STEM Leaders Roundtable: Part I —Research and the Curriculum

Curriculum Working Group's Perspective by Donna Hutchison, Arkansas School of Mathematics, Science and the Arts and Steve Warshaw, PhD, North Carolina School of Science and Mathematics.

Editor's Note:
Recognizing the potential of talented students, dedicated educators, and innovative leaders, NCSSSMST and Sigma Xi, the Scientific Research Society, convened a Roundtable for NCSSSMST STEM Leaders at Research Triangle Park, North Carolina on April 28-29, 2011. The product of the Roundtable will be a blueprint for STEM research in high schools that highlights innovative research programs within Consortium schools, explores ways to extend that research into an array of collaborative settings, and hopefully generates momentum that will inform our local, state, and national leaders.

The following article, on what a school needs to have in place for students to do viable research, is the first of two that summarize the work of the Roundtable's Working Groups. The second will be published in the Fall 2011 issue.

Many thanks to Dr. Jerry Baker, Executive Director of Sigma Xi, for hosting and supporting the Roundtable, and to Laura Nigro, Sigma Xi member, who served as the facilitator.

The North Carolina School of Science and Mathematics recently embarked on a curriculum review, one part of which was to update school-wide curriculum goals. A quick review of 12 websites from some of the most long-established Consortium schools, including NCSSM's, revealed that very few of us list school-wide goals for our students on our sites. Moreover, we don't say much about teaching our students to do research which, as measured by their success in science competitions and frequent entry into STEM fields as professionals, is one of the things we do best.

These observations and some preliminary work by former Executive Director Cheryl Lindeman on a STEM Roundtable Conference put us at the national headquarters of Sigma Xi, The Scientific Research Society in the Research Triangle on April 28-29, 2011, talking about our students' scientific research and curriculum. We tackled questions such as:

- What should such a curriculum look like at a specialized secondary school like ours? At a regular public high school?
- What are the obstacles to establishing a scientific research program in high school?
- Whose is support is needed and what are the necessary components of the school culture to support such a program?

To begin the process of designing a research-based, laboratory-centered, STEM secondary curriculum, our working group asked the following question: What does a school need to have in place to make research viable for all students?

The answers boiled down to three broad criteria: school structure, curriculum, and school culture. Our group felt these characteristics were so inter-related as to be nearly impossible to discuss individually.

First, school structure refers not only to the physical components of the buildings and campus but also to time structures, administrative and faculty community, and parental engagement. Obviously, multiple laboratory and investigative spaces are important to a STEM curriculum, as is a good library and on-line availability for research purposes. Even more important than these, however, is the existence of an engaged faculty and administration. These groups hold much of the responsibility for a successful STEM school in that they must understand, participate in, and support the chaos often engendered by individual inquiry. Finally, but by no means insignificantly, parents must be willing to allow their students to engage in individual inquiry and must encourage independent thinking.

Administrative and faculty support of STEM research is essential. This mindset is evident in their willingness to collegially network with one another and with outside professionals for the benefit of students. Intellectual territoriality is to be avoided; indeed, administrators and teachers should instead demonstrate a belief that all knowledge is valuable and interrelated. These adults should model the collegial environment students will encounter in the world of academic research and professional work. An on-campus Internal Review Board (IRB) can teach students how to connect with potential mentors off campus to create an interdisciplinary network of support. This group will also critique all research proposals to encourage ethical and critical thought. Further, an informal network of interested adults on campus will furnish an easily accessible base of mentors who can directly support the efforts of students during the school day/term. Media specialists can create and maintain a data base of previous work for student reference, while older students can mentor younger in research projects. Original research should be supported, if not expected of all students.

During the school day and term, time must be made available for individual research. This time must be seen as integral to curriculum and supported as such, which means that "individual research time" cannot be the period used for assemblies, teacher planning, tutoring, or other purposes which detract from or even undermine the research process. Suggested uses for such a block of time include meetings between students and teachers mutually engaged in projects, meetings with off-campus mentors, laboratory experiment and data-gathering time, literature search, and data testing and evaluation. Mentored summer research may even be required as part of specific course work. It is critical that once this research time has been created it must be used wisely and well, with students and faculty alike being held responsible and accountable for progress. This accountability must be assessed on a regular basis.

Curriculum, the second element of a successful research-based STEM school, must provide students with exposure to a wide range of topics through a rich variety of courses across all disciplines. The interdisciplinary nature of learning should be stressed, with as much cross-curricular emphasis as is possible within each course. Writing modes necessary to each discipline must be taught and regularly assigned and assessed. Interdisciplinary testing and promotion of inquiry is highly desirable. Such exposure offers students a broad base from which to draw and shows them the reality of STEM research, in which investigators from different backgrounds collaborate to solve specific problems.

This curriculum should strive for both general and specific goals, including but not limited to the following:

- laboratory procedures and safety
- ethics of scientific research and experimentation
- how to contact and obtain mentors
- how to ask questions
- how to engage in library and data-base research
- how to write literature surveys
- how to write in subject-specific modes
- how to collaborate and communicate with classmates and interested adults
- how to design experiments
- how to gather, test, and interpret data
- how to draw reasonable and evidence-supported conclusions
- how to manage time
- how to keep clear, accurate records
- how to mentor younger students in their research projects

Finally, a school culture of continued and active learning/research in an ethical framework must be established. One critical component of that culture is the hiring of the right people in administration and faculty. The "right people" are those with a successful history of encouraging and mentoring student research. Administrators must trust that they have chosen well and allow teachers a fairly high level of creative independence. These professionals will already have bought into the ideas of interdisciplinary learning and individual student investigation, and they must be given the charge of defining the school's culture so they have ownership of what goes on in the academic program. Culture cannot be imposed from above; it must be created by faculty members and students who will live it.

Ideally, the defined culture will include the notion of "failure" in research. Students often believe their project's inability to support its experimental hypothesis means the research has failed;

"This was just the kind of meeting I have always hoped the Consortium would sponsor. Our schools are such a rich source of curriculum ideas that make it possible for high school students successfully to do authentic scientific research. We should be talking with our colleagues and with representatives from the research community, government and business about these ideas and how to implement them, and we did. I look forward to continuing the conversations and finding ways to put into practice more broadly in secondary education what we have learned during our 25 years of sponsoring successful student research."

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therefore, the experiment, they think, must be tweaked to produce a successful outcome. Adults, however, know differently, and such knowledge must be imparted to students. Without the possibility of failure, there is little to gain in doing research. Failure must be an option, for much can be learned from "failed" experiments.

Further, the school culture will include the notions of intellectual risk taking, thus encouraging original research. This risk taking will be supported in a dynamic learning environment that is collegial and directed, as noted above in both school structure and curriculum. High expectations of students and faculty are essential to the culture and curriculum; these expectations should be supported by parents.

The school culture will also include the purposeful management of chaos, as indicated in the structural and curricular need for designated research and collaboration times. In this purposeful chaos, students will learn to share their developing skills and research experiences; they will take ownership of their work and communication about it; they will observe models of the professionals they aspire to become and serve as models to younger students; and they will become independent learners.

Clearly, the creation of an exciting research program in a STEM school is dependent upon three inter-related variables which cannot easily be teased apart. Integral to any successful STEM program is the considered creation of school structure, integrated curriculum, and a dynamic school culture.

Suggested References for Getting Started

Bosak, Susan V., with Douglas A. Bosak and Brian A. Puppa. 1991. *Science Is...A Source Book of Fascinating Facts, Projects and Activities*. Scholastic Canada, Ltd. Ontario. 515 pp.

Cothron, Julia H., Ronald N. Giese and Richard J. Rezba. 1993. *Students and Research; Practical Strategies for Science Classrooms and Competitions, 2nd Edition*. Kendall/Hunt Publishing Company. Dubuque, Iowa. 279 pp.

National Consortium for Specialized Secondary Schools of Mathematics, Science and Technology. 2005. *Guiding Student Research: Making Research Happen in Your Schoo*l. Martin Shapiro, Editor in Chief. NCSSSMST. Lynchburg, Virginia. 214pp.

Websites

How To Do Successful Science Fair Projects. Persistent Link at http://www.sciencenerddepot.com/

National Student Research Center: Websites Recommended by the NSRC.
http://www.youth.net/nsrc/webs.html

Overview of the Top Science Competitions. Persistent Link at http://www.sciencebuddies.org/science-fair-projects/top_science-fair_overview.shtml

Science Research in the High School. Persistent Link at http://www.albany.edu/scienceresearch/