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Real Reform Takes More than "Stirring the Pot"

This article is the first in what will become a continuing series of articles highlighting the perspectives of renowned science educators. The first featured article is by Robert Yager, Science Education Center, University of Iowa, USA. Dr. Yager has directed over 100 NSF projects designed to improve K-16 science programs. He has served as president of seven national organizations which promote the visions central to the NSES Standards. His co-authors have studied with him for the past three years and will carry the knowledge they have gained here back with them to their universities in Egypt and Turkey.

Introduction

Too often reform efforts in K-16 science classrooms consider only the major concepts that define what is to be taught with too little attention to how it is taught! Too often assessment is based on student performances in class and on examinations that measure only the retention of information gained from teacher talk, class recitations, and textbook coverage. The 1996 National Science Education Standards (NSES) portray science as a human endeavor and how this is translated to what should be considered in science classes (NRC, 1996). One example of the reform advocated in the Standards is defining science CONTENT as including eight distinct foci. The eight are listed in the order they appear in the 1996 Standards and used to provide an organizational scheme for school science. These facets are: 1) unifying concepts and processes in science; 2) science as inquiry; 3) physical science; 4) life science; 5) earth and space science; 6) science and technology; 7) science from personal and social perspectives; and 8) history and nature of science.

A first draft of new National Standards has recently been released (NRC, 2010). These Standards resulted from a series of meetings and follow-up communication among 20 experts invited by NRC to coordinate this new effort. Dr. Thomas Keller, the Senior NRC Program Officer involved with the New Standards effort, has been active in informing all regarding the draft document. He publically acknowledged that the focus was on concepts included in Science, Technology, Engineering, and Mathematics (STEM) and not the major changes needed in goals, teaching, and assessment that appear first in the 1996 Standards. All persons have been asked to evaluate the work available regarding the New Standards before a final version is released in 2011. Keller reported that the 1996 standards succeeded with the visions for reform of teaching, staff development, assessment, and defining inquiry. The focus for the New Standards has been largely on the basic sciences with the added inclusion of Engineering as a major new component. Such a change has added over 260 new references for defining Engineering. This is a major addition and indicates a complete reversal of the rationale concerning technology and engineering in the early efforts to revise physics in the mid 60s. The PSSC course was undertaken before Sputnik but enjoyed major NSF support as the new course was developed (Zacharias, 1956). It represented needed reforms in the 60s and beyond, but focused almost exclusively on basic science constructs.

The last three of the eight facets of content in the 1996 Standards have been given little attention over the past 30 years. Basically the reforms were newer looks at understanding the typical science disciplines characterized by the work of scientists and the skills they use to develop the explanations accepted and suggested for use in educational settings. Two reform efforts during the late 60s which were prepared for elementary schools indicate a continuing problem. The Science Curriculum Improvement Study (SCIS) was organized around major science concepts. Another project called Science: A Process Approach (SAPA) focused exclusively on fourteen process skills. In addition to merely listing the important science concepts and process skills which are often used to define and plan school offerings, the 1996 NSES introduced a major new approach and used it as the first facet of content, namely the "unification" of concepts and processes. Both of these are viewed as important "domains" for teaching and learning science in the Yager and McCormack model (1989) as pathways for achieving real student learning with understanding.

Few criticize concepts and processes as comprising the two central domains for science education. In fact, few expect any other foci for defining school science programs. The "unification" of the two was to be done by individuals, including teachers, and to accomplish more than merely outlining concepts and processes to be taught separately from textbooks or state curricula.

Once concepts and processes were unified, they were to represent the world created, known, and used by practicing scientists; they were also organized as three of the NSES discipline categories, namely physical, life, earth/space (facet numbers 3, 4, and 5). Such a classification of these "science" disciplines has been a focus of most school programs for nearly a century. There have been many attempts to promote interdisciplinary courses, K-16. Many of these are often found in elementary schools and middle schools. Surprisingly, such approaches are now being tried in many universities. The place where little change seems to occur is in high school science for college preparation and in college undergraduate offerings. Such approaches are now emphasized in the plan for new Standards. The one innovation with the discipline categories in 1996 was the joining of physics and chemistry into "physical science" – a recommendation that has been ignored by most high schools and colleges. But, the three discipline categories certainly assume that the "unification" of concepts and processes has been accomplished! These "New" attributes are now emphasized and illustrated in the plans for New Standards.

The plans for the 2011 Standards call for the unification of all STEM components and emphases; it is titled: New Conceptual Frameworks and the Development of Goals for K-12 Science AND Engineering Education. This new effort has also created three Dimensions for focusing on the typical disciplines (i.e., Life Science, Earth and Space Science, Physical Science, and Engineering and Technology). Dimension 2 focuses on Cross-Cutting Elements, including their use in society as a whole. The Third Dimension focuses on how scientific and engineering practices work and how they can be included in school science classrooms. The new proposed Standards then move to putting the Dimensions together as expectations with illustrations of student performance expectations. The new effort ends with the inclusion of Prototype Learning Progressions articulating with learning programs for the science disciplines with Engineering added.

Inquiry was listed as the second Feature of Content in the 1996 Standards which has attracted more attention since its use in the early 60s as an obvious and important form of content as well as suggesting needed teaching strategies. Such a focus is also suggested with the proposed new 2011 Standards. Inquiry has become almost a "religious" term accepted by all. It is now used to describe textbooks, teaching approaches, and is included as a major focus in all state curricula. Inquiry has been central to all reform in science education since its inclusion in the NSF-supported projects of the 60s and 70s. Joseph Schwab (1963) defined it as "What Science Is" – and to capture more attention he spelled it "ENQUIRY"! But, many science educators want to add the word "science" as an adjective when referring to "scientific investigations."

Inquiry alone is a word with no unique meaning – something that many science educators applaud! Do students ever feel ownership and use of such content as something designed to affect their own lives? The NRC, in its Inquiry volume (2000), list five essential features of inquiry. They are: 1) Learner engages in scientifically oriented questions; 2) Learner gives priority to evidence in responding to questions; 3) Learner formulates explanations from evidence; 4) Learner connects explanations to scientific knowledge; and 5) Learner communicates and justifies explanations (NRC, 2000, p. 29). For many people these ESSENTIAL features are ignored. Some science educators maintain that the "essential" features cannot be attained (Abell & Lederman, 2007).

The 1996 NSES recommend three other new foci for CONTENT (often also indicating broader uses of inquiry in the discipline categories). These are also included in the Yager-McCormack Domain Model. Unfortunately, conflicts remain concerning these three new areas of CONTENT. Also, conflicts regarding them and/or ignoring them also is a problem when looking at the four goals that were recommended as organizers for school science in the 1996 NSES. These four goals are listed to frame what should go on in science classrooms. The leaders for the New Standards have reported that there is little value in changing or expanding the ways teaching should be improved. The teaching aspects of the 1996 Standards were the areas where there was little or no argument concerning the need of features for improving science teaching.

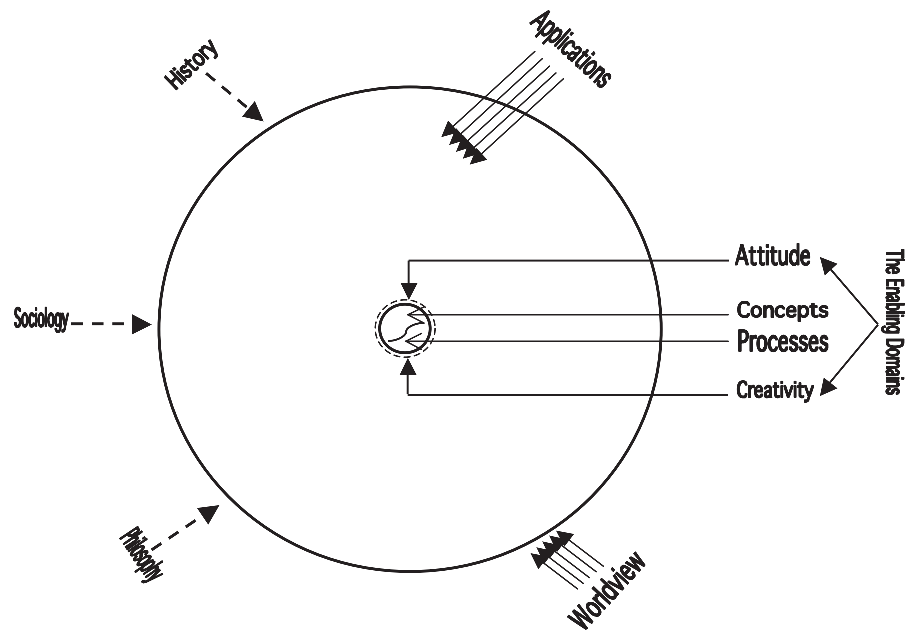
The 1996 goals, teaching features, continuing professional development of teachers, and assessments were not considered by the new efforts. The working team reported that student learning goals should be central goals in achieving the current reform efforts with students – again as related to conceptual constructs. The goals in the 1996 NSES were aimed to produce students who can: 1) experience the richness and excitement of knowing about and understanding the natural world; 2) use appropriate scientific processes and principles in making personal decisions; 3) engage intelligently in public discourse and debate about matters of scientific and technological concern; and 4) increase their economic productivity through the use of the knowledge, understandings, and skills of the scientifically literate person in their careers. The first goal was to ensure that each student has personal "experience with the richness and excitement of knowing about and understanding the natural world". It was to assure that every student has experience with "doing" science as opposed to following directions from teachers, textbooks, curriculum guides, or New Standards (even once a year??)! It was/is a major departure to assume that all students should experience the essence of science for themselves. This is again where the Essential Features of Inquiry should be reviewed! These concerns were not addressed anew by the persons involved with the 2011 "New" Standards. But, they continue as the "New Challenges" for the recommended changes in teaching.

Many now indicate that most students graduate from high school without a single real experience with "doing" science (or dealing with its features, with the five essential features of inquiry, with use of applications of science in new settings). The first goal indicates that real science should be approached in more meaningfully ways with students as major players. The final goal was to prepare students to increase their economic productivity through the use of the knowledge, understandings, and skills of the scientifically literate person in possible careers. This is often included as a desired outcome – but it is hard to measure for most K-12 enrollees at a particular grade level in typical courses called "Science." It will be interesting to see if these continuing concerns were voiced by the many who respond to the 2011 version of the "New" Standards.

One of the first new content facets in the 1996 Standards was the inclusion of technology (the human-made world) in addition to the natural world. It is also important that there was one word added, namely an "and" for appropriate/desired CONTENT; it is listed as science <u>and</u> technology! This is a major reversal from the reforms of the 1960s when Zacharias – the architect of the first of the "alphabet" reforms (PSSC Physics) -- proclaimed that all technology should be eliminated from K-16 science courses "because it was not science"! He argued that including technology (the use of concepts and processes to produce usable devises) was appropriate only for use in special fields (such as industrial arts for non-college bound students) but not science for the college bound. Even though technology was attractive and interesting for most students, it was not to be a part of the school science curriculum. The 1996 NSES sought to alter this and to openly promote the study and use of technology in school science programs. This is where engineering and health (as well as environment and energy) can serve as foci! This change is also a major advance in the proposed "New" Standards.

Among the three new facets of content included in the 1996 NSES as CONTENT was science for resolving personal and societal problems. This content was to be a way of meeting goals 2 and 3 of the NSES reform efforts. It was recommended as an organizer for science study – a reason for learning the "unification" of concepts and processes. This 7^{th} facet of content implies student involvement, use of community experts, ties to informal science, service learning, and actual problem resolutions. These unmet challenges from the 1996 Standards may provide new efforts to focus on the needed changes in teaching. Some suggest use of "projects" as a descriptive term indicating action and involvement for/with students. But, too often these become exercises, ideas students are expected to follow -- where answers are already known. This CONTENT facet aims to put students in the roll of asking questions, proposing answers, seeking evidence for the validity of the answers, and using the ideas in problem resolutions. This learning is demonstrated in its use and action in the school and the larger community – instead of how well information is remembered or if a particular skill can be demonstrated. New "Contexts" are too often missing for both actions. Perhaps the New Standards will be more successfully met than was the case for the 1996 Standards. Ideas need to come from students – not teachers or books! This facet of content must be defined by students as well as the techniques that might be tried for resolving the personal and social issues. The results can help determine if students really learn, understand, and use what comprises school science. The efforts with the "New" Standards efforts may be helpful!

Figure 1: Teaching and Learning Domains and their Use in Promoting More Success in Meeting the Goals that Frame the National Science Education Standards



As mentioned earlier, Yager and McCormack originally proposed in 1989 five domains (later a sixth was added) for approaching needed changes in CONTENT which would entail different reforms that would change teaching, curriculum, and assessment of learning. Figure 1 illustrates their proposed domain structure. The Worldview Domain relates directly to the final facet of science content, namely "history and philosophy of science." This Six Domain model is suggested as important for NSELA leaders. It is a way to focus on the features of the NSES reforms that go unnoticed and/or non-considered in most states and schools, especially by many education leaders. Too many remain enmeshed with the science discipline-based concepts and to a lesser degree the skills that scientists have used as they define curriculum and instruction for use in classrooms. Nearly all the innovative reform ideas indicated by the 1996 NSES CONTENT, especially the last three facets, are usually ignored. All should expect the new standards to further develop these new visions.

The Yager-McCormack model does include science processes and concepts in a central position. But there was the admonition that this "bulls-eye" version is a small place where scientists work and act (perhaps involving only 0.00004 percent of the total human population of the world). And yet typical school programs too often focus attention exclusively on the "what scientists agree to be known and accurate" and to a lesser degree "how they know". Most ignore the problems and the time it takes to get new ideas accepted by the whole scientific establishment – let alone the whole of society. Some may fear that the initial efforts of the new standards may revert science education to a focus on Concept Mastery – even with the enlarged emphasis on Engineering and Technology.

The science concept and process ideas need to be enlarged in terms of the typical attention they are given in defining school programs. The New Standards make this possible. Two Enabling Domains surround the "Bulls-eye model", namely Creativity and Attitude. Both of these domains represent what all students have – even before entering schools. And, yet much evidence exists indicating that both of these domains worsen the longer students are enrolled in typical science courses K through 16 (Yager, Choi, Yager, & Akcay, 2009)! Literature review reveals that a steady decline in positive student attitudes towards science can be observed as students progress from primary through secondary schools (Cho, 2002; George, 2006; Hacieminoglu, Ali, & Yager, In Press). In other words, the more students study science in school, the less positive are their attitudes and the less creativity they display and use.

Carl Sagan (NRC, 1998) has pointed out that all humans are unique in their wonderment about the natural world around them. Young children (before school) are full of questions and awe! Their curiosity seems endless; they have fun learning on their own. Recent research reports indicate that the human brain is at work responding to the natural world while still in the mother's womb. We cannot afford to not focus on attitudes and creativity. They should be enhanced as ways to make reform efforts more successful. That is why they are labeled as the "Enabling Domains"! We expect these domains to be even more central with the New Standards efforts!

In one sense the Enabling Domains are like cell membranes controlling what goes in and out of the concept and process domains as well as for its uses in the application domain which is where nearly all humans live and work. There can be no science or engineering if there are no questions, no curiosity, and no interest in learning more about the natural universe, and/or the advances in technology that can be used for further explorations of the universe and for the improvement of human existence. Education may need to focus more on such explanations and questions as well as needed technologies for dealing with them. This again could be forthcoming even sooner with the 2011 Standards and their focus on Engineering.

The research is clear regarding creativity and attitudes. They can both be improved and used in other contexts with different teaching and with attention to each (Akcay & Yager, 2010). This is where reforms should begin and end – not in a new construction of the same old constructs of curriculum – which are based on what scientists and engineers purport to know and the skills they have used to develop this "knowing". It becomes too often a matter of redoing what the past has proposed!

Some new efforts have been tried where students (K-16 levels) begin their study and involvement with applications of science and technology – which lead them to analyses of the important concepts and processes needed. Some teacher education programs have introduced a whole series of application courses to match the traditional discipline organization of high school and college offerings (Akcay, 2010; Akcay & Yager, 2010). For the most part these application "offerings" ignore the use of the concepts and skills taught for their own sake.

The sixth domain of the Yager-McCormack model is the Worldview Domain. It remains a major effort for many interested in the philosophy of science, its history, and the sociology and psychology of science. It is viewed by many as a new discipline and difficult merely to add to typical science courses. It is suggested in the first chapter of the New Standards. But, many teacher education programs are adding courses in the philosophy, history, and sociology of science. Some call these offerings the Social Sciences of Science. Many use the term Socio-Science (Zeidler, 2003; Sadler, 2009)! Many like this new view of school science. Some even include it as a major learning domain but proceed to teach it like traditional school science, i.e., didactically. Unfortunately, however, typical school and college science programs have changed little. In fact, we still have critics arguing that this Worldview of the science and technology efforts is an echo of Zacharias' earlier comments in the late 60s, namely "these views are not Science"! Nonetheless, it remains a look at what science is, has been, and continues to be. This is something with which every science teacher, science education researcher, and educational leader should be aware and involved. Real reforms are difficult to achieve! The research team involved with Project 2061 (AAAS, 1990) suggested that real change in schools would not be achieved before the year 2061 (the year Halley's Comet will again be seen on earth). This means it will likely take 75 years – the lifetime of typical humans -- to result in real educational change.

NSELA members are invited to interact with each other about these ideas. Use of the NSTA Exemplary Science Programs (ESP) is recommended as a source of information where current NSES reforms have been tried and found to be successful in meeting goals and preparing for life beyond school. The first eight of the NSTA ESP Monographs include: 1) Exemplary Science in Grades PreK-4; 2) Exemplary Science in Grades 5-8; 3) Exemplary Science in Grades 9-12; 4) Exemplary Science: Best practices in Professional

Development; 5) Exemplary Science in Informal Education Settings; 6) Inquiry: The Key to Exemplary Science; 7) Exemplary Science for Resolving Societal Challenges; 8) Preparing for Careers in Science and Technology. All of the ESP volumes have been completed with involvement of the National Science Education Leadership Association (NSELA), especially as new Exemplars are identified and new advances tried and used beyond the examples reported in previous editions.

Too many continue merely to "Stir the Pot" with new efforts to produce teacher-proof curricula and new pathways to achieve the old concept-related goals included in prescribed curricula. We need more who can practice the visions, logic, and features of science teaching; i.e., science as a way of exemplifying the defining features of science itself. This means investigating ways where more positive results can be gained with such direct experiences indicated in the 1996 NSES Goal #1! Nonetheless, it is hoped that the focus of the New Standards will also assist in this arena. Ensuring that all who study science (& all STEM areas) should relate to NSES and all should be emphasized (perhaps as much as 90% of the time) in all "STEM" offerings and at all levels (K-16). This should, however, not be construed as recommending less consideration of the other three goals nor all eight Content facets featured in the 1996 NSES. Initially the New Standards have avoided the 1996 Goals as a starting place for assessing success and initiating actions in the classroom.

We can do without so many merely "stirring of the same old pot"! Instead we need more building of new pots and seeing what can be accomplished with them!! We need more experimenting with the ingredients used and tried in the pot! The New proposed NSES provide ideas for new ingredients! We need more who can stir while also adding ingredients and reporting on the accomplishments and new successes with more learning and more students who can succeed with respect to meeting the NSES goals!! Others should work to add new ingredients to the pot. But, do they always result in more positive outcomes? How can we know without trying??

It is exciting to review the recent work of those involved with the development of the 2011 Standards to consider as all NSELA members continue to lead us to new and expanded visions. The curriculum takes on new proportions.

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