Excellence in STEM Education Requires Efficient and Safe Facilities

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Changes in STEM Education Require Changes in Science and Facilities

How do we create a rigorous, relevant, student-centered learning environment that models real-world contexts and better prepares students for the fields of science, technology, engineering and mathematics (STEM) in the 21st Century? What would it look like?

Our knowledge-based economy is driven by constant innovation. The foundation of innovation lies in a dynamic, motivated and well-educated workforce equipped with STEM skills. However, the nature of our workforce and the needs of our industries have changed over time. Today, an understanding of scientific and mathematical principles, a working knowledge of computer hardware and software, and the problem-solving skills developed by courses in STEM are necessary for most jobs. Therefore, STEM education is an enormous and pressing need in our society. The report of the 2003 Trends in International Mathematics and Science Study (TIMSS), December, 2004, clearly indicated that our students lagged behind those from China, India, and Indonesia. Our national economic prosperity and security require that we remain a world leader in science and technology. Pre-college STEM education is the foundation of that leadership and must be one of our highest priorities as a Nation. It was during this part of the last decade that STEM education became a highly visible part of K-12 education.

In response to this need, Congressman Vern Ehlers, (R-MI) and Congressman Mark Udall (D-CO) launched the bipartisan STEM Education Caucus for Members of Congress.

The STEM Initiative

These fields of STEM are collectively considered the core technological foundation of an advanced society, and an indicator of a society's ability to sustain itself and prosper. STEM is principally a philosophy for teaching and learning that engages an integrated community to respond to a changing world. It is a meta-discipline, the creation of the whole, interdisciplinary and trans-disciplinary among discrete disciplines: science, technology, engineering and mathematics. STEM education is an opportunity for students to engage, explore and make sense of the natural world, through inquiry, project-based learning, rather than merely learn isolated bits and pieces of phenomena.

There is a sense of global urgency to inspire, train and deploy the next generation of scientists and engineers to address the grand challenges of this century. There are several factors that are currently producing changes in U.S. Science Education. One is the decline in the production of science, technology, engineering, and math (STEM) college graduates. Secondly, the drop in the number of US STEM graduates and the rise in the number of STEM graduates in other countries, such as China and India, are causing concern in the business and industry communities. Further, lackluster student performance in national (NAEP) and international science and mathematics (TIMSS) tests by US students and the growing challenges to America to remain globally competitive has caused a renewed interest in science education to the level equal to or even greater than that of the Sputnik (1957) era. STEM is an internationally competitive and rigorous arena.

If we are to prepare ALL students to become college-ready and STEM-opportunity-ready, we must make cultural and instructional paradigm shifts for both students and teachers, teacher preparation, and raise the level of expectations and accountability for EVERYONE. Furthermore, it is equally important to provide effective and safe science facilities' support systems for ALL students.

Changes in Science Education Requirements

Similar to changes in science requirements that occurred post Sputnik, new requirements are being added at both the federal and state levels with the No Child Left Behind (NCLB) Act science assessments. While the current NCLB Act called for states to begin conducting science assessments during the 2007-2008 school year, it did not hold states accountable for the results. Under NCLB, states are required to test student proficiency in science at least once during grades 3-5, grades 6-9, and grades 10-12. There have been legislative proposals, such as the Science Accountability Act (H.R. 5442) authored by Rep. Vern Ehlers (R-MI), to require states to assess student proficiency in science annually in grades 3-8, beginning in the 2009-2010 academic year, to match the NCLB requirements for reading and math assessments. It would also incorporate the science assessments into the NCLB accountability system. Some states have the science assessments at least at the high school level while other states such as Michigan, California and Texas have elementary, middle school and high school science assessments.

These new assessment requirements have stimulated renewed interest in science facilities that have been neglected for over a half-century. Across the nation one sees science facilities as "too few, too small and poorly designed." We have many old school buildings in the United States, and science labs feel their age more keenly than other classrooms, everything from cabinetry to ventilation systems are showing their wear and tear. An inadequate number of science labs have been built and even newly constructed ones are too small and poorly designed to be safe or efficient in enabling excellence in science education which leads to improved student performance.

The evolution of today's science standards has also meant expanding available laboratory space, both to promote inquiry and to leave no child behind. What good science instruction was 40-50 years ago is not the same as effective science instruction now, and there were much different expectations of which students were expected to take science. When ALL students are pushed to achieve at a higher level, they need to have access to efficient and safe science laboratories and classrooms.

To improve student performance and to help school administrators, science teacher/leaders, facility planners and schoolhouse architects overcome these problems the National Science Teachers Association (NSTA) recently published new facilities guidelines, ***NSTA Guide for Planning School Science Facilities*** (Motz et al., 2007). Well-designed, standards-based facilities are the foundation for safe and effective science programs. Don't impede your science education program with poorly designed and unsafe science facilities. Science space in schools is a specialty area that needs to be safely and effectively planned and designed.

Plan, Design and Build an Adequate Number of Science Classroom/Laboratories

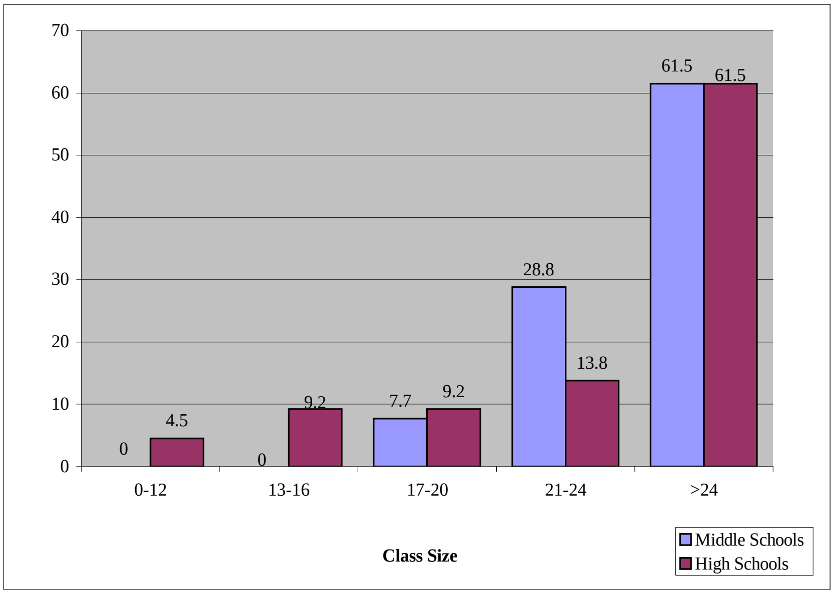
The National Science Education Standards (NSES) describe a science curriculum that is much more inquiry-oriented and project-based than the science education many of us received in school. Providing K-12 science-learning facilities that adapt themselves to a safe, inquiry, project/problem-based curriculum require significant amounts of flexible and movable spaces. Furthermore, school science spaces are expensive. Strategic planning can save money, provide space that will be adaptable to current and future needs, and include furniture and equipment that will stand the test of time and students will give it. Flexibility, durability and usefulness are three key variables to consider.

The easiest way to determine the correct number of science classroom/laboratories is to calculate the number of science teachers and then provide the same number of standards-based classroom/laboratories. The chart below allows one to identify the number of science lab/classrooms needed, based on the number of years of science a school offers. For example, if a middle school has grades 6, 7 and 8 with an enrollment of 600, four science classroom/laboratories are needed.

NUMBER OF LAB/CLASSROOMS REQUIRED PER ENROLLMENT			
Student Enrollment	**No. of Lab/Classrooms when 4 yrs. of science is required**	**No. of Lab/Classrooms when 3 yrs. of science is required**	**No. of Lab/Classrooms when 2 yrs. of science is required**
400	4	3	2
600	5	4	3
800	7	5	4
1000	9	7	5
1200	10	8	5
1400	12	9	6
1600	14	10	7
1800	15	12	8
2000	17	13	9
2200	19	14	10
2400	20	15	10
2600	22	17	11
2800	24	18	12
3000	25	19	13

Source: *NSTA Guide to Planning School Science Facilities*, Appendix I, p.139

Accidents Increase as Science Class Size Increases
And
Accidents Increase as Space per Individual Student Decreases



Source: Sandra S. West, Texas State University, San Marcos
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Spaces per Individual Student

Adequate space per individual student means each student has enough "adequate working space" to safely conduct science laboratory experiences and exercises. For example, an accident in a well-mannered, and on-task, but overcrowded science class occurred some years ago when a student with a beaker of dilute acid in her hand was accidently bumped by an adjacent student. Fortunately, the student did not sustain a serious burn injury. The primary reason the accident occurred was because the students were working too closely to each other and didn't have "adequate working space." In another observed classroom/laboratory experience, high school students were conducting flame tests in a chemistry laboratory. The aisles were too narrow and too many students were "bunched together" in a row while doing a laboratory experiment involving an open flame.

Additional spaces are needed in the laboratory/classroom for science equipment that is being used to conduct science investigations, as well as for storage. Equipment such as stream tables and air tracks require their own large storage spaces. Each student lab station should provide 6 sq. ft. of horizontal work surface area that is approximately three feet wide of "unobstructed working space" and about two feet in depth.

It is for these and many other reasons the National Science Teachers Association *(NSTA)* ***Guide to Planning School Science Facilities, 2007 (2nd ed.)*** recommends 60 square feet per secondary student and classroom/laboratories that are 1,440 square foot minimum for 24 middle or high school students. An additional 10 sq. ft. per student is needed for storage. So a classroom/laboratory of 24 students would require 240 sq. ft. of space for equipment and preparation/storage. The equipment storeroom also needs flexibility to store the variety of sizes and shapes of equipment and materials that science uses for instruction. A variety of, rather than uniform, shelving best serves science storage needs.

Flexible, Modular and Movable

The combination laboratory/classroom design is the only plan that NSTA recommends. A laboratory/classroom is a combination design whereby both the laboratory and the classroom areas are combined into one instructional area. There are several reasons that the classroom/laboratory is the NSTA standard. First, this plan is the most flexible in several ways. It is flexible for teaching a variety of science courses or concepts so that different courses during the day or year can be taught in the same facility. The flexibility of this design also enables the instruction to move seamlessly from pre-lab instruction and review of safety procedures in the classroom area, to the science investigation in the laboratory area and back to the classroom area for post-lab discussion of the findings of the inquiry, analysis of the data and conclusions.

Secondly, science instruction often involves cooperative or collaborative learning experiences that require students to seamlessly move back and forth between the classroom and laboratory as often as the curriculum requires. Thirdly, teachers, using combination classroom/laboratories, report doing twice as much hands-on activity that enable students to have concrete experiences with natural phenomena. This, in turn, enables the students to develop the foundation for understanding both the abstract and concrete components of the phenomena and the use of advanced mathematics, technology and pre-engineering skills and concepts.

Avoid most designs that involve fixed furniture in the middle of the room because it is less flexible and requires a larger space. Middle school science classes usually do well with movable tables in the laboratory area. In high school courses such as chemistry it would be hazardous to use movable tables. Physics, biology, and general science, on the other hand could use large, 4x6 ft. movable tables. However, all of the sciences could safely use a well-planned perimeter-pier design.

The philosophy of the curriculum and instructional modalities should be the driving force in the planning and design process. Well-designed science facilities will enable excellence in science education which can result in improved student performance and teacher retention. If we are to prepare ALL students to become “college-ready” and STEM “opportunity-ready,” we must:

- Make cultural and instructional paradigm shifts for students, all teachers, all teacher preparation institutions, and the entire community.
- Raise levels of expectations and accountability for EVERYONE
- Provide for adequate, safe science facilities and support systems for ALL students

When planning and designing for STEM science teaching facilities, FLEXIBILITY should be at the forefront of the plans. Does the design provide for and support integrated or interdisciplinary instruction? Does the infrastructure provide for enough electrical and computer networking outlets that furniture can be rearranged to meet teaching and learning needs? Is the furniture modular, durable and sturdy enough that it can be often moved to support both small and large-group cooperative and collaborative learning groups? Does the design provide for individual or small-group meeting areas where student(s) can ponder and reflect and work on group problems?

The STEM classroom/laboratory should provide:

- Active, student-centered, inquiry-based experiences
- Equipment to support inquiry, project-based experiences that are both planned and spontaneous
- Innovation and invention-based teaching and learning
- Support for teaching with the use of a variety of instructional strategies and techniques
- Furniture that can be easily moved and reconfigured
- Integration of technology to support both teaching and learning

A rigorous and relevant STEM education will prepare ALL students for success, and appropriate and efficient facilities are an essential ingredient.

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About the Author:

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