K-12 STEM Education
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STEM: A Focus for Current Science Education Reforms

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The definition of STEM (Science, Technology, Engineering, and Mathematics) reforms remains unclear. STEM is not like a scientific term where scientists choose to replace a series of complex observations with a new word. Even with more and more money being spent to support STEM reforms in all K-12 classrooms, we continue to not have accurate ideas of what STEM efforts are and/or what they could/should accomplish. Some STEM changes have been proposed and considered for use in several statewide efforts across the United States. But, to what end? Will major funding improve the personal "doing" of science for all students and at all grade levels?

Project Synthesis (Harms & Yager, 1981) research efforts were completed with major financial support from the National Science Foundation (NSF). It involved hundreds of people concerning the needed research to accomplish student learning successes. But, most lacked coherence and success with real understanding of science for students.

Four goals were identified by Project Synthesis to describe the reasons for teaching science. These same four major goals influenced the aims of the National Science Education Standards (NSES) [NRC, 1996] as well as for the Next Generation Science Standards (NGSS) [Achieve, 2013]. The four goals for school science programs were to include defining specific student outcomes, teaching procedures, and accomplishments of real student learning. The four goals for science education define the reform efforts as follows: 1) the personal exploration of the natural universe and 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.

These common goals continue to be used to describe science reform efforts – but, they rarely define what is done in classrooms to accomplish them or to exemplify current STEM efforts. In science education specific terms are used to indicate the reforms per se with no agreement on measurements of any features in advance. Textbooks are written which provide definitions of major concepts students should know. Such "knowing" often is only an indication of what students are expected to remember to indicate mastery of concepts, which often do not indicate real learning or real "knowing".

When students are asked to elaborate about the explanations of the "doing" of science in classes, students often *only* list facts, concepts, and procedures. It is important to define and describe what is meant by "doing" science by practicing scientists. The first goal indicates new major emphasis for such doing of science. It is central to the National Science Teachers Association's position statement, which defines "both science and technology as human endeavors which involve similar basic procedures. Doing science involves exploring the *natural world* and then seeking explanations – based on evidence – regarding objects and events encountered. Technology focuses on the same features that include the *human-made world*" (NSTA, 2013-14).

When students were asked if they were convinced that they were actually "doing" science in their classes, most answered "of course". They just assumed that studying science in science classes and doing what the teacher expected are actually <u>doing</u> science and not related to doing what scientists do. This indicates the difficulty with what is meant by the "doing" of science. Students are more successful with science when it is seen as working on problems that they have identified. These problems for all students should include problems that are *personal, current, local and/or requiring collaborative* situations in their own lives. Typical science teaching is seen as following what teachers teach. This is especially the feeling offered by high school students in chemistry and physics -- more so than by students in the elementary and middle school grades.

Recently the NGSS leaders have talked about how students should be evaluated and involved in the actual "doing" by describing teaching (practices). These provide eight ways that help define what it means to actually do science. These features of science help improve student learning and mastery of science practices. They include: 1) asking questions (for science) and defining problems (for engineering); 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 (for science) and designing solutions (for engineering); 7) engaging in arguments concerning evidence; and 8) obtaining, evaluating, and communicating information (Achieve, 2013). These NGSS practices are excellent but they do not specify what is to be done by students vs. what is done by teachers.

All science, especially as part of STEM efforts, start with trying to accomplish goal number one by "Asking Questions". It should be emphasized that all science starts with questions and not "knowing". Many involved with STEM are now more interested in encouraging all students to "do" science related to the four goals. This means students asking questions, proposing possible answers, collecting evidence, and deciding on the validity of the answers proposed. All these 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. And yet this does not represent what scientists do as their personal research. Instead, they represent what expert scientists propose as current explanations of the natural universe.

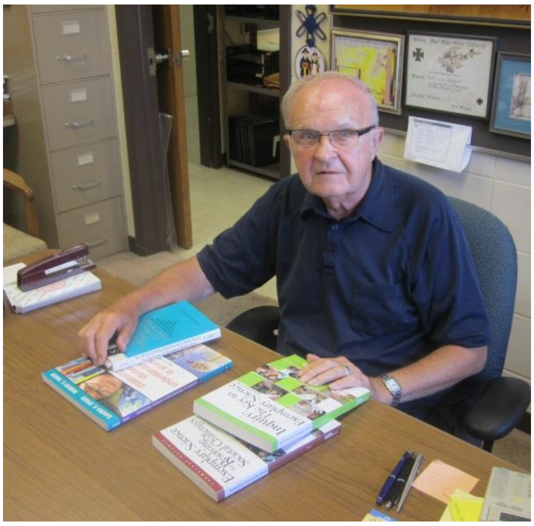
Another major part of the NGSS effort is recognizing "Crosscutting Concepts of Common Core ideas" that scientists have provided in discipline formats and agreed upon over a period of many years. It is merely assumed that the disciplines of biology, chemistry, physics, and earth/space science all lead to separate goals (and content) that can be used for indicating successes for science teaching. Such disciplines are seen as but varied information that illustrate separately and differently the "doing" of science. Science does not start with separate disciplines.

It is interesting to note that Paul DeHart Hurd reminds us in 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 experience with their interactions with students that are designed to enhance their learning. They merely tell students what they should repeat when interacting with other teachers and students and what they need to recall for tests.

Bruce Alberts (2013), 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. Unfortunately, in research institutions the pay-off for success is the research professors undertake (the fact is that publications indicate their professional successes!). They certainly do not include models for effective teaching! It is important to note that until students do something other than recite what they have read and remember what they are told, needed changes will not occur. Professors need to stop using "cookbook" laboratories and calling them needed features of results for science classes. Most students have not even come close to dealing with what science and/or STEM really is. Too often it is just a matter of saying that "doing" science is "doing" what they are told to do and repeating these for class evaluations and/or measured by typical concept mastery tests.

If science is to be taught to accomplish the goals offered in most current STEM reform efforts, we must realize that students need to be more centrally involved instead of just being "receivers" of information and doing labs and passing recall tests. They need to be "doers" in the "doing" of real science. This is certainly something quite different from what is done in most classrooms where the teacher is in charge -- making most of the decisions, including making assignments and describing what is done in most laboratories. The results that are observed, recorded, and interpreted now are pointing to the importance of a "student-centered curriculum" (Cullen, Harris, & Hill, 2012) which too often is prescribed by state science coordinators, politicians, (sometimes by government leaders), and textbook companies that prepare materials for teacher use. Laboratories where all directions are provided should not be considered appropriate until students first identify questions and help in involving other people (even some with opposing views) in the actual collection of evidence. Too often we, like students, assume that "doing" science is only listening, interpreting, recalling, and/or repeating what students are told. Students should be encouraged again to explore and to offer ideas for explaining the things that they see and think about during *their* explorations. They should be encouraged to get information from parents, other teachers, and problems identified by local businesses and other community leaders. STEM requires activities that are central to real reform efforts around the world, which describe 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 like biology, chemistry, physics, and earth/space science. These disciplines become important for scientists who work largely in one of the areas considering their personal 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.

In summary, science should again focus on what questions students have and indications of how they can be used in new situations. Interestingly, however, most scientists are pleased to define science without such "disciplines". Certainly students should be the *thinkers*, the *doers*, and the *arguers* with their own brains. Most now agree on this broad definition for science. To summarize the important meaning of STEM reforms we again need to use language for defining science as in NSTA's official position statement: *both science and technology are human endeavors and involve similar basic procedures, science involves exploration of the **natural world** seeking explanations – based on evidence – for objects and events encountered, and technology focuses on the **human-made world**.* Such reform efforts are essential if real reforms are to succeed around the world. Perhaps 2015 will be the major success year that produces graduates with STEM experiences where they see something students do on their own.



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