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STEM – Changes Defined

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As we move forward with current reforms entitled Science, Technology, Engineering, and Mathematics (STEM), the American Association for the Advancement of Science (AAAS) has recently committed itself to offering some members to work with other scientists and engineers to help design STEM reforms. They are placing volunteers in K-12 classrooms one day a week to make scientific literacy possible for all students. But even with such efforts, the definition for STEM as reform is not clear. It is not a scientific term like the ones scientists choose to replace a complicated observation. Even with more and more dollars being spent to support STEM reforms in all K-12 classrooms, we continue to not have an accurate idea as to what STEM could accomplish over the next decade. Some STEM changes have been proposed and considered in several states for the last four decades. We now know the eight features offered by the Next Generation Science Standards (NGSS) (Achieve, 2013) as reform; but, will they really improve the actual "doing" of science for all students at all grade levels?

Project Synthesis research efforts were completed in 1981 with major financial support from the National Science Foundation (NSF) (Harms & Yager, 1981). It involved hundreds of people concerning the reform research. But, for many it lacked coherence and real understanding of science. There were only four goals identified for the teaching of science. They were originally called "Goal Clusters." These same four major goals influenced work on the 1996 National Science Education Standards (NSES) (National Research Council, 1996) as well as the 2013 Next Generation Science Standards.

The goals needed for school science programs should include defining outcomes, teaching procedures, and student learning. Yet, the four goals are rarely used to indicate student learning and outcomes for all. They include the following: 1) the personal exploration of the natural universe while seeking explanations of the objects and events encountered; 2) use of appropriate scientific processes and principles when making personal decisions; 3) engage in public discourse and debate about matters of scientific and technological concern; and 4) increase economic productivity by use of science understandings and skills regarding careers.

Such common goals continue to be used to introduce reform efforts, but they rarely define what is done in classes to accomplish them! New terms in science are agreed upon as short cuts for scientists to use. Unfortunately, in science education the specific terms are used to indicate the reforms first; but, they are rarely agreed upon in advance. Textbooks are written and used as content outlines of what students should know. Such "knowing" is often a result of remembering and unrelated to "real knowing" and using them in new contexts!

A recent study was conducted with over 100 Iowa science teachers who had not really looked at the goals for science studied in school and considered how they might affect typical teaching (Tillotson & Young, 2013). A sample of their students were asked if they were actually "doing" science in their science courses in their schools; over 90% replied and said "yes." These teachers and students felt that typical teaching provided ways of "doing" science, but when asked for further elaboration about teacher explanations of the "doing" of science, students often only listed facts, concepts, and procedures. Later, the same teachers and students were asked to review the four goals and their use in determining whether their work in classes really identified "Science Doers." This was done after defining and describing what is meant by "DOING" science commented by practicing scientists. While reviewing the goals, goal number one provided major emphasis. It was described as the *explorations of the natural universe while seeking explanations of the objects and events encountered*. When the students were asked a second time if they were still convinced they were actually "doing" science in their classes their answers were altered. Students answered the second time with "No." So, in other words, there is difficulty with what is meant by the "doing" of science. Students are more successful with science when it is seen as working on problems identified by them. These problems for all students should include problems that are *personal, local, current, and/or collaborative* situations.

Studies done in connection with the Iowa Chautauqua Program over a 30 year period have reported that most students think they are "doing" science when they follow the directions and/or information included in textbooks, deal with teacher assignments, or work on procedures in "prescribed" laboratories (Yager, S. O., Akcay, Dogan & Yager, R. E., 2013). Recently, the NGSS leaders have talked about how students could be evaluated and involved in the actual "doing" by describing science (practices). They listed STEM features in eight ways that define the actual "doing" of science. All science starts with trying to accomplish goal number one by "Asking Questions." It should be emphasized that all science starts with questions while also not "knowing." Many are now more interested in encouraging all students to actually "do" science. This means their asking questions, proposing possible answers, investigating a number of things that all represent ways of "doing" science. Too often it is merely assumed that things done in science classrooms can be defined as the "doing" of science.

There are eight features offered by the NGSS for improving student learning and mastery of the practices defining science. These include: 1) asking questions; 2) developing and using models; 3) planning and carrying out investigations; 4) analyzing and interpreting data; 5) using mathematics and computational thinking; 6) constructing explanations; 7) engaging in arguments concerning evidence; and 8) obtaining, evaluating, and communicating information. These NGSS practices are excellent but they do not specify what is to be done by students vs done by teachers!

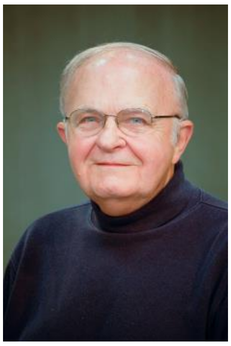
The NGSS unfortunately deal primarily with Crosscutting Concepts that again focus on information accomplished. The second major part of the NGSS effort is recognizing Common Core ideas that scientists have provided and agreed upon over a period of many years. It is merely assumed that the disciplines of biology, chemistry, physics, and earth/space science all lead to separate goals that each can be used for indicating successes for science teaching. They are seen as varied information that illustrate separately but differently the doing of science.

It is interesting to note, however, that Paul DeHart Hurd (1991) reported from the Project Synthesis research that only 0.000059% of all humans across the world are actually practicing scientists. It is important to note that few college science teachers really have had any interest or experiences with interactions with students that are designed to enhance their learning. They merely tell students what they should "know" and use with teachers, other students, and for typical testing for mastery.

Bruce Alberts, a long time NSF staff member who was instrumental in providing funding for science education activities, has identified major challenges for achieving real reform of science education. He was the editor-in chief of The AAAS *Science* magazine for five years where he emphasized the importance of education. Alberts stated that until college science teaching changes, we are going to have difficulty with how K-16 science is perceived and carried out in classrooms and laboratories (Alberts, 2013). Unfortunately, in research institutions, the pay-off for success is the research professors undertake (the fact is that publications indicate their professional successes!). They do not include models for teaching. It is important to note that until students do something other than recite what they read, remember what they are told, and stop doing "cookbook" laboratories in science classes, the situation will not change. Most students have not even come close to dealing with what science really is. Too often it is just a matter of saying that "doing" science is "doing" what they are told to do and repeating them for class evaluations that are measured by typical tests.

If science is to be taught to accomplish the goals outlined in most current reform efforts (i.e., STEM), they are going to have to realize that students need to be more centrally involved instead of just being "receivers" of information. They need to be "doers" in the doing of real science. This is something quite different from what is done in most classrooms where the teacher is in charge: making most of the decisions, including assignments, and determining what is done in laboratories. The results that are observed, recorded, and interpreted now are pointing out the importance of "curriculum" which too often is prescribed by state science coordinators, politicians, (and sometimes by government leaders), and textbook companies, which prepare materials for teacher use. Laboratories where all directions are provided should not be considered appropriate unless students identify questions and help in involving other people -- even some with opposing views, in the actual collection of evidence. Too often we can assume that "doing" science is only listening, interpreting, recalling, and/or repeating what students are told. Students should be encouraged to explore and to offer ideas for explaining the things that they see and thought about during their explorations. They should be encouraged to get information from parents, other teachers, and local business and other community leaders. Science, Technology, Engineering and Mathematics (STEM) requires activities that are central to reform around the world for changing how science in schools is portrayed. STEM should not be linked to ideas and explanations offered by teachers, textbooks, and government leaders. It should be something students create with their own minds. STEM suggests less emphasis upon the classification of science into disciplines which typically are: biology, chemistry, physics, and earth/space science. The disciplines become important for scientists who work largely in one of the areas considering their research. It is a classification scheme, not something that dictates what is expected for teachers to "do" in classrooms and which students are expected to follow.

Interestingly, most scientists are pleased to define science without disciplines in school classrooms. Certainly, students should be the thinkers, the doers, the arguers with their own brains. Most scientists now agree on such a broad definition for science. Once again, it is *the exploration of the natural universe while seeking explanations of the objects and events encountered!* Such reform efforts are essential if real reforms are to succeed, with STEM learning seen as something students do on their own!



Having started his career as a high school science teacher, Robert E. Yager has been a professor of science education at the University of Iowa since 1956. He has served as president of seven national organizations, including NSTA, and has been involved in teacher education in the U.S. and several European and Asian countries. Among his many publications are several NSTA books, including Focus on Excellence *and two issues of* What Research Says to the Science Teacher*. He has authored over 700 research and policy publications as well as having served as editor for ten volumes of NSTA's Exemplary Science Programs (ESP). Dr. Yager earned a bachelor's degree in biology from the University of Northern Iowa and master's and doctoral degrees in plant physiology from the University of Iowa in the U.S.*

References

Achieve (2013). Next Generation Science Standards. Retrieved from http://www.nextgenscience.org/

Alberts, B. (2013). Grand challenges in science education. *Science,* May 31, 2013.

Harms, N., & Yager, R. (1981). *What research says to the science teacher, Vol.3*. Washington, D.C.: National Science Teachers Association.

Hurd, P. DeH. (1991). Why we must transform science education. *Educational Leadership, 49*(2), 33-35.

National Research Council. (1996). *National science education standards: observe, interact, change, learn*. Washington, DC: National Academy Press.

Tillotson, J. W. & Young, M. J. (2013) The IMPPACT project: A model for studying how Preservice program experiences influence science teachers' beliefs and practices. *International Journal of Education in Mathematics, Science and Technology, 1*(3), 148-161.

Yager, S. O.; Akcay, H, Dogan, O. K. & Yager, R. E. (2013). Student views of teacher actions in science classrooms designed to meet current reforms. *Journal of Science Education and Technology, 22*(6), 974-983.