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Yesterday Never Dies

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Contents

On the Cover

This image was taken by Central Virginia Governor's School seniors in the Electron Microscopy lab using their new Hitachi N3400 Scanning Scope. The fibers are from a burlap feed sack showing the flecks of oyster shells. The image was enhanced using Adobe Photoshop.

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Editor's Note

by Jerald "Jay" Thomas

NCSSSMST is approaching its twentieth anniversary. In 1988, fifteen founding member schools recognized the potential of a formal alignment of institutions charged with preparing math, science, and technology leaders. As we refined our mission, clarified our vision, and articulated our goals and strategies, it became clear that NCSSSMST had the capacity not only to serve students with talents and professed interest in STEM fields but that we could also collaboratively transform math, science, and technology education.

The NCSSSMST Journal has since its inception intended to disseminate innovative practices, to present student and faculty research, and to offer a forum for considering ways in which our organization might fully recognize its capacity to influence policy. This issue of the journal, I believe, speaks clearly to our organization's transformation from a cluster of like-minded schools in the late 1980's to an organization poised to affect change in mathematics and science at the state and national level.

In this issue, you will find evidence of the good work occurring at all levels of our organizations. There are several student articles, each of which showcases the fresh perspective and deep reflection on learning within and across disciplines. There are reflections on teaching and learning and on the expanding work of our affiliates. Finally, in an article that demonstrates the strides our organization has taken in influencing math, science, and technology education, you will find reprinted here an article prepared by the Information Technology and Innovation Foundation (ITIF), which captures the history and efficacy of schools like ours. This article was presented in March 2007 on Capitol Hill in an effort to attract federal financial support for the establishment of specialized schools.

You will also see a short note about our fall 2007 student conference, which is being very capably designed and presented by students at Thomas Jefferson High School – evidence that our very own future organizational leaders may be found in our own classrooms. As you read these articles, we urge you to be mindful of the power of disseminating our organization's good work. We are, we believe, on the cusp of significant impact.

In this editorial, I would also like to thank our colleague and the Journal's co-editor, Mr. Gary White, for his years of thoughtful contribution to NCSSSMST. Gary is retiring this spring, but he has very graciously agreed to serve NCSSSMST with some writing and photography when he can pull himself away from all of those long overdue vacations.

Jerald "Jay" Thomas is Co-Editor of the NCSSSMST Journal and is an Assessment Coordinator at Aurora University.

President's Message

Research – If we could name one word that describes the current focus in mathematics and science, this would be the one. Schools that have established research programs are serving as resources for those who are in the developmental stages. Students engaged in research are winning awards for projects that are well beyond what one would expect to find at the high school level. Some of these projects have led to discoveries that will serve the greater humanity in the future.

Research has multiple benefits aside from potential discoveries. The steps one has to follow in using the scientific method can be transferred to learning in other disciplines. Students thrive on this logical progression. They are able to understand why something happens or needs to happen in order to reach a conclusion. There is a beauty to the process.

It is always a pleasure for me to read the submissions for the NCSSSMST Journal. I continue to be impressed by the level of research as well as the writing ability of the students. We are doing many things "right" in the Consortium schools across the country. Speaking of our schools – we have several new schools ready to open at the beginning of the 2007-08 school year. The Tennessee Governor's Academy for Mathematics and Science has 24 juniors ready to start their initial voyage into academic excellence this fall. Kentucky will have an academy opening in August. Schools in Washington, Ohio, New Hampshire and Kansas are also in the formation stages. We look forward to having these "sister" schools as members of our group.

We will see more and more "schools like ours" being created as our legislators focus on the importance of exemplary educational programs in the STEM areas. You, as educators and administrators, serve as the guides for this initiative. Whether it is instituting creative methods of instruction, mentoring young minds in research techniques, or developing goals to prepare our students for future careers, you are creating the leadership of tomorrow by example. Congratulations to all of you who recognize the importance of educational opportunities for students!

Janet Hugo, PhD, is Director of Arkansas School for Mathematics, Sciences, and the Arts and current President of NCSSSMST.

Inverse Effects On Growth And Development Rates By Means Of Endocrine Disruptors In African Clawed Frog Tadpoles (*Xenopus laevis*)

Student paper by Zachary Carl Hackney

Abstract
Previous work on fish, frogs, and salamanders, showed the ability for estrogen (EE2) and anthropogenic endocrine disruptors to skew sex ratios and cause hermaphrodism. This study addressed the effects of estrogens on growth and development rates of African clawed frog tadpoles (*Xenopus laevis*) during their gender determination stages. The effects of estrogen mimics (EM2) have never been studied side-by-side with EE2; I investigated the effects of estradiol β-17 (EE2) and ethynylestradiol α-17 (EM2). Tadpoles were kept individually in containers filled with either EE2 (100 ng/ml), EM2 (100 ng/ml), or dH_2O control. Stage transitions and body sizes were monitored daily over three weeks. Results showed EE2 and EM2 caused faster development rates relative to the control ($p < 0.001$) and slower growth rates relative to the control ($p < 0.005$). While there were no detectable differences between EE2 and EM2 development rates, the growth rate in the mimic treatment was significantly slower than the growth rate in the EE2 treatment ($p < 0.001$). The inverse correlation between development rate and growth rate has implications for the onset of sexual maturity and fecundity. The difference in the growth rates between EE2 and EM2 may be explained by the higher binding affinity of the mimic, which in turn causes the mimic to stay in the body longer than EE2 and may exacerbate the effect on growth rate. How this affects populations of amphibians needs to be explored further.

Introduction
Estrogen (EE2) determines sexual development and behavior while endocrine disruptors, which bind to the same sites as EE2, can have detrimental effects on normal EE2 function (Engell et al., 2005). Anthropogenic EE2 and endocrine disruptors exist at measurable levels in the waters across the world, including Japan, the United States and in Africa (Bennet & Metcalfe, 1998). Fresh and salt-water animals, including fish, frogs and salamanders, are directly affected by measurable levels of EE2 and estrogen mimics (EM2) in the water through increased occurrences of gonadal deformations, unbalanced sex ratios, and decreased ability to reproduce (Clark et al., 1997; Hayes et al., 1999, 2000, 2002; Tollefsen, 2002). Even though there is potential that EE2 or EM2 in the environment might affect humans, it is quite clear from research that they are already affecting aquatic animals (Noriega & Hayes, 2000). Amphibians have been among the hardest struck groups of animals due to their sensitive physiological state and their high exposure to EE2 or EM2 in the environment (Iguchi et al., 2001).

EM2 are entering the water system because so many different common industrial compounds have estrogenic effects (Bayley et al., 1999; Tollefsen 2002). One of the main contributors to the different types of EM2 in the aquatic environment are the byproducts of the plastic making process. There are few regulations on these chemicals and, even if treated, there can be spills of untreated chemicals into the water (Engell et al., 2005). The effects of EM2 have been studied in mammals and fish. A study on the pine vole, a primarily monogamous creature, (Engell et al., 2005) found that females that were injected on a regular basis with the plastic byproduct tended to lose their monogamous tendencies. It was speculated that changes in their brain neural activity were making them act significantly more polygamist compared to the female pine voles who had not been exposed to the plastic byproduct EM2 (Engell et al., 2005). A study by Tollefsen (2002) looked at many different types of EM2 to determine specifically which was causing the problems in fish

Zachary Carl Hackney is a 2007 graduate of North Carolina School of Science and Mathematics.

(Latonnelle et al., 2002; Tollefsen 2002). Some of the specific ones that were identified were: ethynylestradiol, diethylstilbestrol, genistein and many others that had similar structure to EE2.

The impact of EE2 and EM2 in the environment has been studied extensively; however, animals exposed to EE2 or EM2 have not been compared side by side for possible differences in effects. Additionally how EE2 and EM2 affect early growth and development has not been studied. This study addresses both the comparison of EE2 and EM2 and the effects on early growth and development in the sensitive gender determination stages of *Xenopus laevis*, the African clawed frog,

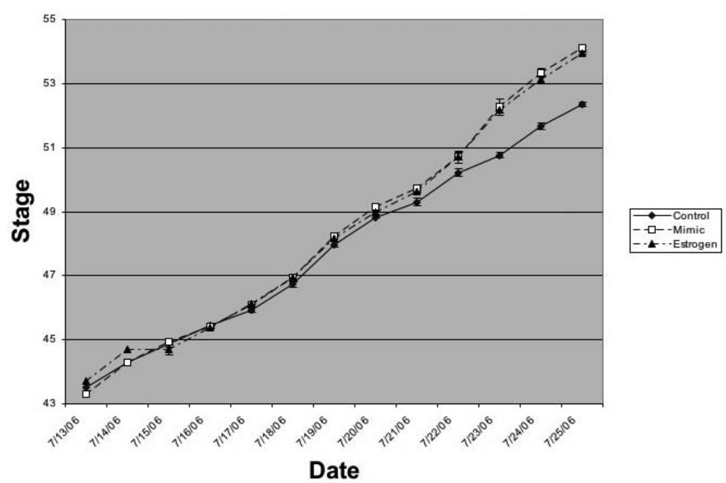
Methods

The study organism was *Xenopus laevis*. The stages of development are well characterized and with a microscope, it is possible to determine how far a tadpole has developed (Nieuwkoop & Faber, 1956). The control consisted of dH_2O. The EE2 solution was made by dissolving, 0.0230g of estradiol β-17 in 250 mL of 70% ethanol. The EM2 solution was made by dissolving 0.0230 grams of ethynylestradiol α-17 in 250 mL of 70% ethanol. Then 1 ml of either solution was mixed with 1000 ml to achieve a final concentration of 100 ng/mL. Thirty sterile Petri dishes were filled with either 30 mL of the control, EE2, or EM2 for a total sample size of 90 dishes. A permit was acquired from the North Carolina Wildlife Resource Commission; that allowed for the possession of *Xenopus laevis*. The *Xenopus laevis* embryos were ordered from Nasco Supply Co. Tadpoles were randomly assigned to treatments and were placed individually into Petri dishes. Every day for three weeks each Petri dish was cleaned, 30 mL fresh solution were added, and each Petri dish received 250 micro liters of dissolved food/day. Every day, each of the tadpoles was observed so that their stage could be determined (Nieuwkoop & Faber, 1956) and their nose diameter measured. This was done by moving each Petri dish under a photographing microscope and a picture at a set magnification, 40X, was taken of their nose. These photographs were analyzed (Motic 1.3, 2000) by drawing a line from the outer edge of each nostril, and the length of this line was recorded as 'nose diameter'. Data analysis consisted of calculating descriptive statistics (mean ± standard deviation) of the variables measured. Additionally, confidence intervals were calculated to compare slopes for growth and development rates and an analysis of variance was performed on nose diameter and stage data (JMP INTRO, 2002).

Results

Comparison of developmental rates (Fig. 1), done by statistical analysis of the rates of change (i.e., calculation of the confidence intervals of the slopes), revealed that the slope of the control (0.768) was significantly different from the slope of the EE2 (1.006, $p < .001$) and the slope of the mimic (1.023, $p < .0001$). At the end of the experiment the control animals average stage was 52.3, (± .0666, 1 standard error) the EE2 average stage was at 53.9, (± .0333) and the mimic average stage was 54.1 (± .0577).

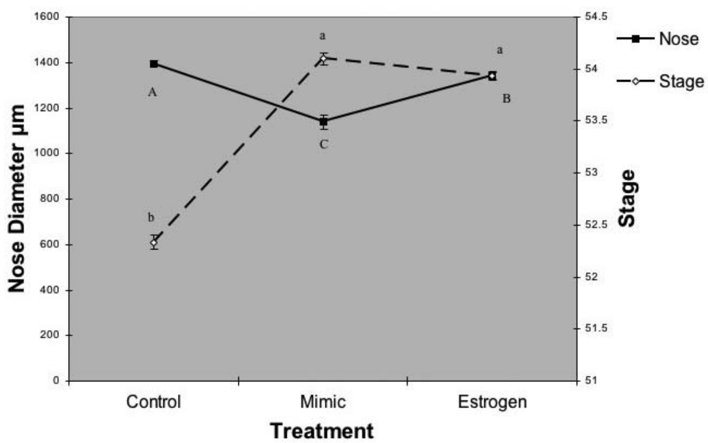
Fig. 1. Stage measured versus the stage of the tadpole development. (N=90). There are three different lines each line representing a different treatment group. One standard error is shown.



A comparison of stage and nose diameter (a measurement of size) shows an inverse correlation for the estrogen treatments relative to the control (Fig. 2). The nose diameters across the treatments were significantly different (ANOVA 2df, $p = 0.0004$). The stage data among the treatments were significantly different (ANOVA 2df, $p < 0.0001$).

A Tukey's mean separation determined which treatment means were different (see Fig. 2 legend for details).

Fig. 2. Comparison of stage and nose diameter by treatment. The left y-axis represents average nose diameter (Ìm). The right y-axis represents average developmental stage (Nieuwkoop & Faber, 1956). Both diameter and stage were measured on the last day of study. One standard error is shown. Letters indicate different means: Nose A, B, C; Stage a, b.



Discussion

There was an inverse relationship between development rate and growth rate across the different treatments (Fig 2). This is surprising because often growth and development are coupled. The control tadpoles developed the slowest, but they grew the fastest. On the other extreme, the EM2 tadpoles grew the slowest but, they were much quicker in their development. These data show that tadpole growth can be stunted by EE2 or even more severely by EM2. On the other hand, both of these chemicals can speed up the rate for development time. The stages between 52-54 are the most important gender determination stages (Nieuwkoop & Faber, 1956) and these are the stages where EE2 and EM2 start to increase development speed (Figure 1). The implication of a shorter development time is that frogs may reach sexual maturity at a younger age and a smaller body size. This suggests that though beyond the scope of this study, frog populations, exposed to EE2 or EM2, may have a greater amount of young, small sexually mature frogs than a non-exposed population.

The primary means by which any estrogenic compound has an effect on the body is by binding to estrogen receptors (Landvatter & Katzenellenbogen, 1982). Estrogen receptors are protein binding sites that can be found throughout the body and have binding sites specific for EE2 to bind to and then cause a specific action, depending where in the body the receptor is. The effect of the EE2 is only felt for as long as the EE2 is bound to the estrogen receptor; because the EM2 has a greater effect than the EE2, it is possible that EM2 may have a longer half life within the estrogen binding sites.

Conclusion

It is clear that EE2 and EM2 greatly sped up the rate of development in *Xenopus laevis*. While the rate of development was being sped up, the growth rate was being slowed down. The inverse correlation between development rate and growth rate has implications for the onset of sexual development and fecundity. The differences between the effects of EE2 and EM2 may be mediated at the estrogen receptors. Estrogen receptors are the highly specialized chemical binding points where EE2 or EM2 bind to have an effect. This study showed how these chemicals affected early developmental stages in tadpoles; now the effect of these chemicals over multiple generations needs to be evaluated. Finally, this study brings to the foreground the need to assess the effects of endocrine disruptors on the earliest stages of growth and development in other aquatic organisms.

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Smutko, M. Yim, to my RBio teacher A. Sheck, and to my parents A.C. and G. Hackney.

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Connections

Student paper by Cindy Wei

"...NCSSSMST?!" I remember back to freshmen year when those nine letters were considered a jumbled acronym and a pain to utter. But now, two years down the line, and our conference debut in only a few months, I remember the NCSSSMST motto, "foster, support, and advance the creative efforts of those specialized schools whose primary purpose is to attract academically prepared students for leadership in mathematics, science, and technology" while preparing our conference. On October 18, 19, and 20, 2007, Thomas Jefferson High School for Science and Technology will hold a student conference attracting approximately 350 students from member schools of the National Consortium of Specialized Secondary Schools of Math, Science, and Technology. This conference will advance student interest in math, science, and technology by bridging the gap with public policy. 2007 marks an important year in Virginia history and because of that, we name our conference—2007: Yesterday Never Dies, blending espionage and history into an interactive three day session. This conference is produced by the dedication of 30-some TJHSST students with the guidance of staff and administration, and with Montgomery Blair High School and sponsorship from GMU.

The most important aspect of our conference is the fact that it is student-run and -produced. By having a student planned conference, we are able to foster creative thinking, planning, and harness leadership abilities through responsibility and teamwork. It is important to preserve the role students play in producing such large conferences because it is the true definition of a "hands-on" education. As a fellow planning member, Yang He, states, "This is a conference by the students, for the students. This is an opportunity to network with 300 of some of the most talented students across the nation in one of the most influential/powerful cities in the world!" This conference connects students from across the country through interests in math, science, and technology. Student-planned conferences ensure that the conference is tailored to the students by presenting them what they want and what they will enjoy.

The club had humble beginnings consisting, at first, of just a handful of eager freshmen ready to tackle a challenge. Little did we know what we were going to embark on, but now, two years and many 8th period meetings past, we are able to boast our plan of the 3-day schedule and present our hard work. Taking advantage of our fortuitous location, only a few miles from the nation's Capital—we knew that our big ticket was being able to have a session in the Capitol with some of our state legislatures. This special excursion would give students the rare opportunity to discuss global warming with Members of Congress and issue experts. One of the planners for the Capitol group, Yang He, says that, "The panel debate would be a priceless experience for students, and a great opportunity for them to connect with their elected representatives." However, as we have learned, not every idea can be achieved with the stroke of a wand. The most difficult step is making the connection. "Our attempts at contacting senators and keynote speakers have certainly been difficult, though not completely fruitless," continues Yang. However, step-by-step we are beginning to make the connections that will bring to our conference full circle.

Another event that we are proud to present is the night on the Cherry Blossom. This boat will be cruising down the Potomac and present breath-taking views of the Washington, D.C. skyline, and give students a chance to unwind and interact with one another in a social setting. The ambiance of good music and food will be able to finish up Saturday night with a bang.

Cindy Wei, class of 2008, is on the Conference Planning Team at Thomas Jefferson High School for Science and Technology.

As a student conference, we want to be able to showcase the work of fellow students and established professors in universities. GMU, a partner and sponsor of our conference, will be hosting a variety of events on its campus. Starting on Friday night, we will present a lively International Night show put on by students of TJHSST and other contributing schools. Then during the day, GMU will present many hands-on activities and interactive studies by their leading professors. These activities will also allow students to work with state-of-the-art equipment on the GMU campus, such as in the ITE School. As well, at TJHSST, current students and alumni will present their award-winning projects. Throughout the day, students will have opportunities to engage in stimulating conversations about higher level math and sciences. The presenters will be able to answer any questions the participants may have.

Planning a conference has been a learning process and has required the work of a cooperating team. All of us, along with a few Montgomery Blair High School representatives embarked on a journey to the Hemlock Overlook Center for Outdoor Education during the summer of 2006. This center is designed to involve individuals and organizations "through experiential team building and environmental education while fostering personal growth and leadership development." This group activity allowed every member of the group to become a link in the process. Meg Barnett, one of the student catering coordinators, describes Hemlock, "I think our Hemlock Overlook trip definitely helped to unite our group. In order to create an effective conference, we need to learn to trust each other to get all of the work done. Hemlock forced us to trust each other to complete each assignment and come together as a team. We needed each and every person to reach our final goal."

As a group, we were able to gain insight into NCSSSMST-sponsored conferences. Our school, supportive of our endeavors, has financed us to attend the NCSSSMST student conference in Salt Lake City, research conference in Atlanta, and policy summit in Keystone, CO. By attending these numerous conferences, we were able to research the pros and cons of specific events, the importance of detailed scheduling and organized transportation, and also, have a great time. Master scheduler David DyTang remarks, "Our experiences at Salt Lake City provided us with the groundwork for our conference by allowing us to understand what should go into the event from a participant's point of view."

This entire journey has been a learning process for each of us. Our job requires setting a goal, establishing connections, and achieving them by constantly pushing forward. Because the job is so large, it cannot be accomplished by a one-man team. Delegation is critical to ensure that all bases are covered. "I've learned that delegating work is critical to plan something like this. Each member has to do his or her own job — if one person ends up doing it all, the workload is crushing. It has also helped me organize my own life, by setting aside time for school work and NCSSSMST work," replied Meg Barnett when asked what she had learned from this experience. As well, other members, such as Steven Chen, stated, "Our group has become more polished in writing letters and selling our ideas to others. We have become more experienced in convincing others to help us plan this conference." Not only will we be able to say we had a fun time planning this conference, but also that it was an extension of our progression of leadership, planning, and character. Our main sponsor and facilitator, Mrs. Waterfall responds, "Watching this group take responsibility, courageously chart totally unknown territory of busses, Congress, the Park Service, Lab Directors and more, in addition to remaining stellar students in a demanding atmosphere, has been one of the highlights in a career of public service."

We are all excited to be able to present our conference during the fall of our senior year. This conference will be the culmination of over four years of hard work, cooperation, and dedication. Many of us, such as Tim Chen, joined this group early freshmen year because, "Sure there are many other clubs to join but this one was a planning committee, done by students; something I wouldn't find at an ordinary school." That is what this conference is— special and out of the ordinary. If you would like to check us out, our website is activities.tjhsst.edu/ncsssmst. We will keep you updated!

Addressing the STEM Challenge by Expanding Specialty Math and Science High Schools

Position Paper by: Robert D. Atkinson, Janet Hugo, Dennis Lundgren, Martin J. Shapiro, and Jerald Thomas

In June 2006, several NCSSSMST executive committee members and past presidents were invited by Dr. Rob Atkinson, President of the Information Technology and Innovation Foundation (ITIF.org), to contribute to a paper on the need for specialized STEM high schools. The paper was presented on Capitol Hill by Dr. Atkinson and Dr. Jay Thomas, NCSSSMST Vice President, in March 2007. With the endorsement from several Congressmen, David Price (D-NC) and Brad Miller (D-NC), this paper informed a section of HR 2272, which was signed into law in August 2007 as the America COMPETES Act. The act increases federal funding for education and research and development in science, mathematics,engineering and technology education in the next three years, including increasing funding of specialized high schools. This article is reprinted with permission from ITIF.

If America is to succeed in the innovation-powered global economy, boosting math and science skills will be critical. This is why a wide array of task forces and organizations has recently raised the clarion call for more and better scientists and engineers. While the policy proposals offered are wide ranging, one key policy innovation has surprisingly been largely ignored: the role of specialty math and science high schools. Today, there are well over 100 of these high schools throughout the nation. And evidence shows that these schools are a powerful tool for producing high school graduates with a deep knowledge and strong passion for science and math that translates into much higher rates of college attendance and graduation in scientific fields.

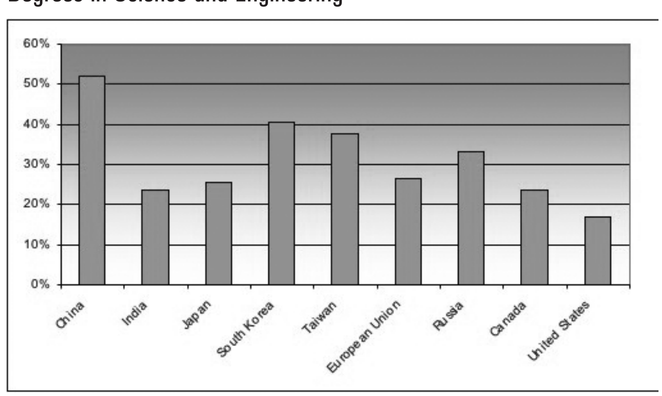
As a result, any solution to the scientist, technician, engineer, and mathematician (STEM) shortage must include a national commitment to expand the number of specialty math and science high schools. To do this, Congress should allocate $180 million a year for five years to the National Science Foundation to be matched by states and local school districts and industry with the goal of tripling enrollment in math and science high schools to around 140,000 by 2012.

The STEM challenge

The United States faces a new and pressing competitiveness challenge as a growing number of nations seek to gain global market share in technology-based economic activities. While the national policy response must be multi-faceted,[1] ensuring an adequate supply of talented scientists and engineers is one key step.

However, on a host of science, math, and engineering metrics, America is falling behind. The United States now lags behind much of the world in the share of its college graduates majoring in science and technology. As a result, the United States ranks just 29th of 109 countries in the percentage of 24 year olds with a math or science degree (See Figure 1).

Figure 1: Percentage of First Degree University Students Receiving Degrees in Science and Engineering[2]



As the economy is becoming more science and technology-based, fewer American students are studying science, technology, engineering and math (STEM). For example, while total U.S. citizen non-science and engineering graduate degrees increased 64 percent between 1985 and 2002, the graduate degrees in STEM fields awarded to U.S. citizens increased by just 14 percent, while degrees in STEM fields awarded to foreign-born students more than doubled (See Figure 2).

In some fields there has been a marked decline. For example, there are fewer non-biological science and engineering doctorate degrees being awarded to U.S. citizens today than in 1996 (See Figure 3). Likewise, bachelors degrees in engineering granted to Americans peaked in 1985 and are now 23 percent below that level.

So far the United States has been able to rely on foreign students studying and working here to make up the shortfall of domestic talent. In 2000, over half of all Ph.D. scientists under the age of 45 were foreign born, up from 27 percent in 1990 (See Table 1). But it's not clear that we will be able to rely on foreign scientists and engineers to fill the gap in the future. Fewer foreign students are coming to the United States for their degrees and fewer are staying after they graduate.[4]

Even in the face of these statistics some argue that today's worries about a STEM shortage will prove as illusive as past worries. It's true that well publicized warnings about shortages of STEM talent made in the 1980s and early 1990s did not come to pass. But it's important to recognize two key factors. First, those predictions did not, and could not, have taken into account the significant decline in funding for research in the 1990s, prompted in part by defense downsizing and federal fiscal shortfalls. Had funding not been cut, shortages could very well have appeared. Second, and more importantly, the United States made up for shortfalls in American-born STEM graduates by expanding immigration of STEM talent.

Figure 2: Percent Change in U.S. Graduate Degrees: 1985-2002[3]

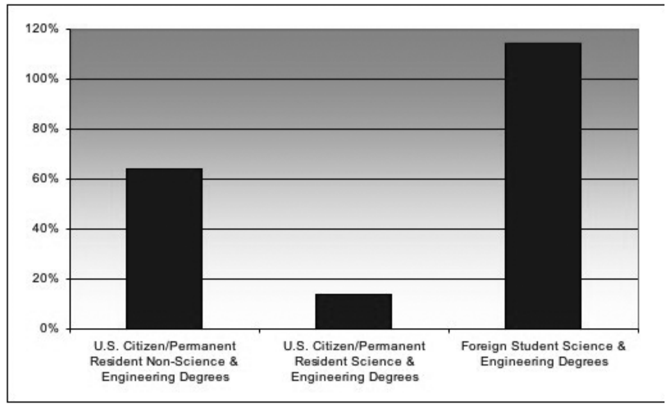


Figure 3: Non-Biological Sciences Science and Engineering Doctoral Degrees Awarded to U.S. Citizens[5]

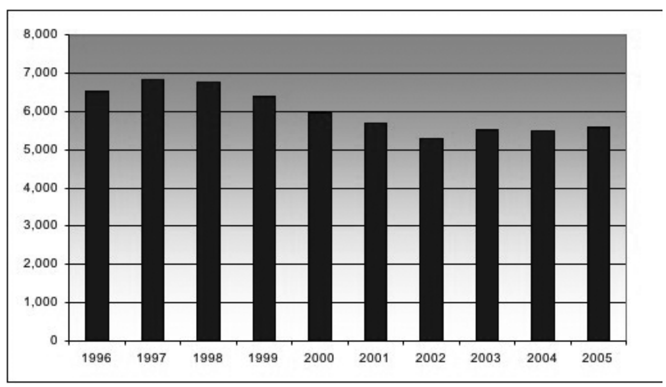


Table 1: Foreign-born Share of Scientist and Engineers Employment[6]

	1990	2000
Bachelors	11%	17%
Masters	19%	29%
All PhD	24%	38%
PhDs < 45	27%	52%
Post-Doc	51%	60%

Proposed Solutions to the STEM Challenge

There is no lack of proposals to address the STEM challenge. Proposals fall into two major categories: easing immigration and boosting domestic supply. With regard to the former, there is considerable focus on easing immigration rules to make it easier for foreign-born scientists and engineers to work in the United States. While such steps are important in the short run, over-reliance on foreign-born STEM personnel involves considerable risk. As we saw after 9-11, numbers of STEM immigrants can decline suddenly. Moreover, other nations, particularly Canada, Australia and Great Britain, have increased their recruitment of STEM talent.[7] As other nations get richer and STEM employment opportunities there become more plentiful it will be harder to attract and retain foreign STEM talent.

The second major policy focus centers on boosting the supply of U.S. STEM talent. Some proposals have focused on boosting incentives to encourage college graduates to obtain graduate degrees in STEM. For example, Congressional legislation would expand NSF doctoral fellowships. Other proposals focus on increasing the retention rate of undergraduates in STEM fields, in part by expanding NSF's Science, Technology, Engineering and Mathematics Talent Expansion Program and by encouraging development of Professional Science Masters programs.[8] Still other proposals focus on making it easier for students interested in STEM, especially underrepresented minorities and women, to go to college and study STEM fields, through programs such as NASA's Science and Technology Scholarship Program and NSF's Robert Noyce Scholarships.[9]

Finally, and most relevant to this policy brief, a wide array of proposals would seek to intervene farther back in the STEM pipeline at the K-12 level. These include expanding professional development programs for science teachers;[10] enhancing science enrichment programs; using No Child Left Behind to judge scientific educational outcomes; and boosting science teacher quality, either through stricter requirements, providing incentives to attract higher quality teachers to science,[11] and/or making it easier for scientists and engineers to become teachers.

To solve the STEM problem, policy makers should focus on all the areas above. Surprisingly, however, virtually all the reports on this issue and the legislation addressing it largely ignore one of the most potentially successful policy interventions in this area: specialized math and science technology high schools. One report that did mention specialty math and science high schools was the National Academy's *Gathering Storm* report, but it did not contain specific policy recommendations towards implementing them.[12] Moreover, the PACE-Energy Act (S. 2197), based on report, contains a small program to let energy national laboratory staff assist in teaching at such high schools.[13]

By creating an environment focused more intensely on science and technology, these schools have been able to successfully enable students to study science and math, often at levels far beyond what students in conventional high schools are at; they can then go on to degrees in math and science at relatively high levels. It's time to build upon this successful model and significantly expand the number and scope of our nation's math and science specialty high schools.

What are Mathematics, Science and Technology High Schools?

There are close to 100 math and science high schools (MSHS) across the nation, members of the National Consortium for Specialized Secondary Schools of Mathematics, Science and Technology, with pull-out programs with 125 students, to full day programs and dedicated high schools of over 4,000 students, to state sponsored residential schools, enrolling over 47,000 students in total. Approximately three-quarters of these schools are full-day schools, 25 percent are half-day programs, and 18 percent are residential schools.[14]

While a few MSHSs date back to the early 1900s,[15] many were developed after 1980 in response to a growing concern about the competitive position of the U.S. economy. In response, several states established new public high schools with an emphasis on mathematics, science and technology such as Thomas Jefferson High School for Science and Mathematics in Northern Virginia, The North Carolina School for Science and Mathematics (NCSSM) in Durham, The Illinois Mathematics and Science Academy (IMSA) in Aurora, and the Eleanor Roosevelt High School in Greenbelt, Maryland. Congress allocated funding for magnet schools of mathematics and science to assist school districts under supervision of the courts with desegregation plans in the late 1980s. Many of the science and technology magnet schools were placed on the high school campuses with disproportionately high numbers of African American students in order to bring non-black students into these schools. The magnet programs were developed using a school-within-a-school concept. The Center for Advanced Technologies in St. Petersburg, Florida, The Blair Science, Mathematics, Computer Science Magnet Program in Silver Spring, Maryland, and the Conroe Academy of Science and Technology in Conroe, Texas are examples of the school-within-a-school concept.[16]

Mathematics, Science, and Technology High Schools differ from the general education found in comprehensive high schools in key ways. First, as the name implies, MSHSs focus much more extensively on STEM curricula. For example, in addition to the three years of lab science and three years of mathematics required by the state for high school graduation, Florida's Center for Advanced Technologies offers students an opportunity to declare a mathematics-science major by taking four additional courses in mathematics and science, often Advanced Placement Courses.[17]

Second, students don't just take more STEM courses; they take more advanced courses and do more advanced work.[18] Indeed, the coursework and integrated curricula of MSHSs go over and above the normal graduation requirements for general education students. For example, students at the Arkansas School for Mathematics, Sciences, and the Arts can take courses in Biomedical Physics, Immunology, Micro-biology, Multivariable Calculus, Number Theory, Differential Equations, Math Modeling, Computer Programming III, and Web Application Development. The focus at these schools is not on the College Board's Advanced Placement offerings, but on courses beyond AP. Students are expected to work at a college level of instruction and learning.

The majority of these specialized schools have a focus on a graduation requirement of research in an area of math-science-technology where they are taught to ask the right questions, use 21st Century state of the art tools to find the right answers, and then effectively communicate these answers. For example, some schools have requirements where the students are assigned a research mentor with whom they will work over the course of the time they are at the school. Students also compete in science fairs, research symposia, etc. as the capstone for these research projects. These projects are often entered into national competitions such as the Siemens-Westinghouse Science Talent Search, the International Science and Engineering Fair, Chemagination, DuPont Challenge, Exploravision, Neuroscience Creativity Prize, Thinkquest, Young Epidemiology Scholars, and Young Naturalist Awards.

A third distinguishing feature of these schools is their level of partnership with other organizations. Collegiate, corporate, and alumni organizations have formed significant partnerships with these schools. While some partnerships have been in support of specific events, others have been long-term partnerships supporting research and innovation among students and faculty. Collegiate partners, for example, often provide classroom, dormitory, research, and financial support to these schools.[19] For example, at the Governor's School of South Carolina, every rising senior is placed for six weeks in the summer at an off-campus program. Many of the students work with a research professor at an in-state university.

Finally, while it's difficult to assess and compare educational environments, MSHSs are distinguished by the high level of student and faculty engagement. Many students get turned on to mathematics and science because their instructors are engaging and their own love of learning is contagious.[20] One finds a great deal more interaction between students and instructors at these schools. Students are eager to spend time with people who are interesting and interested in them. One school principal calls it "hanging on the faculty member's legs." It's not uncommon to find instructors surrounded by students during off periods or after classes. When a student conducts research under the tutelage of an interested teacher, the mutual excitement grows. This is one reason why most of these students do not want to take the summer off or spend it working at a fast-food restaurant. Instead, they are hooked on learning and want to take advantage of all that is offered.

This is also a reason why instruction is less traditional. As a general rule, instructors do not spoon-feed information; rather they focus on student responsibility for solving problems, digging for the information, researching for understanding. It's unusual to find traditional instruction at these schools – the "I'll tell you, then you'll repeat it back to me" style of instruction that is found in most educational settings. MSHS faculty focus on student learning rather than simply faculty teaching, and expect the development of critical thinking skills and learning beyond simple understanding.

Moreover, because students and faculty are passionate about STEM, the normal issues in conventional high schools where kids interested in science are labeled as nerds, or where girls are discouraged from being smart, largely disappear. As one high school principal said, "females stop worrying about their looks and whether they will be popular. Instead they compete with the males in their classes and find that the guys like them for their smarts and not just their looks."

Specialty Math and Science High Schools Are an Effective Tool for Boosting STEM Talent

While the educational environments and pedagogical processes at MSHS are exemplary, the key question is whether they produce results. While formal studies are few, there is some evidence that these schools are highly effective at producing graduates not only with high levels of aptitude in STEM, but who go on to further study and careers in STEM. For example, one study of 1,032 graduates finds that these schools perform very highly.[21] MSHSs' graduates leave high school and college as highly prepared, very satisfied and efficacious students of mathematics, science, and technology: 99 percent of graduates enroll in college within one year of high school (compared to 66 percent nationally) while 79 percent complete college in 4 years (compared to 65 percent in private universities and 38 percent in public universities).[22] Moreover, 80 percent of graduates intend to earn a master's or doctorate degree, while just 10 percent of 30 year olds have a graduate, professional or doctorate degree,[23] while 53 percent of students among those in the highest quarter of family SES expected to complete graduate or professional school.[24] Students also voice very positive views of their high school experience, with 85 percent of college seniors indicating that their high school enhanced their critical thinking and 76 percent indicating that their high school enhanced their research skills.

Most importantly, however, MSHS graduates earn undergraduate and graduate degrees in mathematics, science, and technology fields in significantly higher numbers than the general population. Approximately 56 percent of MSHS graduates earn undergraduate degrees in mathematics or science-related fields, compared to just over 20 percent of students who earn an undergraduate degree. It is especially important to note that over 40 percent of females earn such degrees – nearly double the national average. And a significant percentage of those female MSHS graduates who do earn a mathematics, science, or technology degree indicate plans to seek employment or advanced study in highly specialized fields. These findings are consistent with trend data gathered over time by MSHS schools that conducted independent graduate follow-up. Graduates of MSHSs distinguish themselves from their academic and professional peers. While it is likely that among any population of gifted and talented students a significant number would become high achievers in their chosen fields, the opportunities afforded to students through MSHSs clearly enhances such correlated critical skills.

Graduates of specialized schools have distinguished themselves in many ways in mathematics and science research in college and beyond, and there is abundant evidence that students' ability to ask questions and pose novel solutions was recognized and enhanced by their specialized school experiences. One female student, for example, matriculated at Harvard University and embarked on a four-year study of a particular species of mushroom. She had begun her groundbreaking research in a mentorship experience in high school, and her original high school research led to the revision of texts on the subject. Graduates of MSHSs frequently comment that the most influential experiences in high school were the opportunities to engage in their own research and inquiry – opportunities not available at their home schools. High school, suggested one graduate, "Taught me not to rush into difficult problems but to step back and evaluate the situation so that I can tackle it from the right angle." Another student, a Harvard undergraduate and Yale law school graduate, suggested that he would never have known that Harvard and Yale would be an option for him had he remained at his rural Midwestern school. Students from rural, poor, or inner-city schools have consistently commented that, upon matriculation at a MSHS school, they recognized for the first time that there were students who shared their interests, that it was acceptable to be smart, and that there were teachers who were interested in them and eager to challenge them.

Challenges

Significant challenges face current and emerging specialized mathematics, science and technology high schools. Specialized high schools are continuously confronted with issues of sustainability, committing a high level of energy to promote, improve and fund their schools. The governance structures of specialized schools differ widely. For example, some operate under the purview of a college or university, while others report to local boards and district-level stakeholders. Hence, with different funding sources, governance structures, and stakeholders, specialized schools regularly face issues related to public support and curriculum, facilities, and funding.

Public Support and the Issue of "Elitism"

Perhaps the largest challenge facing the MSHS movement is the ambiguity that exists in our nation regarding excellence. On the one hand there is growing recognition of the importance of meeting the new challenge of a "flat world" by ensuring that the best and the brightest enter in STEM fields and receive top level training and education. Yet, at the same time there is a suspicion that helping a relatively small group of students excel is some how elitist and unfair. At the local level, citizens sometimes balk at supporting specialized math and science schools as they are often regarded as elitist schools that drain financial and human resources from the general population of students. While boosting the quality of K-12 schools and especially underperforming ones, STEM education should not he held hostage to, in this case, misplaced concerns about fairness. It is clearly in the national interest to ensure that some students who are passionate about STEM receive the support and educational environment they need to excel.

This does not mean, as some might believe, that MSHSs cannot or should not focus on expanding their opportunities to the widest possible groups of students. In general, minorities and females are underrepresented in specialized mathematics, science and technology schools just as they are in these fields in higher education and in professional fields. Moreover, research literature in education is rife with evidence that minority and low-income/low socioeconomic status gifted and talented students are woefully under-identified, under-challenged, and under-represented in public schools.[25]

As a group, however, specialized mathematics and science schools have found not only effective strategies for identifying such students, but also actively implement plans for support and retention of such students. Many of these schools engage in energetic efforts to identify, engage and train the most capable and talented pool of students. Hence, to actively recruit and support talented students, regional or statewide mathematics and science programs offer opportunities to students who might otherwise not be recognized. For example, in Pinellas County, Florida, with approximately an 18 percent African-American population, less than 4 percent of those students are served in the public schools' International Baccalaureate (IB) program. The specialized mathematics and science school, however, typically serves over 10 percent of a group historically under-represented in higher education mathematics and science. More broadly, NCSSSMST, the association of MSHSs, through support from the Alfred P. Sloan Foundation, the Siemens Foundation, and Associated Colleges of Illinois, has initiated a multiyear study to identify and assess successful practices in reaching under-represented groups.

Facilities and Funding
School districts are often reluctant to commit the resources to create and provide ongoing support for schools for mathematics, science and technology. Such reluctance is manifested by concerns related to the high cost of science and technology laboratories and equipment. Specialized mathematics, science and technology schools require quality, up-to-date laboratories and research spaces. Viable laboratories should be designed to accommodate a variety of projects, innovative research studies, teamwork, and spaces for building technology projects, online connections, supportive technology and current equipment.[26] In the standard, comprehensive high school, the cost per student in a laboratory science class is one of the highest costs in the school. To provide the laboratories needed at specialized schools, the cost is even higher.

Effective MSHSs also need quality curricula; current textbooks and curriculum materials do not meet the demands of these schools. MSHSs devote significant energy and resources to and enhance currently available curricula. Other schools actively develop innovative curricula designed to challenge their own students and to inform educational practice at the local and state levels. Indeed, part of these schools' mission statements is a charge to transform mathematics and science education at the local, regional, or state levels. Such outreach efforts demand that faculty be allowed to stay current in their academic fields, engage in educational research, and be released for faculty development outside their own schools. All these additional resources – laboratories, curriculum and educational outreach – cost extra money. Given that much of the benefit of MSHS will accrue to the state as a whole, the nation, and indeed the world, in the form of more and better scientific research and engineering, it's not surprising that the locally-funded school system under-invests in this kind of knowledge infrastructure.

Policy Recommendations
Solving the STEM challenge will require an array of responses at a range of educational levels, (K-12, college, graduate school, work-related immigration). However, a key part of any solution needs to be the significant expansion of specialty math and science high schools. As we noted above, more so than other high schools, math and science high schools produce benefits that local communities, and even states will not capture. Rather than be seen as solely the responsibility of local school districts, or even states, they should be seen for what they are: a critical part of the scientific and technological infrastructure of the nation. Thus, we believe that the National Science Foundation should play a key role in supporting and expanding such schools. As a result, Congress and the Administration should set a goal of approximately quadrupling enrollment at such high schools to around 250,000 students. This will require both the creation of a significant number of new high schools, but also expansion of others with room to grow. To do this, **Congress should allocate $180 million a year for the next five years to the National Science Foundation to be matched with funding from states and local school districts and industry, and invested in both the creation of new MSHSs and the expansion of existing ones.**[27] Moreover, a share of these funds should go toward establishing MSHSs focused on under-represented populations. States and/or local school districts would be required to match every dollar of federal support with two dollars of state and local funding. Industry funding would count toward the state and/or local school district match.

Second, institutional partnerships are a key to success of MSHSs. Whether it's the donation of research equipment, the opening of their facilities to students and faculty, or mentoring of students, technology-based companies can play an important supportive role. As a result, **Congress should modify the research and experimentation credit to allow companies to take a flat (non-incremental) credit for donations of equipment to high schools.** Math and science specialty high schools are an institutional innovation that has a proven track record in helping educate more scientists and engineers. By building on this model Congress can help address the need for scientists and engineers.

Endnotes

1. Robert D. Atkinson, “Will We Build It and If We Do Will They Come: Is the U.S. Policy Response to the Competitiveness Challenge Adequate to the Task?” (Washington, D.C.: The Information Technology and Innovation Foundation, 2006): <www.itif.org/files/aaasfinal2006.pdf>.

2. National Science Foundation Statistics, “Global Higher Education in S&E” (National Science Foundation, 2006): <www.nsf.gov/statistics/seind06/c2/c2s4.htm>.

3. National Science Foundation Statistics, “Chapter 2: Higher Education in Science and Engineering,” (National Science Foundation, 2006): <www.nsf.gov/statistics/seind06/pdf_v2.htm>.

4. Anna-Lee Saxenian, *The New Argonauts: Regional Advantage in a Global Economy* (Cambridge, MA: Harvard University Press, 2006).

5. National Science Foundation Statistics, “Doctorates Awarded 1996-2005,” (National Science Foundation, 2006): <www.nsf.gov/statistics/nsf07305/content.cfm?pub_id=3757&id=2>.

6. Source: Richard Freeman, Harvard University.

7. David Hart, “Global Flows of Talent: Benchmarking the United States,” (Washington, D.C.: The Information Technology and Innovation Foundation, 2006): <www.itif.org/files/Global_Flows/pdf>.

8. A Senate bill would authorize up to $20million in seed money for colleges to set up “professional science master’s” degree programs to provide that kind of training.

9. Congress passed legislation in 2006 increasing the amount of Pell grant awards for students studying math, science or languages.

10. President Bush’s American Competitiveness Initiative proposes quadrupling spending for a program to train schoolteachers to lead Advanced Placement and International Baccalaureate classes in mathematics and science.

11. House legislation would boost funding for an NSF program that provides financial support to juniors and seniors majoring in math and science if they work as schoolteachers after graduation. The program gives scholarships of $10,000 a year in exchange for up to four years of teaching.

12. The National Academy of Sciences, “Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future,” (The National Academies Press, 2006): <www.nap.edu/catalog/11463.html>.

13. The legislation states: “CHAPTER 1 – ASSISTANCE FOR SPECIALTY SCHOOLS FOR MATHEMATICS AND SCIENCE. SEC. 3171. ASSISTANCE FOR SPECIALTY SCHOOLS FOR MATHEMATICS AND SCIENCE: (a) In General – Consistent with sections 3165 and 3166, the Director shall make available necessary funds for a program using scientific and engineering staff of the National Laboratories, in which the staff – (1) assists teaching courses at statewide specialty secondary schools that provide comprehensive mathematics and science (including engineering) education; and (2) uses National Laboratory scientific equipment in the teaching of the courses. (b) Report to Congress – Not later than 2 years after the date of enactment of the Protecting America’s Competitive Edge Through Energy Act of 2006, the Director shall submit a report to the appropriate committees of Congress detailing the impact of the activities assisted with funds made available under this section.”

14. The demographics of the schools which are members of the National Consortium for Specialized Secondary Schools of Mathematics, Science and Technology are: 75 percent are full-day schools, 25 percent are half-day programs, 18 percent are residential, 80 percent are non-residential, and 2 percent take both residential and non-residential students. 69 percent are grades 9-12, 4 percent are grades 10-12, 22 percent are grades 11-12, and 5 percent include elementary and/or middle school students. (NCSSSMST, 2004)

15. During this early 1900s a few specialized high schools emphasizing mathematics and the sciences were developed, such as the Bronx High School of Science and Stuyvesant High School in New York City. Congress played a role, allocating large sums of funding through the Smith-Hughes Vocational Act of 1917 to promote home economics, agriculture, and the manufacturing trades. One example of this was the establishment of Brooklyn Technical High School in the early 1920s.

16. By 1988 these schools had reached such a critical mass that a group of mathematics, science and technology schools began to network and recognized issues of common concern. The result of the dialogues that developed from shared concern was the establishment of the National Consortium for Specialized Secondary Schools of Mathematics, Science and Technology (NCSSSMST). Beginning with fifteen charter members in 1988 the NCSSSMST has now grown to almost 100 institutional member schools and an even greater number of affiliated colleges and universities.

17. Many MSHS students are able to take these extra courses by taking regular education graduation requirements such as Economics, American Government, Physical Fitness and health online at the Florida Virtual High School.

18. Seth Hanford, "An Examination of Specialized Schools as Agents of Educational Change," (Education Resources Information Center (ERIC), 1997): <eric.ed.gov/ERICDocs/data/ericdocs2/content_storage_01/0000000b/80/22/36/e4.pdf>.

19. There are numerous examples of such partnerships. Collegiate Partners: Andrews University (Berrien County Mathematics and Science Center); Worchester Polytechnic Institute (Massachusetts Academy of Science and Mathematics); The City College of New York (High School for Mathematics, Science and Engineering); University of Arkansas (Arkansas School for Mathematics, Sciences, and the Arts). Corporate Competition Partners: Motorola Corporation (support for NCSSSMST Professional Conference); Baxter Healthcare of Tampa Bay FIRST Competition (support for Center for Advanced Technologies). Other Corporate sponsors for FIRST include Raytheon, GE, Motorola, NASA, the U.S. Department of Defense (support for Internet Science and Technology Fair). Academic Competition Partners: The Siemens Corporation; Intel; Young Epidemiology Scholars and the College Board.

20. Jonathan Plucker, "Aspirations of Students Attending a Science and Mathematics Residential Magnet School," (Education Resources Information Center (ERIC), 1996): <eric.ed.gov/ERICDocs/data/ericdocs2/content_storage_01/0000000b/80/23/df/32.pdf>.

21. Most recently, the NCSSSMST board of directors commissioned and supported a four-year longitudinal study of its graduates. This study gathered post-graduate data on students at one and four years after high school graduation and assessed students on several critical questions: their intended college major and plans for post-graduate study; the degree to which their high school enhanced their critical thinking, creative thinking, and research skills; and overall satisfaction with a specialized high school experience. J. Thomas and B.L. Love. "An Analysis of Post-Graduation Experiences Among Gifted Secondary

Students." *NCSSSMST Journal* 6.1 (2002): 3-8. See also Jay Thomas and Brenda Lee Love, "NCSSSMST Longitudinal Study of Graduates: A Three-Year Analysis of College Freshman and College Seniors," *NCSSSMST Journal* 7.2 (May 2002). (NCSSSMST = National Consortium of Specialized Secondary Schools of Mathematics, Science and Technology.)

22. Source for national figures are: U.S. Department of Education, National Center for Education Statistics, "Digest of Education Statistics," Table 181: <nces.ed.gov/programs/digest/d05/tables/dt05_181.asp>, and U.S. Department of Education, National Center for Education Statistics, 2000/01 Baccalaureate and Beyond Longitudinal Study: <nces.ed.gov/das/library/tables_listings/show_nedrc.asp?rt=p&tableID=1378>.

23. National data from United States Census Bureau, "2005 American Community Survey PUMS," accessed via DataFerrett, <www.census.gov/acs/www/Products/PUMS/acs_pums_download_via_ferrett.htm>.

24. National Center for Educational Statistics, "The Condition of Education 2006: Postsecondary Expectations of 12th-Graders," (National Center for Educational Statistics, 2006): <nces.ed.gov/programs/coe/2006/section3/indicator23.asp#info>.

25. For example, J.H. Borland, R. Schnurr, and L. Wright, "Economically Disadvantaged Students in a School for the Academically Gifted: A Postpositivist Inquiry into Individual and Family Adjustment," *Gifted Child Quarterly* 44.1 (2000): 13-32.

26. The general high school science laboratories usually do not meet all these demands. There are many NCSSSMST schools that have designed facilities that indeed meet these needs. For example, The Center for Advanced Technologies in Florida has included in its specialized high school a large research laboratory built to vocational education specifications. The laboratory includes industrial level power connections, bays to build robots and technical projects, laptop computers with science probes and related equipment, broadband Internet connections, science stations for long term experiments, work stations for students to collaborate and make presentations, and secure storage for chemicals and equipment. Unfortunately, most schools do not offer students technology or resources that are reflective of the resources they will encounter in college or, to be sure, in their professions.

27. Some of the expansion would come from construction and creation of new specialty MSHSs. Costs of building such a high school can range from around $11 million (for rehabilitating an existing building) to over $50 million for constructing a new MSHS in an area where land prices are more expensive. Some expansion of enrollment would come from expanding existing high schools, where the price would presumably be less. However, even at these schools the costs can be higher, particularly for more extensive laboratory equipment. Overall these funds will be used as a federal incentive to spur states and local school districts to create more specialty math and science high

Technology Focus:
Enhancing Conceptual Knowledge of Linear Programming with a Flash Tool

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Mathematical knowledge can be categorized in a different ways. One commonly used way is to distinguish between procedural mathematical knowledge and conceptual mathematical knowledge. Procedural knowledge of mathematics refers to formal language, symbols, algorithms, and rules. Conceptual knowledge is essential for meaningful understanding of mathematical ideas (Hiebert & Carpenter, 1992) because it is knowledge rich in relationships. Students use conceptual knowledge to develop underlying meaning for procedural knowledge, and to make decisions and problem-solve (Bransford, Cocking, and Brown, 2000; Hiebert & Lefevre, 1986). Competency in mathematics requires both procedural and conceptual knowledge.

Traditional approaches to mathematics teaching and assessment too often overemphasize procedural knowledge at the expense of conceptual knowledge. Not surprisingly, research shows that students' performance on procedural tasks is often adequate but that their conceptual knowledge of mathematics is poor (Grouws, 1992; Silver & Kenney, 2000). The National Council of Teachers of Mathematics (NCTM, 2000), other organizations (e.g., CBMS, 2001), researchers and educators (e.g., Ball, 1991) advocate for placing more importance on the development of conceptual mathematical knowledge.

Illustration: The Corner Point Theorem in Linear Programming

In intermediate algebra and pre-calculus courses, linear programming is often taught as a three-step procedure in which, given an objective function and a list of constraints, students must (1) graph the given constraints in two-space to construct a feasible region, (2) find the corner points of this feasible region, and (3) determine which point or points in the feasible region maximize or minimize the given objective function. In step (3), rather than testing each and every point inside and along the boundaries of the feasible region, the Corner Point Theorem reduces the task to simply testing the corner points. Sometimes called the Fundamental Theorem of Linear Programming, the Corner Point Theorem states:

"Let S be the feasible region for a linear problem, and let $z = ax + by$ be the objective function. If S is bounded, then z has both a maximum and a minimum value on S and each of these occurs at a corner point of the S. If S is unbounded, then a maximum or minimum value of z on S may not exist. However, if either does exist, it must occur at a corner point of S" (Barnett, Ziegler, & Byleen, 2001, p. 472)

We have observed through years of informal conversations and discussions at workshops and conference sessions around the country, and through a small study, that a majority of those who teach linear programming do not understand why the Corner Point Theorem is true. This is the case despite the fact that teachers know and teach procedures associated with this theorem year after year. Essentially, they do not have a conceptual understanding of the Corner Point Theorem. One teacher stated "I know that's what happens but as far as the why's...that's a little sketchier." A second teacher told us "The one thing I felt like I really didn't know was how to do a good explanation of why the max and minimum points occur at the vertices," and a third added "Well, [the corner points] must have some meaning in terms of maximizing or minimizing something."

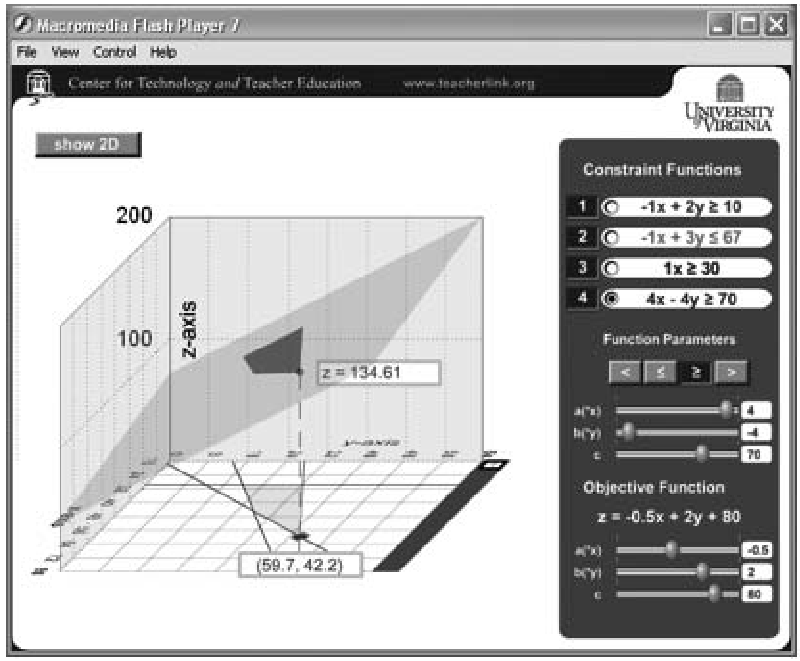
Some teachers try to verify the Corner Point Theorem by having students substitute into the objective function various points from inside, along the boundaries, and at the corners of the feasible region to determine where the objective function appears to have the highest and lowest values. Others do not even try to convince students that the theorem is true. Indeed, one teacher told her students “People have done enough of them that they know that the highest and lowest end up at the corners. Take my word for it.”

Linear Programming Tool

Digital technologies offer ways to advance conceptual mathematical knowledge. The NCTM (2000) recognized technology’s potential in its Technology Principle: “Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students’ learning” (p. 24). In particular, appropriate technology can facilitate the use of multiple representations (numerical, algebraic, and graphical) of mathematical concepts to promote development of conceptual understandings (Garofalo, Drier, Harper, Timmerman, & Shockey, 2000; Jiang & McClintock, 2000).

We developed an interactive Flash tool to help teachers and students visualize and deduce why the Corner Point Theorem works. Our Linear Programming Tool allows one to input up to four constraint functions and an objective function to be optimized (see Figure 1). One can graph these constraint functions and display the feasible region in two dimensions, like one would see in a textbook. As the cursor is moved over the feasible region, the x and y coordinates are displayed, along with the corresponding value of the objective function. Such two-dimensional representations, while often helpful, do not necessarily lead students to understand the linear programming algorithm. Once the feasible region and the graph of the objective function are displayed in *three dimensions*, however, students can easily see that the graph of the objective function is a plane that goes up or down linearly (or stays flat) in each dimension. Because there are no bumps or humps in the graph, as a point in the feasible region is moved in any dimension toward a boundary, its image point is either going up or down on the feasible region’s projection on the objective function surface. Students can then make sense of the fact that the objective function reaches its extrema over corner points.

Figure 1. Linear Programming Tool



Teacher’s Responses to the Linear Programming Tool

After working with this Flash tool the most high school teachers said they believed using it would help their students develop conceptual understanding of the Corner Point Theorem. They made comments such as “That’s exactly what we need to see in class because it would be awesome to make them see why that happens,” “This would make it a lot easier to understand the concept - I would use it in a heartbeat,” and “This would make it a lot easier to understand the concept without having to actually graph it.” These teachers thought the tool would be helpful in presenting the Corner Point Theorem, even though it involved three-dimensional ideas. While a few teachers expressed concerned about the use of a three-dimensional graph, others thought the end result would be worth any extra time needed to discuss three-dimensional graphing. For example, one teacher stated “It would take a day to go over, and look at the big impact you have on linear programming.”

Using the Linear Programming Tool

We encourage you to download and use our Linear Programming Tool (Windows or Mac) in your own classes. And, we welcome your comments and your suggestions for improving this tool. You can freely download the tool from our Flash download page at: http://www.teacherlink.org/content/math/interactive/flash/home.html. We have other Flash tools, addressing topics that range from basic fractions through calculus, which can also be downloaded from this page. Feel free to try these tools as well.

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Student Reflection Paper: Enhancing the Humanities in Schools Like Ours

By Everett Brokaw

This issue's humanities reflection presents a student's argument for attention to the humanities in a math, science, and technology program. Everett Brokaw, a senior at the Illinois Mathematics and Science Academy, recognizes that his specialized school experience has been enriched by personal journeys through literature and through encounters with faculty who integrate math, science, technology, and the arts in their daily instruction.

Schools like ours pride themselves on rigorous classes focused upon mathematics, science, and technology (MST). In many of our schools, classes in the humanities are taken alongside those in math and science. Further, our institutions enroll some of the brightest students in the nation. Integrating the humanities into our students' experiences is vital to a results-oriented education.

With our schools' specialization in math and science, the humanities provide an amazing opportunity to support those fields. Cooperation and integration are key. Writing classes can focus on proper formatting for research papers. History classes can teach the history of mathematics or technology. From a student's perspective, the classes mesh with one another. For example, last semester I enrolled in History of Astronomy, taught by Dr. Rob Kiely, a science historian, and the connections were amazing. Foreign language courses allow students to conduct and present research in new, diverse settings. Our English courses can tap into the wealth of literature written about the sciences; for example, LeCouter's Napoleon's Buttons engages both the historian and the chemist. Interdisciplinary cooperation with the humanities is a great approach for the MST-focused curriculum, if applicable. Integration with the humanities provides a meaningful complement to the MST concentration.

Throughout my three years at the Illinois Mathematics and Science Academy (IMSA) I have been particularly interested in balancing the MST-heavy curriculum around me with my own interests in literature and theology. I have done two years of research on faith-based literature by completing, reviewing, and discussing a total of over 40 books alongside two amazing mentors and numerous other individuals. I chose the works, and the choice to conduct research was entirely my own. Therefore, when I speak of the humanities, I immediately jump to this particular example, because reading has become a passion.

A critical element of the entire project was my free choice. I was able to choose what material I read and, moreover, choose to read it; the project became my own because I was engaged in my work. Students, though, rarely, if ever, possess either option in a literature course: they cannot choose whether to read or which book to pick up. A simple poll of our students would probably show that they despise Heart of Darkness, and logic tells us that forcing them to read it likely results in a decreased passion for literature. Making an experience such as reading painful through the choice of material makes it difficult for students to take an interest. Some of us (myself included) can appreciate Conrad's work for its high quality of literature, but future doctors, mathematicians, and engineers will probably find it stifling, along with the curriculum in which it is taught. There needs to be a compromise between literature that is high in quality and that which is accessible by the students. I do not suggest that we throw out the classics. Perhaps, though, there needs to be a more thoughtful approach to the literature chosen for discussion.

Everett Brokaw is a 2007 graduate of the Illinois Mathematics and Science Academy in Aurora, IL.

Our students have a desire for philosophy, a capacity for deep discussion amongst themselves about the real issues of our time. They can make meaningful connections between the events in their own lives and the books they read, and the same is true with the art they view or the historical situation they examine. If our students are to be engaged in their learning, I think it quite fitting that they are given a fair opportunity to offer their input: not just by raising their hands in the classroom, but by contributing input in the curriculum itself.

The details of student-input booklists may get tricky, but I address the overall mission: In order to engage the students in what they are learning, let them choose some of what they encounter. Here I focus upon reading. I do not suggest that our syllabi become a matter of democracy, but offering students the chance to nominate a few the books for an English class may be a very worthwhile endeavor. From experience and many long discussions with my peers, I will say that students are by and large willing to read a book if they think it worth their while, but that the contrary is also true. When students are engaged in a given book (I cite *Crime and Punishment*), the discussions are deep and personal both in and out of class.

Countless times over the past three years I have sat under the trees and talked about literature with interested students: coffee shops and our residence halls are also favorites. We talk about books that made us think, that taught us something, and books that were just fun. Students really do care about books, but probably more about books that are of interest to their generation instead of the teachers. Ask students that graduated from your institution what they found the most engaging, and put them in the curriculum whenever possible. I guarantee that you will not regret doing so. I just finished *Brave New World and The Perks of Being a Wallflower*, and I think that students in schools like ours would be able to take a lot from both. Try some books that will help them, like Richard Light's *Making the Most of College*. Reason and the current attitude of the students can also come into play; Kerouac's *On the Road* may be a great choice for the last book before graduation or summer break.

I should offer some sort of disclaimer, because I feel I have been fortunate in my classes at IMSA, especially the humanities. A vital element therein has been the discussion, rather than lecture, setting. The desks are arranged in a circle rather than in rows, and the teacher does more facilitating than teaching. The seminar setting in which the students are at the center really makes the course personal. This, if not currently the practice at all schools like ours, is an amazing opportunity to engage students.

Overall, I feel that our schools must examine the worth of humanities within the math, science, and technology setting. We must attempt to maximize the humanities' potential, both as ends to themselves and means to greater contextual understanding of math and science. I focus here upon a few examples such as reading, student-input curricula, and interdisciplinary humanities, but the possibilities are endless. Our best tools are a group of the most innovative and motivated students in the country. They push their own limits and our curriculums should help them do so on a few of their terms. Ask their opinions and take their advice, especially your own graduates, who can speak for how well their MST-based education works in college and beyond.

I would invite anyone interested in reading or developing a curriculum along the lines suggested here to contact me <brokaw@imsa.edu>. I would also like to thank my mentors, Dr. Bosco and Mr. Casey, and all who have helped me along the way.

Teaching and Learning:
Hokie Spirit

By Cheryl A. Lindeman

If you didn't know what a Hokie is, I am sure you have it in your mind now – a flashing image of a college campus struck by tragedy on April 16th. For those of us who teach in Virginia, the news reports left us with immediate questions – Is one of our students in the group? It was a very long week for all of us because this type of tragedy could have taken place on any learning campus. Various departments on Virginia Tech's campus are active in NCSSSMST activities. Therefore, the April 16th event involved one of our affiliate member campuses.

If we reflect about our most difficult teachable moments in our careers, I am sure the Virginia Tech tragedy was extremely taxing on our minds. For those of us teaching high school seniors, who were in the process of sending deposits to Virginia Tech, it was particularly agonizing. For myself, I faced a college biology class with 7 future Hokies (as we call them) walking quietly into the lab and starring right at me. You could hear a pin drop in the room. Luckily, the Commonwealth of Virginia has a "moment of silence" followed by the pledge of allegiance. I asked for a moment of silence for the victims. When it was over I allowed the students to offer comments. The room was still silent. What could they say?

The healing for all of us was hearing good news reports from campus. The students at Virginia Tech showed the nation how they could work together to begin the insurmountable task of healing. Those of us who knew of our graduates attending VT called to make sure the students and their families were okay. Hearing the echo "Are you okay?' was a familiar sound. Our NCSSSMST conference registrar, John Wenrich, has his office located on campus at VT. Luckily, he was in San Francisco at a Conference with some of our NCSSSMST past presidents.

The Virginia Tech's Office of the President has set up a special recovery web site. It is located at: http://recovery.vt.edu . The executive committee of the NCSSSMST Board of Directors recommended a donation to the Hokie Spirit Memorial Fund. Our prayers and concerns go out to the VT Hokie Family.

Dr. Cheryl A. Lindeman is a biology instructor and partnership coordinator at Central Virginia Governor's School for Science and Technology in Lynchburg, VA.

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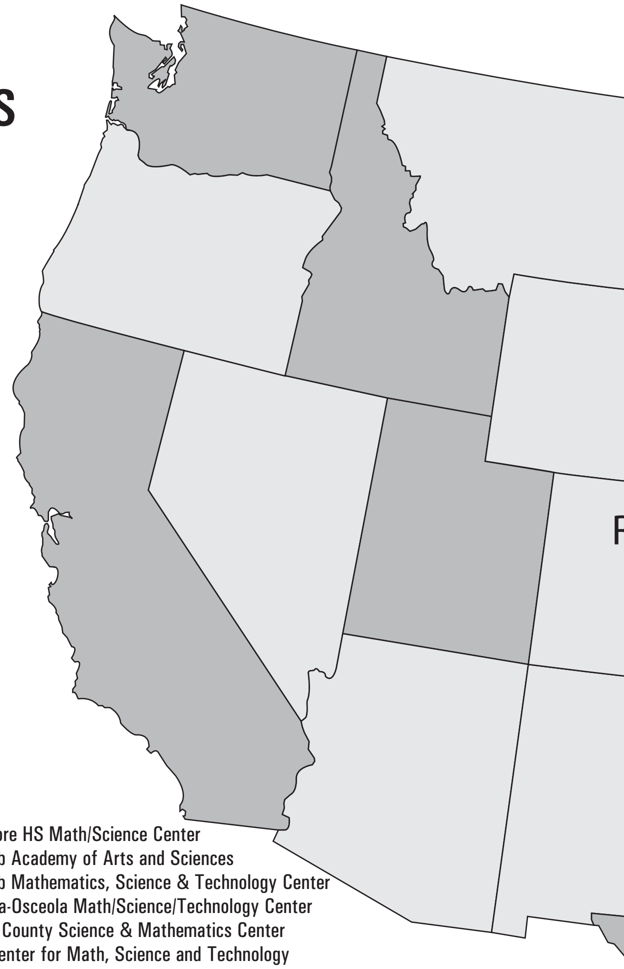

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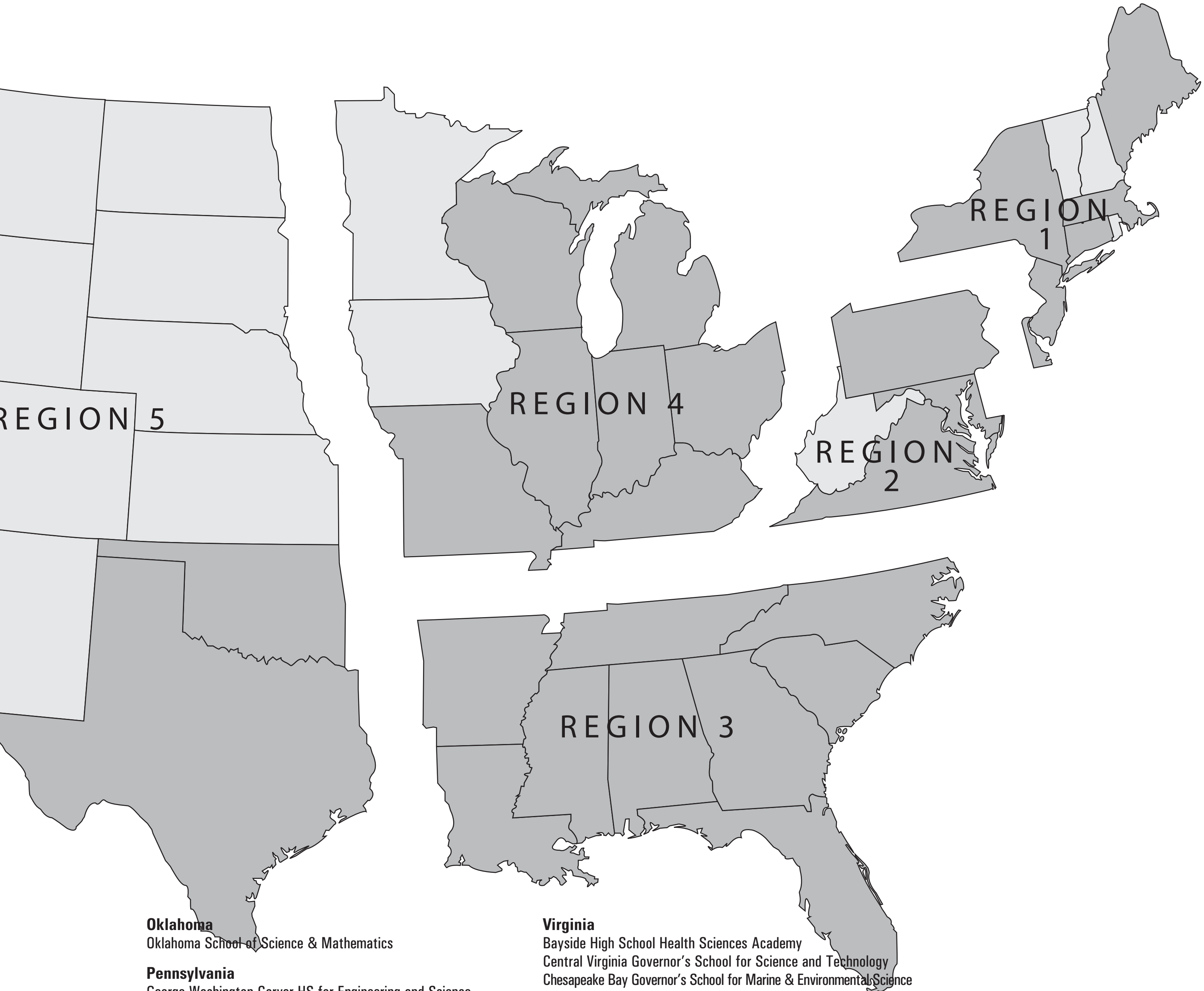

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Editorial Scope The purpose of the journal is to provide a forum for the discussion of innovation in secondary mathematics and science education and to disseminate information about Consortium member institutions.

Objectives

- To publish feature articles related to innovation in secondary mathematics and science education. Topics may include interdisciplinary curriculum; implementation of reform standards; infusion of technology into curriculum; creation of student centered active learning environments; original research of mathematics and science pedagogy; theoretical or conceptual positions; connections between science, mathematics, technology and society; connections between research and practice; discussion of current issues in mathematics and science education; and development of community and higher education partnerships. See feature article summaries on web site.
- To provide a forum for high school faculty members to report innovative classroom practices. See teacher practice summaries on web site.
- To provide a forum for Consortium students to report results of their original research. See student research summaries on web site.

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Handling of Manuscripts All manuscripts will be acknowledged upon receipt. The manuscript will be reviewed by at least two members of the Editorial Review Board. See web site for more details.

Tables and Figures All tables and figures must be submitted in camera-ready form (publication quality). Tables and figures should not be imbedded in the Word document. Authors will be charged a set-up fee of $25.00 if artwork is not acceptable quality. Tables and figures should be prepared on separate sheets at the end of the running text. Indicate in the text where they are to be inserted. Tables and figures should conform to APA guidelines.

Photographs Photographs are encouraged and welcomed if they are relevant and support the content of the article. See web site for more details.

Submission Check List for Feature Articles and Teacher Partner Summaries

____ Cover page
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____ Electronic version emailed
____ Cover letter signed by all authors
____ APA format used for all citations and references cited

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Student Research Summaries

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The manuscripts should follow the format of a research paper written in an abbreviated form. Manuscripts must include the following sections: Abstract, Introduction (encompassing literature review), Methods, Results, Discussion and Conclusions and Bibliography (APA format). The total number of tables, figures, graphs, pictures, etc., submitted with a manuscript is limited to three.

Manuscripts should be between 6 and 7 double spaced pages in length including tables, figures, and photographs.

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For publication, manuscripts must include a cover letter from the student and faculty or administration acknowledging the student's research. If necessary, a letter from the student's mentor not associated with the school must be included if research was conducted outside the student's school.

Submission Check List

____ Cover page, including title, students' full name, class year, high school and email address
____ One paper copy with all graphics placed in the document
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____ Student author letter stating original work
____ Mentor letter if applicable
____ Photographs if applicable including credit description
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____ APA format used for all citations and references cited (visit www.apastyle.org)
____ Electronic version emailed to NCSSSMST contact listed below

Notification of manuscript receipt will be sent to the student and teacher. If revisions are needed, the student and teacher will be given instructons.

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Upon publication, each author will receive a complimentary copy of the journal issue in which the article appears.

Submission of Manuscripts

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About NCSSSMST

The National Consortium for Specialized Secondary Schools of Mathematics, Science & Technology (NCSSSMST) was established in 1985 to serve educators and students in the growing number of specialized high schools throughout the United States. NCSSSMST is a forum and clearinghouse for the exchange of information and program ideas among faculty, staff, and students from member schools and affiliated organizations.

The Consortium comprises a network of research and development secondary schools with strong college and university affiliate members. As of May 2007, the 100 member schools and centers located in 30 states enroll more than 37,000 students. Each member school addresses specific needs of its area, and most serve districts or states, depending on their charter. Two associate institutions are in the process of developing new schools. Over 90 colleges and universities are members and participate in program-related activities or sponsor special events.

Brief History

Seeking to increase communication among the mathematics, science, and technology specialized schools, four such schools—the North Carolina School of Science and Mathematics, the Thomas Jefferson High School for Science and Technology (VA), the Louisiana School for Math, Science and the Arts, and the Illinois Mathematics and Science Academy—hosted an organizational meeting in the spring of 1985. Representatives from 15 schools attended, and NCSSSMST was founded to foster growth and interaction among similar programs.

Governance

NCSSSMST is a nonprofit organization with IRS 501(C) (3) tax-exempt status and is incorporated as a non–stock corporation in the Commonwealth of Virginia. The Board of Directors, composed of leadership from institutional members, meets at least four times a year to establish policy and set direction. The fiscal year is July 1 through June 30. NCSSSMST has implemented a strategic plan, and the board serves as the strategic planning team. The institutional membership elects the Board of Directors and officers of the corporation for three-year terms. The Board employs an Assistant to the President to handle day-to-day business.

Membership

NCSSSMST membership is extended to public and private secondary schools, colleges and universities, organizations, and individuals whose primary interests are congruent with the mission of the Consortium.

Categories for membership are as follows:

Institutional Membership — Open to specialized secondary schools or schools with specialized centers located in the United States that have nonprofit status and primary objectives congruent with the Consortium's mission.

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The benefits of membership include an annual student conference, annual professional conference, an Issues and Connections conference series, student research symposia hosted by colleges and universities, summer institutes, and the following publications:

- Newsletter — published three times a year
- NCSSSMST Journal — a juried forum (published twice a year)
- Membership Profile — biennial report of the Consortium
- WWW site—www.ncsssmst.org—organization's link on the site

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