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STRONG STEM EDUCATION: AN IMPERATIVE FOR THE FUTURE

By Geoff Coltrane, Director of Program and Policy

In April 2009, the James B. Hunt, Jr. Institute for Educational Leadership and Policy, in partnership with the North Carolina Science, Mathematics, and Technology Education Center (SMT Center) and the International Center for Leadership in Education (ICLE), hosted the 2009 *North Carolina Science Summit*, *Best Practices in STEM Education: Building Momentum for Science, Technology, Engineering, and Mathematics (STEM) Education in North Carolina*. More than 350 educators, administrators, and policymakers from across North Carolina and 16 additional states participated in the *Summit*, which was a follow-up to the 2007 *North Carolina Science Summit*, *K-8 Science Education: Elements that Matter.* The two-day event showcased some of the nation's leading STEM-focused schools, as well as instructional models, leadership approaches, and successful strategies for improving STEM education. Presenters also discussed why it is important in today's economy for all students to get a strong STEM education and why students are not currently getting the STEM education they need to be successful.

The Hunt Institute has an abiding commitment to help policymakers support and sustain educational improvement in North Carolina. This issue of **coNCepts** highlights some of the critical challenges in STEM education, key discussions from the 2009 *North Carolina Science Summit,* and ideas for taking action and moving forward on this vital education and economic development issue.

> *Science, technology, engineering, and math are essential to building prosperity. The U.S. should be the world incubator for innovation, which means we need great schools and must be the best in science.*
>
> *— James B. Hunt, Jr., Chairman*
> *Hunt Institute Foundation Board*

The STEM Education Landscape

At the *Summit*, Dr. Sam Houston, president of the SMT Center, shared that North Carolina's students need a strong understanding of STEM to be economically successful and productive citizens. During the past decade, the state has experienced a dramatic shift from manufacturing and agriculture to high-tech, high-skill industries that require a strong background in the STEM fields. The state's future prosperity depends on an educated workforce ready to enter these emerging industries.

The jobs of the modern economy, even those in non-STEM fields, now require higher-level thinking and problem-solving skills. To be successful in the 21st century workforce, students must be able to think analytically, communicate effectively both orally and through writing, collaborate with others, and use technology. As citizens, they also need a strong understanding of these areas to make informed decisions about complex civic issues such as managing energy resources, protecting the environment, and improving public health. A solid STEM education prepares students with this knowledge and these skills.

The country's international competitiveness, however, is at risk because too few students pursue and complete college degrees in the STEM fields. According to data from the National Science Board, more students, both nationally and in North Carolina, are gaining access to college, yet proportionately fewer students are choosing STEM majors. In 2005, 32 percent of all higher education degrees awarded in North Carolina were in science or engineering, a proportion in line with the national average of 30 percent. However, this figure falls dramatically below the rate of most international competitors, including Japan, China, and Singapore, where more than one-half to nearly two-thirds of college degrees awarded were in science or engineering.[1]

Between 1996 and 2005, while the number of all higher education degrees awarded in North Carolina increased by 25 percent, the percentage of science and engineering degrees awarded dropped from 35 percent to 32 percent.

Source: National Science Board, *Science and Engineering Indicators*

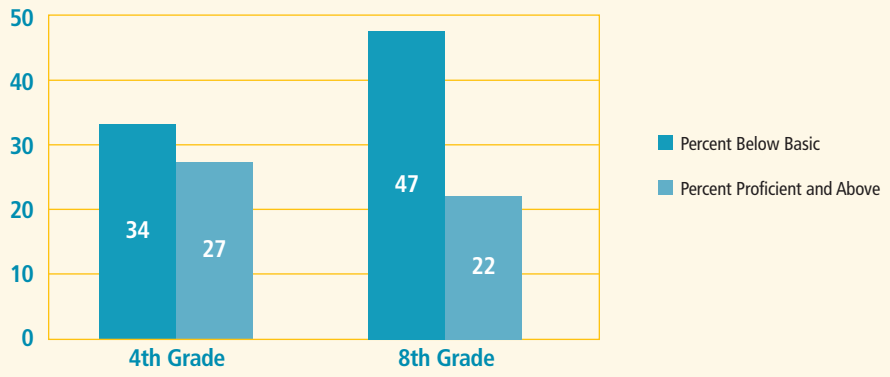
In 1983, *A Nation at Risk* documented that U.S. students underperformed on science and mathematics assessments in comparison to other students internationally. Today, U.S. students continue to underperform on the two major international assessments of STEM achievement: the Programme for International Student Assessment (PISA), which measures scientific literacy and mathematical knowledge among 15-year-olds, and the Trends in International Mathematics and Science Study (TIMSS), which measures mathematics and science knowledge of fourth and eighth grade students. In addition, data from the National Assessment of Educational Progress (NAEP) show that on average, North Carolina students score lower on the NAEP science assessment than students in more than half of the other 44 states participating in the assessment.[2] For more information on U.S. performance on the PISA and North Carolina's performance on the NAEP science assessment, see Charts 1 and 2.

Chart 1: U.S. Performance on PISA Math and Science Assessments Since 2000

	2000 (OUT OF 27 COUNTRIES)	2003 (OUT OF 29 COUNTRIES)	2006 (OUT OF 30 COUNTRIES)
MATH	18th	23rd	25th
SCIENCE	14th	19th	21st

Source: Organisation for Economic Co-operation and Development, 2007.

Chart 2: North Carolina Student Performance on the 2005 National Assessment of Educational Progress in Science



Source: National Center for Education Statistics, 2005.

In order to remain competitive in the global economy, and to improve STEM education, our state and nation must address a range of issues: standards, curriculum, assessment, and teacher expertise.

Standards

Content standards define what students should know and be able to do at each grade level and for each subject. In 2007, the Hunt Institute commissioned a National Research Council (NRC) study to investigate the current status of state content standards. The study, *Common Standards for K-12 Education: Considering the Evidence,* demonstrated that state standards vary greatly from state-to-state, meaning that students in a biology course in one state may not learn the same concepts as students in another state. The study also revealed that state content standards, including science standards, often contain too many topics for teachers to cover in a school year, excessively repeat the same concepts from year-to-year, and are poorly sequenced.[3]

During her remarks at the *Summit*, Dr. Judith Rizzo, executive director and CEO of the Hunt Institute, explained that the "mile wide and inch deep" nature of state content standards leads to confusion about what is important for teachers to teach and for students to learn. Dr. Bill Daggett, president of ICLE, reinforced this point during his keynote address, sharing research from his organization that indicates between one-quarter and one-third of most states' standards and objectives are both unimportant for students to learn and are not tested on state assessments.[4]

While North Carolina's state science standards often receive favorable reviews for their clarity and focus on grade-appropriate content,[5] the Department of Public Instruction (NCDPI) is seeking to combat the "mile wide and inch deep" concern about the state's standards through the Accountability and Curriculum Reform Effort (ACRE).[6]

As Angela Quick, deputy chief academic officer for NCDPI, shared in her presentation at the *Summit*, ACRE is working to redevelop and narrow down subject matter content standards, including science, while maintaining essential knowledge and skills.

Curriculum

Evidence from the NRC study indicates that without well-developed, clear, and rigorous content standards, it is nearly impossible to develop effective curricula and well-aligned instructional resources.[7] To be effective and to drive good instruction at the classroom level, curricula and instructional resources must be relevant and meaningful to students and aligned to state content standards.

A 2007 National Academies report suggests that the vital hands-on processes involved in the study of science should be taught simultaneously with the acquisition of science facts.[8] All of the schools highlighted during the *Summit* created a more engaging, relevant science curriculum by using hands-on, inquiry-based, and interdisciplinary instructional practices, consistent with current research and best practices in science education.[9] Inquiry-based science is an instructional methodology through which teachers facilitate the study of science by modeling the processes used by scientists: crafting questions, forming hypotheses, designing experiments, analyzing evidence gathered through investigation, and drawing conclusions based on the evidence.[10]
For instance, students at McKinley Technology High School in Washington, D.C., a school featured at the *Summit*, demonstrate interdisciplinary, inquiry-based learning through the study and design of their own video games. During the video game design process, students must draw upon the knowledge and skills learned in their physics and mathematics courses.

Several efforts are underway in North Carolina to bring more integrated, inquiry-based curriculum to STEM classrooms. The Leadership and Assistance for Science Education Reform (LASER) *K-12 Science Education Strategic Planning Institute* helps districts to create strategic plans focused on enhancing the level of inquiry-based instruction in kindergarten through 8th grade. The network of STEM-focused high schools being developed in partnership with the North Carolina New Schools Project is creating curricula that integrate STEM content across all courses. For more information on these initiatives, see page five.

Assessment

Science is often not tested at the elementary and middle school levels because state systems primarily focus on holding schools accountable for student achievement in reading and mathematics. While K-12 science standards and accountability at the high school level have existed in North Carolina for more than a decade, the state did not begin to assess elementary and middle school students in science until it was required by *No Child Left Behind* (NCLB) during the 2007-08 school year. The assessment results, however, were not included in a school's performance composite for accountability purposes until the 2008-09 school year and are currently not included in a school's calculation of Adequate Yearly Progress (AYP) under NCLB.[11]

Because of this lack of formal accountability for science, elementary school teachers tend to spend significantly more instructional time and attention on English/language arts and mathematics. In 2004, the most recent year for which data are available, North Carolina teachers in grades four through six spent just two hours per week teaching science, compared to nine hours teaching English/language arts, seven hours in mathematics, and three hours in social studies.[12]

In addition to focusing more instructional time on tested subjects, teachers also rely on state standardized assessments as guides for what to teach in the absence of carefully aligned curricula.[13] The "isolated paper and pencil" model of assessment currently being used in most states can lead teachers to emphasize the memorization of science facts in science courses instead of building opportunities for open-ended discovery and collaboration. At the *Summit,* Dr. John Bransford, a professor at the University of Washington, shared that state assessments measure the knowledge students have gained, but not how well they can apply that knowledge. Bransford introduced *Summit* participants to a redesigned, computer-adaptive assessment that focuses on real-world problems embedded in simulated activities. Through these activities, students learn and apply their knowledge, and teachers receive feedback regarding student progress simultaneously. According to Bransford, closely integrating assessments into instruction provides teachers with a much more meaningful picture of a student's knowledge and how he or she applies that knowledge to solve problems.

North Carolina's current assessment system for science and other subjects is centered on a series of "paper and pencil," end-of-year tests. NCDPI plans to improve the system by creating additional assessments that will better measure students' knowledge and better inform teachers' instruction. Through the ACRE initiative, NCDPI will work to create classroom assessments that are more integrated into classroom activities, blend instruction and assessment, and provide teachers with better and more timely information about their students' learning.

Teachers

The 2007 National Academies report, *Rising Above the Gathering Storm,* stated that teachers are key to increasing the STEM workforce by improving student achievement and inspiring student interest in the STEM fields.[14] Nevertheless, schools and districts struggle with recruiting and retaining qualified teachers of STEM. Research in North Carolina reveals that seven out of every ten new science and mathematics teachers hired during the 2005-06 school year filled vacancies as a result of teacher turnover rather than to accommodate student growth.[15] Finding qualified science and mathematics teachers to fill vacant positions is often a struggle for schools and districts. School districts in North Carolina consistently rank high school and middle school math and science teaching positions as among the most difficult for which to hire licensed teachers.[16] Because of this difficulty, it is common, as participants at the 2007 *Summit* noted, to find middle and high school science teachers teaching science classes that are not in their licensure area, especially in biology, chemistry, earth science, and physics.[17]

To enhance the practice of teachers who remain in the classroom, both beginning and experienced educators need high-quality professional development throughout their teaching careers. Many of the presenters featured at the *Summit* shared that professional development focused on effective classroom instruction was a critical component in the design of their STEM schools and in the academic success of their students. Research indicates that at least 60 to 80 hours of sustained professional development are needed to produce a meaningful change in instructional practices, yet science teachers nationally have reported receiving far fewer hours of professional development in science content and instructional methods.[18] In addition, according to John Cafarella, a former district supervisor of K-12 science and mathematics programs and a presenter at the *Summit*, it is equally important for school administrators to participate in the same professional development as their science teachers so they can effectively evaluate and support their teachers' instructional efforts. Finding time during the school year, as participants at the 2007 *Summit* noted, is the biggest challenge in North Carolina to providing high-quality, sustained professional development.[19]

Several initiatives are underway in North Carolina to improve support for teachers of STEM. The *Collaborative Project* assists five low-income, rural districts in recruiting and retaining science and mathematics teachers and provides professional development to help improve science and math instruction. The *Statewide Institute for Teaching Excellence* (SITE) offers a series of professional development workshops focused on improving science and mathematics content knowledge and instructional practices for teachers. *Career Awards for Science and Mathematics Teachers* provide five-year stipend awards to master teachers of STEM for professional development and collaboration with other master teachers. The *NC STEM Community Collaborative* is working with local communities around the state to identify needs and corresponding resources to help the communities build a high-quality STEM education system. For more information on these initiatives, see Box 1.

Current Efforts to Improve STEM Education in North Carolina

The Department of Public Instruction (NCDPI) and various other organizations have undertaken a number of efforts to address the challenges in STEM education, including:

- **The Collaborative Project,** a three-year pilot project jointly administered by the Public School Forum of North Carolina and the SMT Center, aims to improve teacher and principal quality in five low-income, rural school districts. The program provides professional development, stipends, and recruitment and performance incentives for mathematics and science teachers and administrators, as well as funding for afterschool programs. The program is intended to serve as a model to improve teacher and principal quality statewide.
- **The North Carolina LASER K-12 Science Education Strategic Planning Institute** is a partnership between the Burroughs Wellcome Fund, the SMT Center, and NCDPI that guides teams of K-8 teachers, administrators, and community leaders through the development of a district-level strategic plan to implement an inquiry-based science program. Thus far, approximately one-quarter of North Carolina's school districts have participated in LASER, with the intent that all districts will eventually participate. The Institute is conducted by the National Science Resources Center, which developed LASER and has established eight regional sites across the country to implement the program.
- **The Statewide Institutes for Teaching Excellence (SITE),** a partnership between the North Carolina Mathematics and Science Education Network and NCDPI, involves a series of grade-level and subject-specific teacher workshops aimed at improving teachers' mathematics and science content knowledge, instructional practices, and assessment strategies.
- **The NC STEM Community Collaborative** strives to improve STEM education for high school students by facilitating a needs assessment and working to connect local communities with available resources needed for fostering world-class, sustainable, and scalable programs. The Collaborative is an initiative of MCNC, a non-profit networking and technology organization that operates the North Carolina Research and Education Network.
- **The North Carolina New Schools Project (NCNSP)** is working with local school districts to create a statewide network of STEM-focused high schools that will prepare students for future STEM-focused careers. Currently, 17 NCNSP STEM-focused, innovative high schools are in operation or preparing to open.
- **The Career Awards for Science and Mathematics Teachers**, a partnership program of the North Carolina State Board of Education and the Burroughs Wellcome Fund, provides a $35,000 award for five years ($175,000 total) to master science and mathematics public school teachers in North Carolina. The award is intended to provide these educators with professional development and collaboration opportunities with other expert science and mathematics teachers.

A Need for Systemic Change

While current efforts to improve STEM education in North Carolina show promise, they must be better coordinated, carefully evaluated, and more broadly disseminated to achieve sustainable statewide reforms. The Carnegie Corporation of New York and the Institute for Advanced Study's Commission on Mathematics and Science Education outlined a comprehensive, action-oriented approach to reform in their recent report, *The Opportunity Equation: Transforming Mathematics and Science Education for Citizenship and the Global Economy*. The report emphasizes that today's students need a deep understanding of science and mathematics for the United States to remain competitive in a global economy.

Acknowledging past work, calls for action, and the growing body of best practices and programs in STEM education, the Commission determined four broad areas of reform priority: higher levels of mathematics and science learning for all students; common standards in mathematics and science that are fewer, clearer, and higher, and coupled with aligned assessments; improved teaching and professional learning, supported by better school and system management; and new designs for schools and systems to deliver mathematics and science learning more effectively.[20]

To ensure all students receive a high-quality STEM education, our state must have a comprehensive, integrated, standards-based STEM education system. Building on the Commission's recommendations and discussions at both the 2007 and 2009 *Summits*, policymakers might consider the following actions to continue building such a system.

1. **Bolster efforts to establish and adopt a set of fewer, clearer, higher, and internationally-benchmarked standards.** Content standards are the backbone of a high-quality, effective education system. Establishing rigorous standards for the STEM fields will ensure that North Carolina's students receive the preparation they need to be economically competitive with their peers. Rigorous standards are also the basis upon which relevant and meaningful science **curricula, instructional resources, and assessments** can be developed.
2. **Direct and coordinate resources towards preparation, professional development, recruitment, and retention for teachers of STEM subjects.** Policymakers need to design and implement a combination of aligned teacher preparation and professional development focused on science content and effective instructional practices; additional classroom and school-level supports; and incentives to prepare, attract, and retain high-quality teachers in STEM fields. All students, especially students in low-performing schools, must have access to high-quality instruction in STEM delivered by qualified, well-prepared teachers.
3. **Sustain efforts to develop a statewide comprehensive data system.** Policymakers and education leaders should continue to support the work already underway in North Carolina to develop a comprehensive, longitudinal **P-16 data system**. The system should include data around student performance and measures of teacher effectiveness that can be used to identify best practices and track progress in STEM education reform. In addition, it is important that teachers and administrators receive appropriate training on how to use the data to improve instruction and better support students.
4. **Champion the importance of STEM education.** To ensure that North Carolina remains economically competitive, all students must receive a high-quality STEM education. Political, business, and education leaders must raise public awareness of the economic importance of a high-quality STEM education and must make certain that schools are held accountable for student achievement in science at the elementary, middle, and high school levels.

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