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A Century of Leadership in Mathematics and its Teaching

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LEADERSHIP NOTES FROM THE FIELD

Mathematics department faculty have prior experience and outside interests that enliven and enrich the instruction they deliver in the classroom. They often take leadership roles, and the scholarly environment at Teachers College is uniquely supportive of their reflection on the character and meaning of leadership.

In the following section, *Leadership Notes from the Field*, authors present the stories of projects of special importance to them. Three articles discuss the building of schools. Stuyvesant has arguably the strongest mathematics program of any public high school in New York City. Stuart Weinberg and Maryann Ferrara chronicle the development of that mathematics department, which they chaired in turn over many years. The HELP Primary school in Uganda and the Nambale Magnet School in Kenya are at the opposite end of the economic spectrum, but they too teach mathematics to youngsters. Peter Garrity and Nicole Fletcher discuss their assistance to the development of the school in Masese, Uganda. Similarly, Phil and Loretta Smith participated with the Nambale school's founding, and they write of the complex project of funding and building a new school in a developing country.

Among the common threads to these articles—the power of mathematics education to lift the less fortunate, the personal rewards of serving others, the time and effort it takes to build a school—the most pertinent to our leadership theme is *collaboration*. At Stuyvesant leadership is spread across the faculty and the levels of the organization, "shared leadership." For the Nambale school a charismatic priest sparked the work and contributions of many individuals and groups, "distributed leadership." The Mathematics department at Teachers College is itself a highly collaborative environment. It is fitting that we close the Journal's leadership issue with personal observations by department faculty regarding the collaborative nature of leadership.

young Kenyan. The curriculum is up-to-date. Except for the context of problems and examples, the mathematics taught at the school is roughly similar to that encountered in the United States.)

Today the school stands on over eight acres of land in Nambale in the western part of Kenya, not far from Kisumu and Lake Victoria. Home to over 200 students ranging from pre–K to grade 5, the school employs a staff of 29, including a head teacher (responsible for curriculum development and faculty matters), teachers and teachers' aides, a social worker, a secretary, a facilities superintendent, food-preparation staff, a maintenance worker, a gardener, a laundress, and security personnel. The annual operating budget is approximately $130,000. An addition to the classroom, food, and dormitory buildings is a new residence for a housemistress and her family, as well as a fish pond, home to a tilapia farm providing an additional food source for the school community.

The school is achieving its mission of providing a good education for a significant number of children in a very poor part of the world. Many students, coming to school for the first time and preparing to learn, eat, and sleep at the school for the next several weeks, arrive with nothing but the clothes they are wearing. They have nothing else to bring, often not even a pair of shoes. (Controversies over whether or not to wear the school uniform are nonexistent.) Roughly half of the enrolled students are on full scholarship and live in the dormitories, their way paid by continuing donations raised in Kenya and the United States.

The future? No one is resting on laurels here: plans are underway for a Nambale Secondary School so that students currently enrolled can continue their education. You can "visit" the Nambale Magnet School yourself at www.nambalemagnet.org.

Shared Leadership in the Education of the Gifted: The Stuyvesant Experience

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Stuyvesant High School is a New York City institution for gifted students with an educational heritage deeply rooted in the tradition of Science, Mathematics and Technology. This article describes Stuyvesant's Program in Mathematics and a leadership model of shared responsibility and leadership-by-example. The article concludes with a brief narrative on the teaching of mathematics.

Keywords: leadership by example, gifted students, shared responsibility

In the years since the founding of Stuyvesant High School in 1904, the mathematics department has endeavored to provide its students with a high quality program in mathematics. That has meant responding to changes in society and to changing views about the way in which mathematics is taught and learned.

Stuyvesant began as an all-male manual training high school with courses focused on engineering and housed in a venerable but overcrowded building on East 15th Street in Manhattan. Today, Stuyvesant is a coeducational school of over 3,000 students who travel from the city's five boroughs to a ten story state-of-the-art facility in the north end of Battery Park City. Last year, more than forty percent were considered economically disadvantaged and qualified for free or reduced lunch. They come to benefit from Stuyvesant's tradition of excellence in mathematics, science, and technology and sit in classes that often have enrollments of 34 students. Last year, forty six percent of the graduating class were National Merit

winners, finalists, semifinalists, or commended students. The average SAT math score was 728.

The math-science-technology offerings are embedded in a broader program of courses and activities that is able to meet the needs of a student population endowed with diverse talents and interests. Stuyvesant students can apply for 112 electives, including 31 Advanced Placement courses. They can join the hundreds of musicians who belong to the Symphonic Band, Orchestra, Concert Chorus, Chamber Choir, or other musical groups. Students can engage in research, join the staff of the school newspaper, be a member of the speech and debate team, join the fencing team, perform community service through ARISTA, be a stage-hand or act in the original theater production SING! or participate in over 100 other student-oriented organizations, publications, clubs and teams. It is a program with great rewards for students who are willing to go beyond the basic academic core. The richness and diversity of the program provides an opportunity

and framework for a more interdisciplinary approach to learning, a goal that should be explored and developed more robustly in the future.

Curriculum: The Program in Mathematics

Although some incoming students are placed in higher level courses, including calculus, most are placed in Euclidean geometry. Top performers are placed in an enriched geometry course, where subject matter is studied in greater depth and with an emphasis on reasoning and proof.

In addition to the required courses, freshman can select one of two electives, Math Team or Math Research. In research classes, students engage in guided independent study by reading articles in academic journals, writing papers to be shared with classmates, and developing expository skills with the expectation of presenting their work in the New York City Metropolitan Math Fair Competition. In junior year, students may continue to pursue their interest in research by enrolling in a two semester Intel Math Research Program that includes mentoring in the summer between junior and senior years.

In the freshman and sophomore math team classes, students encounter topics not ordinarily found in the standard core curriculum and focus on problem solving strategies. The academic environment is one in which problems are evaluated, discussed and solved using a variety of perspectives and methods. Students develop an appreciation and respect for the contributions of their peers. There are three freshman math team classes, two sophomore classes, and two junior-senior classes that meet every morning at 8:00 AM and are taught by faculty. In the junior and senior math team classes, students also teach entire topics and create original problems for presentation to the class. On occasion, Stuyvesant math team alums will visit and present to the team. Students can take advantage of a library of problem solving books and previous competitions, including the AMC exams and The Art and Craft of Problem Solving by Stuyvesant alumnus Paul Zeitz. Participation in summer programs is encouraged. This year, over one thousand students sat for the AMC exam, one hundred eighteen were invited to take the AIME and a handful will advance to the USAMO with the hope of representing the USA as part of the six-person Olympiad Team, as did Dr. Zeitz in the past.

Juniors study precalculus and some "double up" by taking Advanced Placement Calculus AB or BC. This enables the students to elect linear algebra, multivariable calculus and differential equations in senior year. Other electives include AP Statistics, non-AP Statistics and Mathematics of Financial Markets. The top few students who complete multivariable calculus and differential equations in their junior year have an opportunity to take advanced courses at New York University

including courses in topology, introduction to mathematical analysis, advanced linear algebra and complex variables.

We should note that many middle schools are aware that Stuyvesant assesses incoming students' algebraic competence. That knowledge may have an impact on a number of middle school programs. Whereas we approve of the inclusion of algebra in their curricula, it should be done thoughtfully. Acceleration should not take place at the expense of enrichment and other-than-algebra-based ways of thinking and problem solving. Middle school students need to have time to explore and appreciate the beauty of mathematics.

Shared Leadership and Responsibility

How does a program of this complexity evolve from a "traditional" algebra-through-calculus sequence? It happens because of a leadership model in which the ideas of students and teachers are valued and a framework of faculty interdependence flourishes. With avenues of input from administrators and faculty, a community of professionals blossoms and grows. It is a model of shared responsibility and leadership-by-example.

Professional development is a shared responsibility for transmitting school and department norms and practices. Teachers have bought in to the idea of inter-visitations, and sharing teaching materials and ideas about teaching and learning. Before teaching a course for the first time, new teachers observe classes taught by veterans to learn how to implement content and process standards. At department meetings, teachers' best practices are presented and discussed. Teachers experience the kind of teaching they are expected to implement in their own classroom.

Selection of the textbook for a course begins with the formation of a committee of teachers. After examining what is available, committee members "sign off" on the selected title. This is an important decision, one that can impact as many as 800 students in the selection of a single textbook.

Teachers are responsible for revising course syllabi. As they teach a course, teachers prepare a narrative on recommended changes. Teachers meet in committee, make revisions, and then bring the department chair into the decision-making process. Recommendations may include extension and reordering of existing topics and the addition of topics for enrichment.

Teachers are encouraged to submit recommendations for new courses. Although approval by the principal's cabinet is required, the process begins with teachers. Presently, the mathematics department is considering bringing back Mathematical Explorations and looking at the Teachers College model for a new Discrete Mathematics course in which different topics are taught in alternate terms—perhaps

graph theory one term and combinatorics the next—thus giving students options.

Computer programming courses were first taught at Stuyvesant in the 1970's, well before technology became prevalent in schools. Two veteran mathematics teachers, Sylvia Schwartz and Muriel Holland, studied computer programming on their own and developed a course of study. Hardware included key punch machines and an IBM 1130; the language was Fortran. Later, the school received both DOS-based desktop and Apple computers. As the program evolved, there was a convergence of knowledge acquired independently by teachers and by students, each population informing the other. It was the quintessential Stuyvesant classroom dynamic. A great leap forward took place in 1992 with the move to a modern ten story building in which a fiber optic backbone with 450 computers was installed. Throughout the design phase, faculty and staff worked with architects, engineers, and a systems integrator. To insure that all staff and faculty would be able to utilize this new resource, professional development, created with faculty input, was implemented both before and after the move. Today, all sophomores take a full year of introductory computer science. Electives include Advanced Placement Computer Science, Computer Graphics, System Level Programming, and Software Development.

Teaching and the Nature of the Mathematics Classroom

Leadership-by-example may be seen in the classroom where teachers continue to improve their craft by implementing and modeling standards-based instruction. We conclude this article with some ideas about teaching which apply to any mathematics class.

In its Professional Standards for Teaching Mathematics, the NCTM (1991) called for a "shift toward classrooms as mathematical communities" in which mathematics is taught and learned with understanding. The National Research Council (2001) included in its definition of mathematical proficiency the idea that students should develop the "habitual inclination to see mathematics as sensible, useful, worthwhile, coupled with a belief in diligence and one's own efficacy." The authors agree that mathematics programs must be designed so that students develop a "productive disposition" toward mathematics and that this will encourage individuals to continue to grow mathematically long after formal study has concluded (for a further discussion of classroom culture, see Hiebert et al., 1997; Hillocks, 1999).

Teachers require a strong background in mathematics. However, teachers also must know how students learn and they must acquire the pedagogical content knowledge necessary to anticipate the needs and difficulties students

may have. In order for standards-based instruction to be realized, professional development must be designed so as to "transform" teachers' ideas about teaching. Smith (2001) writes that teachers "must thoroughly overhaul their thinking about what it means to know and understand mathematics, the kinds of tasks in which their students should be engaged, and, finally, their own role in the classroom" (p. 4). Research suggests that changing teachers' beliefs and practices must be done "in tandem" through well-designed professional development.

Teachers need to have high expectations that students are capable of learning with understanding, that all students need to be challenged, and that their students can make important contributions in class. Teachers need to design instructional activities in which students are engaged in complex tasks, spend time constructing knowledge, and work independently or in groups (Hillocks, 1999). During a lesson, the situations to be resolved and problems to be solved should be more challenging than the student might be comfortable with—but not so difficult as to discourage his or her making an effort.

Orchestrate mathematical discourse so that it is meaningful and productive. Include in your lesson preparation questions you wish to ask during the lesson. After posing a question or presenting a situation to be resolved, give students the opportunity to think on their own and in creative ways. Ask open-ended questions that encourage students to explore. Keep in mind that the most valuable resource that gifted students have is access to each other's talents and abilities; so, have them interact with each other frequently, whether in small groups or during the class as a whole or when working independently on projects.

Avoid "more of the same" and repetitious review. On occasion, take students off the beaten path. How many students have used the parity or pigeonhole principles to solve a problem, utilized a matrix to find the probability of a compound event, or constructed perpendicular bisectors of line segments to produce a Voronoi diagram?

Students may be intrigued by problems that lead to unexpected and/or counterintuitive outcomes. Reflect on the following situation that is well known in problem solving circles:

> Alpha, Betty, and Charles competed in the 100 yard dash. Alpha finished the race 10 yards ahead of Betty; Betty finished 10 yards ahead of Charles. How far ahead of Charles was Alpha when Alpha crossed the finish line? Assume that the three ran at uniform speed.

One solution involves proportional reasoning and will likely appeal to students who appreciate elegant thinking processes without a lot of computation. Hint: the answer is not 20.

Consider the case of students who studied the mathematics of apportioning members of the United States

House of Representative. While on this path less travelled, one student, Tom, wrote, "I never thought that the literature I've read about the 'American Identity' would have such a strong correlation to a math subject." Deciding on a method of apportionment involves more than examining the mathematics but relates to "what America values." Analyzing a method of apportionment for adherence to rules and for the possible existence of paradoxes in the context of fairness says that "we value a just process." The students found the topic "intriguing" because of "how alive it is, a topic as important now as it was in revolutionary times." Jenna wrote, "I love history . . . and I think it is very interesting that our Founding Fathers' debate can be related to the mathematics of apportionment." Sam wrote that the topic "gave me a new lens from which to view history." The topic appealed especially to those who considered themselves to be "humanities types" and provided an opportunity for both mathematical and literary expression.

How do we fit this topic in an existing curriculum short of starting a new course? Steal time! How? Go back to the previous paragraph that begins with "avoid more of the same and unnecessary repetition and review." And continue to look for new pathways for introducing your students to the mathematics they need to know.

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Mathematics Teaching and Learning: A Reflection on Teacher Training in Rural Uganda

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Building an elementary school, developing mathematics curriculum, and training teachers in Rural Uganda is a task filled with many challenges due to the lack of resources and high levels of poverty in the area. Embedded in these challenges are opportunities for creativity and leadership as teachers begin to shift from an education framework based on rote memorization and learner passivity to one that includes collaboration, active learning, and teaching for understanding.

Keywords: Uganda, mathematics teacher training, professional development, African elementary school

When asked the question, "What do you need?" an unemployed teacher and resident of Masese, Uganda replied, "Some paper, pencils, and $30 per month."

HELP International, a medical relief non-profit organization, opened the first free school in Masese in May 2009 with one teacher and 40 students in an open shed. The multigenerational cycle of illiteracy started to break on that day. Today, the HELP Primary School educates 400 children pre-kindergarten through fifth grade with nine teachers in a newly constructed school building.

HELP Primary School, located in a small village outside of Jinja, was created to offer free education to those students who could not afford the fees typically required to attend school in Uganda. Masese has many generations of uneducated people due to extreme poverty. Dr. Peter Garrity, Adjunct Professor of Mathematics Education at Teachers College, and Nicole Fletcher, PhD student at Teachers College, have joined forces with HELP International to assist in the development of the HELP Primary School. Here is their story.

In 2010, medical volunteers from HELP International expressed their desire to start a school and their need for educational expertise in doing so. That same year, I[1]

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[1] First person singular references here refer to the first author.