practices” (p. 129). In 2005, a new law was enacted in which the content of the syllabi and how student learning was to be assessed was placed under the scrutiny of the French parliament, giving a greater say in education matters to society at large (although not specifically to teachers as a separate group).

Standards as Guidelines Versus Standards as Prescriptions

In some countries, especially those with a federal system of government, standards act as a framework that guides the development of curriculum and instruction throughout different parts of the country. In other countries, especially those with a single highly centralized education system, standards are sometimes synonymous with core curriculum (Labudde, 2007). Whether they act as guidelines or prescriptions is often related to the degree of specificity of the standards. When standards are written at a high level of generality, there is more room for flexible interpretation and variations occur in what is taught.

As noted earlier, France is a highly centralized country, and the curriculum is under the tight control of the central government. The government is responsible for the course syllabi in each discipline at each grade level, and these syllabi are mandatory throughout the country. The syllabi are, in essence, both the standards and the curriculum. An introduction to each syllabus lays out the goals of the course, and the syllabus itself specifies the content, the knowledge and abilities to be addressed, examples of activities to be used, and the time to be devoted to each part of the syllabus. For example, as part of the chemistry syllabus for 15/16-year olds, students are required to follow a protocol for synthesizing a chemical compound and comparing it with a natural extract that contains the same compound as has been synthesized. The activities are described as follows: “Synthesis (or semi-synthesis) of one or several chemical compounds, implying simple techniques such as reflux, heating, filtration, separation. Verify with previously acquired knowledge that a synthesised chemical compound is identical to the same compound contained in a natural extract” (Malleus, 2007, p. 235). According to Malleus, teachers in France appreciate such detailed instructions and would feel uncomfortable without them.

In Denmark, on the other hand, the aims for teaching are stated with considerable room for variable interpretation. Below, for example, are the goals for teaching biology in grades 7–9. Each subject area focuses on four specific areas of study. For biology, the four areas of study are: living organisms and their environments, environment and health, the application of biology, methods and ways of thinking in biology.

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The core knowledge and skills for the area "environment and health" includes:

- Describe and explain important functions of the body.
- Know different factors influencing the human health.
- Describe human exploitation of nature and know about sustainable development.
- Relate to contemporary environmental problems and their significance for human health and nature.

According to Dofin (2007), "even the most detailed level allows latitude for the individual teacher" (p. 76).

In Chinese Taipei, the broad education guidelines that were published in 1998 were followed by curriculum guidelines for seven learning areas for 9 years of compulsory education in elementary and junior high school in 2000. As noted earlier, here too the guidelines provide guidance to teachers rather than describing or prescribing the contents of the curriculum.

The main goals of the new guidelines of the science and technology learning area in grades three through nine include the following:

- to cultivate an interest in and a passion for science inquiry and habits of active learning,
- to acquire methods of inquiry and a basic competence in learning science and technology and to be able to apply one's learning to daily life,
- to cultivate a loving environment, and treasure resources and respect life,
- to cultivate competence in communication, teamwork, and getting along harmoniously,
- to cultivate independent thinking and problem-solving and stimulate their potential,
- to be aware of and explore the interactive relation between humans and technology. (Chiu, 2007, p. 309).

Even at the highest level of specification, there is room to adapt instruction based on these guidelines to the local situation. The following are illustrative of the level of specificity used to describe the knowledge and skills students should have about chemical reactions in grades 7–9 in Chinese Taipei:

- Recognize some illustrations of chemical change in daily life (the milk soured or fermented, for example) and find through experiment that the possible causes are light, air, or temperature.
- Understand the diversity of change in an experiment (three states, precipitate, and the changes of color and temperature).
- Understand the acid-base property of a solution when salts are dissolved and the operational definitions of acid, base, and salt through an experiment; know the characteristics of solutions of an acid and a base; and realize how to apply and discriminate between them in daily life.
- Know the characteristics of ions and understand that the electrolyte solution conducts electricity with the ions. (Ministry of Education, 2003, cited in Chiu, 2007, pp. 313–314).

The point is that countries differ in whether standards are treated as guidelines for curriculum development or as descriptions of the curriculum itself. They also differ in the level of specificity of their content standards which, in turn, affects how the statements are interpreted.
These differences in tradition would significantly affect how an international standards document was viewed and used.

**Content Differences**

Countries also differ with respect to the content from each science area they think is most important. Achieve, Inc. (2010) conducted a review of the standards of 10 countries to identify standards that had exemplary features “worthy of emulation.” After a preliminary review of all 10 countries (Canada, Chinese Taipei, England, Finland, Hong Kong, Hungary, Ireland, Japan, Singapore, and South Korea), they chose 5 (Canada, England, Hong Kong, Japan, and Singapore) for an in-depth analysis by content experts in biology, chemistry, and physics. Content experts also reviewed the Earth and Space Science standards of three countries that have upper secondary level standards in Earth/Space Science (Canada, Chinese Taipei, and Japan). The analysis was based on a protocol that Michigan State University had used in their 1997 study analyzing content standards of countries that had participated in the Third International Mathematics and Science Study (Schmidt, McKnight, & Raizen, 1997). The protocol provided content experts with a common metric for analyzing the standards of the various countries. The content experts were asked to respond to questions in the following six categories:

- **Coherence**: Are the standards based on an underlying conceptual framework that reflects the science as a unified discipline?
- **Focus**: Do the standards focus on the most important concepts in the major fields and do the expectations for a year or grade span appear to be manageable?
- **Rigor**: Are concepts developed in depth, is the level of cognitive demand of the standards appropriate to the grade level or grade span, are mathematical applications required, and do the standards require students to engage in laboratory or field investigations?
- **Progression**: Do the standards develop essential content with increasing depth from one grade level or grade span to the next?
- **Specificity**: Are the standards specific enough (at the right grain size) to guide instruction and are performance expectations tightly connected to the content knowledge required?
- **Clarity and accessibility**: Are the standards clear, logically organized, and user-friendly and are they scientifically accurate? (Achieve, 2010, p. 40).

At the largest grain size, the study found that all of the countries focus on key ideas from the three disciplines of biology, chemistry, and physics, although there were differences in the specific content that they emphasized from those disciplines. According to the Achieve report, countries dedicate the greatest proportion of their standards to Biology and Physics content: 28% to Biology and 43% to the Physical Sciences (Physics and Chemistry). Earth and Space Science had an average of only 9%. The remaining 20% fall under “cross-cutting content” (Achieve, 2010). What is interesting from the U.S. perspective is that although there was remarkable agreement among the comparison countries, there was a different pattern in the United States. In particular, there is considerably less emphasis on Physical Science at the elementary and middle school levels in the United States than in the other countries and more emphasis on Earth and Space Science. In part, that is due to the relatively equal treatment given to Life, Earth, and Physical Science in U.S. standards documents, including *Benchmarks for Science Literacy* (AAAS, 1993), *National Science Education Standards*.
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(NRC, 1996), and the Science Framework for the 2009 National Assessment of Educational Progress (National Assessment Governing Board, 2008). There were also differences within each of the specific categories that Achieve used in their analysis:

Coherence. As evidence of coherence in standards, Achieve looked for "an underlying conceptual framework that reflects the nature of science" (p. 48). They focused on the National Research Council's vision, articulated in Taking Science to School, that science is "both a body of knowledge and an evidence-based, model-building enterprise that continually extends, refines and revises knowledge" (Duschl, Schweingruber, & Shouse, 2007, p. 2).

One of the most important aspects of the nature of science in the NRC statement is that it involves evidence-based reasoning. The Achieve study found that there is explicit mention of the importance of supporting claims with evidence in some but not all of the countries' standards. In some of the countries where it is present, it is not a consistent theme throughout. The study also found differences in how the countries address independent student investigations. Some countries expect students to conduct extensive investigations that they design themselves; others have a laboratory requirement that involves carrying out more routine activities. The study also found inconsistent results around the idea that science involves model and theory building that is constantly subject to revision. In particular, they found that most countries do not place much emphasis on key points in the history of science during which major conceptions were fundamentally altered.

Focus. The Achieve study found that all five countries that were part of the in-depth analysis (Canada, England, Hong Kong, Japan, and Singapore) try to limit the content that is covered by focusing on selected concepts or themes. But each country does so in a somewhat different way and focuses on different concepts. One country may emphasize electrical energy and limit coverage of force and motion. Another may emphasize ecosystems but not give much attention to natural selection or extinction. Overall, content experts raised enough questions about the specifics of content focus in the various countries to suggest that this is an area where there is limited agreement among countries and between the Achieve content experts and the policymakers of each country.

Rigor. According to the Achieve report, some countries are clear about the expectations they have for students, and the standards generally show what they expect through verb-based performance statements. The Achieve study found that Canada, Hong Kong, and Singapore attach performance expectations to each content standard, which indicate a range of cognitive challenge. England uses a rubric to define levels of cognitive performance on a scale of 1–8, which at the upper end includes high-level cognitive demand (e.g., plan, communicate, evaluate). Japan does not include performance expectations. The study also examined the extent to which each country incorporated mathematics into the science standards as another indicator of rigor. Here, too, there was variation from country to country. Canada, Singapore, and Hong Kong favor a qualitative approach at the Primary and Lower Secondary levels. England takes a more quantitative approach, expecting students to apply formulas and make routine calculations. Singapore's qualitative approach continues through grade 10, but then becomes much more quantitative at the Upper Secondary level. The same is true for Hong Kong.

Progression. The Achieve study found that countries did not do well on developing essential content with increasing depth from one grade level or grade span to the next. In some countries there is a clear effort to build content complexity for a given topic from grade level to grade level, but in other cases the Achieve study found that conceptual development

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throughout the grades was weak or non-existent. The study also found that the expectations from one grade span to the next were sometimes inconsistent, especially where there was too great a conceptual jump between elementary grades and upper levels.

Specificity. The Achieve study found that the five countries that were studied in depth vary considerably in the degree of specificity of their content standards, both from country to country and within country from grade span to grade span. They found that most countries are quite specific in their expectations at the upper levels, with the exception of Japan, where the standards become more general at the upper grade levels.

Clarity and Accessibility. The Achieve study noted that the standards from Canada, England, Hong Kong, and Singapore were especially well organized and clearly written and could function effectively to guide instruction.

Summary of the Achieve In-Depth Analysis

Although Achieve reviewers found positive features in the way science content was described in all of the standards documents, they did not think that any of them could be considered as exemplars across all levels and all content areas. They pointed to a number of areas of weakness:

- **Incorporation of mathematics**: The study concluded that this is an area in which none of the countries have been completely successful, even though the importance of integrating mathematics with science standards is widely recognized to be important.
- **Evidence-based inquiry**: The study concluded that none of the countries has been completely successful in calling for students to consistently focus on evidence to support claims.
- **Chemistry foundation for concepts in modern biology**: The content reviewers pointed to what they considered to be an insufficient “foundation in chemical bonding, reactions, and some aspects of organic chemistry for students to comprehend essential concepts in modern biology” (Achieve, 2010, p. 58).
- **Interdisciplinary connections**: There was also a concern about the lack of connections made between disciplines “that would reinforce student understanding of how a concept in one discipline has explanatory power in another” (Achieve, 2010, p. 58). The exception to that was the Earth and Space Sciences, which by their very nature are interdisciplinary.
- **Learning progressions**: The study found that none of the countries’ standards could “serve as an overall exemplar from the Primary through the Upper Secondary levels” (p. 58) when it comes to how standards are organized from grade to grade. The report pointed in particular to a gap between Lower and Upper Secondary standards in terms of the complexity of content and performance expectations. In particular, they noted this disconnect in complexity in the application of mathematics in the standards of a number of countries.

In summary, there are many similarities but also significant differences in how science content is described in standards documents of the countries that were studied. Countries also differ with respect to how they meet the criteria that were established by the content experts who took part in the Achieve study. Each of these differences raises questions about what an international standards document in science would look like. How much mathematics or quantitative reasoning would be included? How much focus on evidence-based reasoning? How many interdisciplinary connections? These and other questions would have to be considered in any conversation about the nature of an international standards document.

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What Issues Should Be Attended to When Developing a Common Set of International Standards?

Clearly, there are many ways in which countries differ or are similar in their approach to standards. Many of these differences and similarities were noted above in the discussion of Achieve's evaluation of a sampling of standards from countries that performed well on international tests. Given the various approaches to standards, what would it take to create a set of guidelines that would be welcomed internationally? This next section of the article considers a number of challenges that should be considered in creating standards of any kind, whether national or international. Twelve challenges were suggested by Labudde (2007) in the context of the HarmoS (harmonization of the compulsory school) project in Switzerland. These challenges are also applicable more broadly and deserve close attention in any consideration of a globalized view of science education. A number of them are discussed here, either in the way that Labudde (2007, pp. 279–295) originally identified them or modified to make them applicable to the current discussion. They are offered as a starting point to begin to think about the kinds of issues that would have to be considered in creating an international standards document.

The nature and purpose of standards need to be well defined. Certainly, before embarking on an effort to create international standards, we need to be clear about what their purpose would be and how they would fit with existing standards documents currently being developed and used by countries around the world. At a minimum, we can safely say that a common international standard document for a global understanding of science would not have the force of law; it would be a guide for countries to use as they saw fit. Some might adopt it formally for their own country as part of their national standards, but that would be a choice made by individual countries.

Standards should be coherent within a single grade and from grade to grade. Coherence, integration, and coordination are important within each content area and between science and other content areas such as mathematics, the social sciences, language arts, and the humanities. Ideally, coherence, integration, and coordination would extend from elementary school through the university level. This would allow for teaching and learning of critical ideas to be cumulative within each grade and from grade to grade, and it would provide opportunities for teachers to build on what was being taught in other grades and in other subjects. A standards document for global understanding of science should demonstrate a progression of understanding from grade to grade as well as connections among ideas within a content area. It should also be possible to show applications to mathematics, the social sciences, language arts, and humanities. This suggests that experts from these other areas would be part of the standards development process and that they would have the opportunity to suggest how their disciplines would contribute to a globalized understanding of science.

Strong consideration should be given to describing student outcomes in terms of competencies that integrate knowledge of science concepts, use of knowledge in real-world contexts, and dispositions to use knowledge to explain phenomena and solve science-related problems. Any discussion of what we expect as the outcomes of science education for a global understanding of science needs to consider whether these outcomes will be primarily about science content or be broadly integrated and focused on dispositions, attitudes, and capabilities, along with science knowledge. Because of the efforts of a number of countries and of PISA to state expected learning outcomes in terms of competencies, we now have a significant accumulation of experience in this area. It should be possible to assess the effectiveness of those efforts to use competency models to both describe and assess what students should know in science.

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Any standards document, whether written in terms of integrated student competencies or in terms of discrete knowledge and skill statements, must reflect the results of research in science education as well as a country's traditions and values regarding education. It is certainly too much to ask that an international standards document accommodate all of the established precedents of individual countries, but the creation of international standards should reflect an awareness and sensitivity to the variety of approaches that countries take, and they should take into account what research says about student learning in science. According to Labudde (2007), standards should be built on the following considerations:

- Results of research in science education, including insight into students' preconceptions, their conceptual changes, and the advantages and disadvantages of different teaching methods.
- The current science curriculum of a country, including the main objectives of science education, the contents typically taught in a country, and the preferred teaching methods.
- General objectives of education of the particular country, such as the value and appreciation of social and communicative skills.
- The structural frame of science education, including the qualifications of the science teachers, the capacity of the country to deliver in-service training, the amount of time devoted to science teaching each week, and the equipment and material available in schools.
- The extent to which a country has been affected by international approaches, such as the PISA 2006 concept of scientific literacy, which might have an influence on their own national standards and may lead to a positive attitude toward such an international effort.

The development and definition of standards is a cyclic process, including normative decisions and empirical evaluations. It is important to approach standards setting as an iterative, cyclical process. After they are developed and used, an effort should be made to determine if they are effective. In particular, are they written at the appropriate level of difficulty, or are they too demanding for most students? In the United States, states revisit their science standards every several years. PISA revised the 2003 framework in science for the 2006 testing. Standards development is an expensive and labor-intensive process, but if resources can be made available, there should also be a way to make adjustments to the standards as new knowledge is gained. This would ensure that the standards would continue to be appropriate for the purpose they were intended. This means, as well, that a mechanism would be needed to oversee, fund, and guide the development of research that would inform standards revision.

Transparency and involvement of reflective practitioners and key stake holders are necessary conditions to develop and implement standards successfully. As Labudde (2007) puts it so well, “The implementation of standards needs a broad basis of legitimation. Therefore, the involvement of all parties concerned is needed in order to ensure the acceptance of reform and a successful implementation” (p. 286).

It is well known that acceptance of innovation in education requires the participation of the parties involved. Any effort to create standards that would inform the science education programs of countries around the world would require a process for obtaining their input and incorporating it into the document. PISA has accomplished this by creating a mechanism for involving all OECD countries in setting the framework that guided the development of the PISA program. This could serve as a model for any future attempts that might be made to create a global vision for science education. Such an approach should consider in particular
the role that classroom teachers might play in the process, given that ultimately they are the
ones who will implement any changes, and without their support very little will actually be
accomplished.

The function of the assessment must be determined and communicated in a transparent
manner. As noted earlier, assessment and standards typically go together. Assessments can be
used to judge the performance of students or teachers, or they can be used to provide feed-
back on the effectiveness of the system as a whole. PISA was designed to give countries
feedback on their educational systems, which could then be used to begin conversations about
the strengths and weaknesses of their educational systems and how they might improve them.
Some countries have gone beyond that purpose and used the results of PISA as an account-
ability measure.

Understandably, any system of international standards and tests would have to provide
countries with feedback on how well their students are performing in the areas specified in
the standards themselves. Individual countries would use the standards and tests in the way
that they found most appropriate. The challenge of any process to create standards and tests
would be to do so with an awareness of the variety of ways they might be used, so as to
maximize their usefulness to countries. For example, countries may find it helpful if the
results of testing could be used diagnostically to identify specific misconceptions students
have or strengths and weaknesses they have in particular aspects of logical reasoning.
Countries might also find it helpful if the results of international testing could be easily
combined with testing in their own country to create more useful national systems of
assessment.

There are potential advantages and disadvantages of standards and accompanying
assessments that need to be considered. In addition to the value of having all students world-
wide understand the nature of science and the science content that is related to our global
existence, there are a number of other potential advantages that can come from the globaliza-
tion of science education. One positive outcome is the greater collaboration of teachers world-
wide. This is increasingly possible as Internet communication and social networking grows in
popularity. There is no reason why educators around the world cannot share ideas about how
to put into practice a set of international standards they would be charged with implementing.
An agreed-upon set of standards could also lead to better teacher education programs world-
wide, greater harmonization of those programs with intended student learning outcomes, and
joint efforts to align teacher preparation with international goals.

But there are problems that can arise as well. The most often cited criticism of standards
and accountability through assessment is the narrowing effect that standards can have on the
curriculum (Nentwig & Waddington, 2007). Therefore, it is essential that any international
guidelines do in fact “guide” and not dictate, and that there is room for each country to
incorporate what they consider to be the most important ideas into their curriculums. These
differences provide the opportunity for continuing discussions about what is most important
to teach, which can then guide the revisions of standards in the future. There is also a fear
that standards reduce the amount of innovation and originality that comes from individual
teachers. All due consideration should be given to the value that comes from the desire of
teachers to interpret the standards as they see fit and accommodate them to their own local
situation.

Conclusion

I began this article by asking whether it would be productive to start a conversation about
creating common international standards and accompanying assessments that build on what

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has already been accomplished by the international assessment programs. In particular, would it be productive to begin such a conversation around the theme of science for effective global citizenship? It goes without saying that there are science-based issues that confront us all, and understanding the science that underlies those issues is critical for effective global citizenship, but, as this article has pointed out, along with some commonly held attitudes and approaches to standards development, there are also significant differences in how countries view science content standards, which would certainly make such a project challenging.

PISA and TIMSS have provided an entry into the world of internationally negotiated framework setting in science. Having to agree on a framework for developing assessments on which countries are compared and which inform the degree of effectiveness of the science education programs of each country has a way of focusing attention on what is most important. This is a difficult process because it requires developing a broad consensus around competing interests. Although progress in this area has been made through the efforts of PISA and TIMSS, some would argue that there is still room for improvement. Some wish to see more curricular content tested on the PISA assessments, and others wish to see more focus on socially relevant issues (Carter, 2005; Sadler & Zeidler, 2009). Sadler and Zeidler (2009), for example, concluded that PISA items were "standard decontextualized process questions embedded in a brief, but unnecessary story" (p. 916). The authors found that the released items "seem quite removed from the SSI [socioscientific issues] movement" (p. 909). I believe the work begun by PISA and TIMSS should be expanded in new directions with efforts that will shine light on the issues of greatest importance for all students to learn in a globalized world.

The use of such standards and accompanying assessments would of necessity be voluntary, in the same way that is being proposed by the Common Core Standards movement in the United States (Common Core, 2010). Perhaps a common core that could be supplemented by each country would be the most effective way to proceed.

The framework should be written in language that is general enough to allow countries to interpret the standards and use them in ways that are most appropriate to their own needs, but the language also has to be precise enough to provide guidance. Standards that use language that is too vague are not helpful. For one, they encourage misinterpretation, which can lead to confusion and frustration. What is needed are statements of science knowledge and skill that can be illustrated using a variety of cases and instances, but which convey the same basic meaning to all who read them. Statements that simply say students should understand global warming or the nature of the international food supply are only minimally helpful in providing direction for instruction. But, to be used effectively by a range of countries, neither should the framework include hundreds of detailed statements such as the specific range of wavelengths at which carbon dioxide absorbs radiation from the earth. A challenge would be to find the right balance that provides useful specificity that is both helpful and not overburdening. Finding that right balance would be one of the challenges of such an effort.

Difficult decisions, such as whether the focus should be on specific content knowledge or more integrated competency models, would also have to be made. There are differences of opinion concerning which is the most appropriate way to describe learning goals for students and what the balance should be. If well written, discrete content statements can have a clarity about them that can effectively guide instruction and assessment. Integrated competency models may be more difficult to describe and assess but may more accurately describe what we hope the result of education will be. There are also differences concerning whether all citizens should know how to design and conduct scientific experiments or if, instead, students should learn how to be critical consumers of science (Lederman & Lederman, 2007). Can an appropriate balance be found? Finally, an honest discussion needs to take place regarding the

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current paradigm that is driving the globalization of science education, built primarily around international competition for science knowledge and economic development. How much room is there for genuine collaborative efforts rather than simply trying to achieve a competitive advantage? Decisions should be made intentionally by the science education community, based on the results of careful and thoughtful analysis and research, not simply as imperatives of institutions and trends that are largely beyond our control. In the words of Carter (2005): "... science education needs to problematize its reforms so the connections to globalisation and its ideologies can be fully investigated and elaborated" (p. 572).

This is not a short-term project, and the issues that are raised by the descriptions I have presented of how science education is carried out in the various countries barely scratch the surface of what needs to be considered. But it is something on which we should begin a conversation. To be effective, the actual writing of international science education standards should be done in a way that allows for an iterative process of revision to continue over the long term. This, of course, requires international leadership of the highest quality. International leadership at all levels is difficult because the world is organized into competing national entities. Policymakers naturally think of their own country’s interests first and only then do they pay attention to what is good for the world. Often what is in the best interest of all is not seen as being in the best interest of an individual nation. But the project has value and deserves the attention of all of us.

References


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