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Subcommittee on Research and Science Education
Hearing on "A Systems Approach to Improving K-12 STEM Education"

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Chairman Lipinski, Ranking Member Ehlers, and distinguished members of the Subcommittee on Research and Science Education, I offer my sincere gratitude for the opportunity to testify about the efforts of my colleagues and I at the University of Illinois at Chicago in our work with the Chicago Public Schools. UIC and other institutions of higher education in the Chicago area are proud to part of a STEM education system that extends from preschool to graduate school.[1]

I would like to take a few moments, if I may, to describe the very special situation of the University of Illinois at Chicago. The University is part of the land grant institution for the State of Illinois but, in contrast to many other land grant institutions, we are located very much in the center of the city and at the intersection of many transportation routes. This is by design, for we are a campus that, from our start, has focused on integrating its research, scholarship, service, and patient care on the needs of the city, combining a research university's ability to create fundamental new knowledge with the exciting opportunity to link that knowledge to the needs of the city where possible. In addition, our diverse undergraduate student population reflects the demographics of northeastern Illinois; almost one third of our students are underrepresented minorities and no single group is in the majority. We are also academically diverse, with strong programs in STEM and the health sciences, associated with our large medical sciences campus.

Of course, today the focus will be on our work in association with K-12 teaching. In this case, much has occurred in the last twenty years that, as I will discuss, exemplifies how universities can benefit from close partnerships with public school districts, often supported by federal and private funding. I should also point out that, while I will focus on UIC, it is fortunate that in Chicago there are several other institutions of higher education that are involved with systemic change in the district. In many cases they are working collaboratively with each other and I will be citing their work, also.

I have been asked to comment in three areas, which I take in sequence. But before I do so, I would like to present a logic model for this work that provides a structure for our work and my further remarks.

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1. I have prepared this testimony and am responsible for its content, but I do wish to acknowledge that many individuals contributed material for this testimony. They are cited in different places. In addition, three individuals who helped me with additional review and comment are John Baldwin, Steve Tozer, and Carole Mitchener of UIC, Stacy Wenzel of the Center for Science and Mathematics education at Loyola University Chicago, and Dean Grosshandler of the Northwestern University Office of Science, Technology, Engineering, and Math Education Partnerships.

Our model of a STEM education system sees K-12 school systems and universities as part of a cycle that includes students educated in K-12 who move on for more specific training in higher education. The colleges and universities have the opportunity to educate these students further, in specific disciplines, so those students are able to participate in STEM and health science careers. In addition, colleges and universities affect K-12 education by producing teachers, who need deep disciplinary knowledge and the skills to be able to work well with the diverse learners in K-12 settings. Further, colleges and universities work with existing teachers, both to provide deeper training in current topics in STEM and in STEM education and to receive from those teachers a better understanding of the actual issues that matter in K-12 STEM classrooms. The systematic study of these endeavors produces educational research. Finally, districts and universities together engage in work to bring this research into practice. This logic model is affected by others who participate in the STEM enterprise, including of course public and private employers, who both employ STEM graduates and, in some cases, actively work with K-12 schools and institutions of higher education in preparing better students. Also, the model is focused on the university as a partner. Clearly, the vitality of Chicago's informal science programs, through After School Matters, the museum community, and the media are all essential parts of STEM education, though poorly represented in this model itself.

This picture is all well and good on paper, but in practice it requires three other elements that don't always fit on a traditional organizational chart: strong, enduring, relationships among the individuals and the institutions involved; leadership dedicated to this interaction within and among institutions; and research-based knowledge of effective ways to carry out instruction and to support change. Relationships, leadership, and research are not just one-time events but they depend on excellent communication over time. Conversely, things that hamper relationships, undermine effective leadership, and stymie the translation of research into practice are all dangers to effective STEM education systems work. Also, a central part of the translation of the model into effective practice is to note the context of our work, and of the work done in our district. UIC and its partners enthusiastically embrace the idea that urban education is an opportunity for truly exciting work. The work is also very challenging as we strive to bring educational excellence to all students. Hence, understanding well how urban schools work is present into all of our efforts, for example in our Noyce, GK-12, and MSP programs.

In the figures on the next page, I show two examples of how aspects of this logic model have informed our work in Chicago. The first shows the graphical description my colleagues and I used in organizing our most recent NSF GK-12 project. For this, we identified specific learning communities that would be essential to the success of the project, and who would be affected by the project. In the second figure I present the logic and research model that we are using in our current NSF Math and Science Partnership project. In this case, there is a flow of events, capturing more clearly both the cyclical nature of our plans and the outcomes we have identified for our research and evaluation program. In both cases, the interconnections—the way things happen—depend on people working together, informed by research.

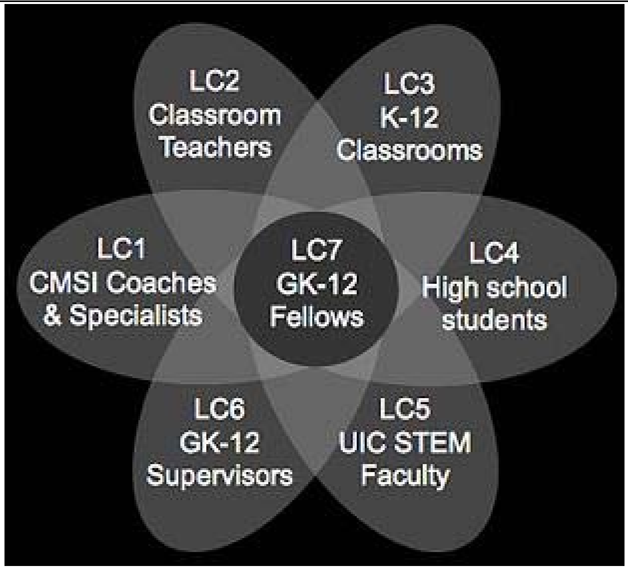

Figure 1: Relationship of learning communities with the NSF GK-12 project, "Scientists, Kids, and Teachers," (NSF DGE-0338328). CMSI refers to the CPS's *Chicago Math + Science Initiative*

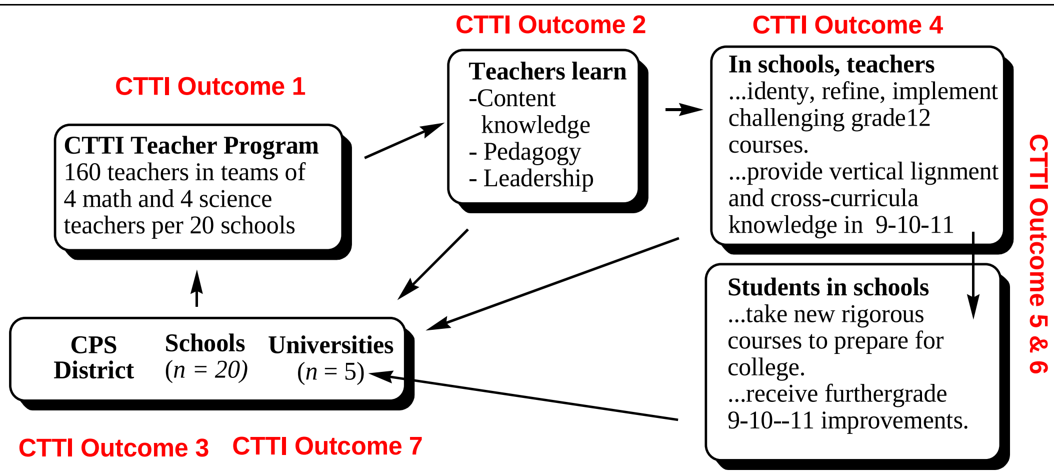

Figure 2: Logic model and outcome mapping for NSF MSP project, "The Chicago Transformation Teacher Institutes," (NSF DUE-0928669)

1. Brief description of the University of Illinois at Chicago's (UIC) K-12 science, technology, engineering and mathematics (STEM) education programs and initiatives.

In the table below I list nine different ways UIC's STEM education programs and initiatives for the last twenty years have impacted K-12 STEM. I will illustrate many with one or two specific examples. Note that this also means that I am leaving out many other equally interesting examples, so this is not a comprehensive description of all activity, just of all types of activity. Also, the particular ways in which our support from the NSF Noyce, GK-12, and MSP programs impact STEM K-12 education are deferred until the next question for my testimony.

Table 1: Areas of activity for UIC and partner programs in K-12 STEM education

Area	Activities
(a) Teacher education	For individuals who have already entered the K-12 teaching workforce. This includes formal coursework, workshops, professional development, and teacher participation
(b) Teacher preparation	For individuals prior to entry into K-12 teacher workforce. Includes formal degree and alternative certification programs.
(c) Classrooms	Work within K-12 STEM classrooms including specific instructional work by K-12 teachers.
(d) Learning	Research and development work on STEM learning, including out-of-classroom instructional work, applied to K-12 learners.
(e) School leadership	Development of leadership systems for schools, including school and district administrators, coaching, and leadership within specific K-12 STEM content areas.
(f) K-12 systems	Research and development work on system-wide issues, including district policies, analysis of outcomes, and standards for instruction and assessment.
(g) Instructional materials development	Creating and implementing formal materials for use in K-12 schools, including textbooks and technology environments.
(h) Linking STEM research to K-12	Programs to bring current STEM laboratory research work into contact with K-12 settings, directly or indirectly.
(i) Higher education policy and practices	Activities to change the ways in which UIC works with K-12 programs, at the level of the district, the school, and (especially) the students who enroll in STEM programs in college.

(a) Teacher education

Current teachers are the most important part of the K-12 STEM enterprise for the simple reason that they provide the vast majority of the instruction to the students. As with any professional practice, however, the education of a teacher should never cease. Teacher learning occurs in many different forms, including the ways in which a teacher learns about her own students and her own teaching and shifts practice accordingly. For the University, teacher education activity primarily consists of outreach through courses and workshops.

One particular example of such teacher education work is *The Algebra Initiative*. This is a partnership of CPS, DePaul University, the University of Chicago, and UIC with leadership provided by, among others, John Baldwin at UIC, Lynn Narasimhan at DePaul, and Paul Sally at Chicago. Each University offers a one-year course of study for participating teachers. The funding for the program has come from the district through tuition support and from the Chicago Community Trust. Teachers who will teach algebra in an elementary or middle school are required to complete this program by the CPS if their school is to meet the district requirements for offering Algebra I in eighth grade, a key requirement for rigorous work in high school and, ultimately, college. As described by the CPS, “Topics included in the course sequence are the structure of algebra, linear equations and inequalities, graphing linear equations, algebraic identities, arithmetic sequences, introduction to quadratics, and using algebra to model problems.” In this case, then, the faculty at the university provide direct content training to teachers, making use of the concept that a deep understanding of content that is specific to a course, in this case algebra, is essential for effective teaching (Monk 1994; Hill et al 2005). Thus, *the Algebra Initiative* has university faculty providing their content expertise in the context of a much wider, district-supported effort, backed up by mandates for teacher certification from the Chicago Board of Education, which requires that teachers pass an exam written by the university partners to teach algebra in 8th grade. This program has increased the number of formally qualified 8th grade algebra teachers in Chicago from 43 in 2004 to over 300. Through this work, over half the elementary schools in the system now can have qualified algebra instruction.

(b) Teacher preparation

Although the education of a teacher is an ongoing process it begins with preparation and initial certification. Specific and creative work to reform how this is done makes use of support from the NSF Noyce Teacher Scholars program, described in much more detail later on. Here, I want to bring in a different aspect of teacher preparation: the “normal” path pursued by students who enroll in a traditional preparation programs as undergraduates. It is of course vital that STEM teachers understand content deeply, and we are proud of the disciplinary rigor associated with the degree programs in science and mathematics teaching. But, especially for undergraduates, it is important that students in teacher preparation tracks are taught content at least in part with an eye to their future careers as teachers. This is part of the reason why UIC, in partnership with several area community colleges, received NSF support for the *Chicago Collaborative for Excellence in Teacher Preparation* (NSF DUE 9852167). That project built upon and expanded relationships between the UIC College of Education and STEM departments teaching content courses. That project resulted in several new courses for UIC, including planning for what became a set of three content courses and one capstone course in the natural sciences, which received further support through an NSF CCLI grant (NSF DUE 0311624). The implementation of the three content courses at UIC and its partner institutions (Varelas et al 2008) has been accompanied by research and dissemination work that demonstrates the gains that occur for this population of students when instruction is provided in a context rich inquiry environment. In this case, we have research to back the claim that these courses do positively impact student attitudes towards science (Wink et al 2009) and the learning of content itself (Plotnick et al 2009). As of July, 2009 more than 240 students have participated in these courses at UIC with a retention rate towards a teaching degree over 50% and an overall retention rate of more than 80% that is well above the norm.

(c) Classrooms
Thus far, the programs I have described are located at the University. However, work in actual classrooms and schools is also essential. For example, Maria Varelas and Chris Pappas in the UIC College of Education have recently concluded the NSF-funded portion (NSF DRL-0411593) on "Integrated Science-Literacy in Urban Early Elementary Classrooms (ISLE). This was fundamentally a research project that also engaged teachers in the collaborative work to:

- Integrate children's literature and non-fiction books with hands-on explorations and various other representational tools, such as writing, drawing, and acting out, in order to strengthen their teaching and their students' learning of science;
- Develop interactive teaching practices helping students build on their own experiences and understandings and both learn and enjoy science;
- Conduct a teacher inquiry that will inform their practice;
- Develop more flexibility with scientific knowledge and ways to engage their students with it;
- Appreciate the funds of knowledge that young children from sociocultural, ethnolinguistic, and socio-economic groups that are usually underrepresented, underserved, and underestimated bring to the classroom.

The ISLE project is an important example of how UIC research can be interwoven with actual instructional work, advancing both learning and classroom practice in a way that directly informs the research community through conventional presentations and publications (for example, Pappas et al 2009; Varelas et al 2008; Tucker-Raymond et al 2007). The new modes of instruction also become the basis of materials for other teachers, and hence ISLE continues beyond the NSF phase in the form of continuing professional development.

(d) Learning
Another way in which UIC faculty connect research with K-12 instruction and learning is to take a learning sciences approach, and I am proud to be among the faculty who, led by Susan Goldman and James Pellegrino, have initiated the UIC Learning Sciences Research Institute (LSRI). Among its goals is to be a locus for studies that look at some of the fundamental issues in learning and bring them to bear on specific classroom questions. One of the ways this matters most is in questions of how to teach using emergent technological tools. Josh Radinsky, for example, studies the learning that can occur using the tools of Geographic Information Systems (GIS). In collaboration with other Learning Sciences researchers, he has designed and studied classroom environments that incorporate GIS as a tool in social studies classrooms, part of a larger project in how representations of data are, or are not, made meaningful to students (Radinsky et al 2005; 2008). This also was supported through NSF's educational research programs (NSF DRL 0337598) and has direct implications for science teaching (Radinsky 2008).

(e) School leadership
Teaching does not occur in a vacuum and there are too many examples of excellent opportunities that are not sustained because of issues within the school that are outside of the control of the teacher. Hence, for effective STEM education to develop and continue, school leadership must provide the environment and the resources needed by teachers. At UIC, Steve Tozer and his colleagues in the College of Education have for the past six years been implementing and documenting an innovative program in *Urban Education Leadership* that focuses on improving student learning through developing instructional leadership at the school level. The program

teaches aspiring and practicing principals to work productively with leadership teams in the schools. Specific coursework and coaching occurs in the area of science and mathematics: while it is not possible for all school administrators to be trained in how to teach these areas, it is a core goal of the UEL program to ensure that they are all well versed in how different disciplines require different approaches to teaching, such as the use of inquiry curricula. The program also emphasizes leadership by teams (Mayrowetz, 2008), and for high schools, this places department chairs in particularly central roles in building new school cultures for student academic success. In the departmentalized high school, students benefit from program coherence throughout the department, which requires department-level systems, structures, and leadership to achieve them. The program has received recognition in part because it measures the success of its graduates by their impact on student learning outcomes in schools, and its principals now lead 10% of Chicago's 130 high schools. It has therefore generated over a million dollars annually from such sources as the CPS, Eli Broad Foundation, McCormick Foundation, the Chicago Community Trust, Fry Foundation, McDougal Family Foundation, and the W. Clement Stone Foundation.

(f) K-12 systems

The logic model I presented at the outset and the areas of activity for UIC work with K-12 STEM education derive, in part, from the work of many researchers. In Chicago, the tradition of studying the K-12 system (and beyond) is a rich one, especially in the last fifteen years. This is perhaps best known in the work of the Consortium on Chicago School Research, based at the University of Chicago (Roderick et al 2009). The CCSR has had many projects that overlap with UIC work, and much of the work in STEM has included the contributions of Stacy Wenzel, now associate research professor at the Loyola Center for Science and Math Education.
Several groups are responsible for the extensive data collection that underpins this work, most importantly CPS itself through its office of Research, Evaluation, and Accountability. Some of this was spurred by NSF through the Chicago Urban Systemic Program grant, which I discuss in more detail later on. Wenzel is now PI on *Scale Up of Math and Science K-12 Education Reform in a Large Urban District*, an exploratory capacity-building grant from the NSF (DRL 0733550). The project studies the systemic reform of math and science education in the Chicago Public Schools from 2002 to 2008. (Deiger et al 2009; Wenzel et al 2009).

The task of finding out how students perform on K-12 assessments begs the question: what will be assessed? In the era of NCLB and in the face of 50 different sets of state standards, this is a daunting question, especially at the national level. Recent moves to align or even share standards among the states will help there, but so too it is vital that K-12 STEM systems understand how assessment should drive, not just follow, instruction. This is very much the them of the work of my colleague Jim Pellegrino in learning sciences. He has served as head of several National Research Council study committees, including the committee that issued the NSF-funded report *Knowing What Students Know: The Science and Design of Educational Assessment* (2001). He served on the NSF-funded NRC Committee on *Test Design for K-12 Science Achievement*. Dr. Pellegrino was currently a Co-PI on an NSF ROLE project *Making the Invisible Visible: Children and Teachers Learning about Physical States and State Changes* (DRL 0529648). He is also PI on a recent project with the College Board (DRL 0525575) *From Research to Practice: Redesigning AP Science Courses to Advance Science Literacy and Support Learning with Understanding.* From these will come both general concepts about assessment and also specific recommendations on how assessment should be used in K-12 STEM education. One way this occurs in partnership with CPS is through a grant (NSF DRL- 0732090) on the assessments embedded in math curricula and their role in supporting the teaching and learning process. This work specifically works with CPS-adopted curricula (themselves NSF-developed) that are already being implemented in schools.

(g) Instructional materials development

One of the least considered partners in K-12 teaching, and indeed in all teaching, are those who develop and sustain materials for the classroom. These materials include textbooks and technology. As I have discussed, this is sometimes the outcome of research and teacher education programs. But there are other projects that have materials development as their major thrust. At UIC, this has occurred in the context of the *Teaching Integrated Math and Science* program, initiated in the 1980's with NSF support. The project was founded by two UIC faculty members, physicist Howard Goldberg (retired) and mathematician Philip Wagreich. It has received more than $20 million in external funding since 1990 from the National Science Foundation (NSF), the State of Illinois Scientific Literacy Project, and Eisenhower funds, as well as direct support from school districts for professional development activities. Commercialization has occurred through three different products: *Math Trailblazers*, now its 3rd edition, *TIMS Laboratory Experiments*, which are used in both math and science instruction, and teacher education materials, the *Teacher Enhancement Resource Modules.* The project is very much alive, providing the basis for both professional development of current teachers, reform-based materials for use in teacher preparation, and a basis of research work on mathematics learning (Brown et al 2009; Castro-Superfine et al 2009). In its most recent NSF-supported revision, the project conducted 3 years of research in *Math Trailblazers* classrooms. Based on the results of the research the curriculum was revised and field tested for an additional 3 years, using overall more than 200 teachers in 40 schools in 16 districts in 8 states in either the research or field test. Thus, university-based materials development, fully connected to professional development and the tools of university research, provide an important venue to study and support multiple components of K-12 STEM education. More than 70 schools in CPS alone are using the curriculum, representing close to 20% of the district's K-8 programs.

(h) Linking STEM research to K-12

The previous seven areas of activity are all ones that, in principle and in practice, can be done separately from a university like UIC. Indeed, important partners in K-12 STEM education reform are private and government research agencies; alternative certification programs; and publishers and independent curriculum developers. But, besides granting degrees, UIC also has the potential to add much to K-12 STEM teaching because it is a research university with extensive work in all STEM and health research fields. As I discuss later, there are too few examples of this kind of work to translate current research into K-12 settings. There is good support for bringing teacher and teacher candidates into teaching, including through Research Experience for Teachers programs such as the UIC-based Chicago Science Teacher Research Program (NSF-EEC 0502272 and 0743068), led by Andreas Linninger, a chemical engineering professor. In those cases, the transfer of STEM research to K-12 depends on the future work of the teacher. Direct curriculum impact is a different story. One very effective example is the collaboration between Vera Pless, a distinguished mathematics professor, and Janet Beissinger of the LSRI. With NSF Instructional Materials Development support (DRL 0099220) they developed a now commercialized textbook to teach middle school students cryptography, *The Cryptoclub*. This drew upon Pless and Beissinger's own expertise in the area of codes to bring important concepts in mathematics, including number theory, to a classroom experience that fully engages students. More recently, they have opened up this community to others through a follow-on project to make the *Crypto*club and its mathematics available for informal learning after school and online (DRL 0840313). The Cryptoclub example points to the ways in which university faculty can identify the fundamental content, in this case mathematics, that underlies their work, then link it to an important application that, properly managed, brings dramatic current research areas into the experience of students.

Another possible way to link research and high school science, at least, may arise as an outcome of the recent work of NSF Chemistry Division through its *Undergraduate Research Collaborative* program. The five URC's seek to develop methods to bring science research into the early years of the undergraduate STEM curriculum. One, led by Gabriela Weaver of Purdue and with myself as a co-PI, is the Center for Authentic Science Practice in Education (CASPiE; NSF-CHE 0418902). CASPiE is based on modules written by science and engineering faculty to permit students to learn the skills needed to carry out actual research in an area, such as antioxidants or biosensors, and then to engage in the research itself (Weaver et al 2006; 2008). Recently, with support of an RET supplement to Nina Hike Teague of CPS's Curie High School, we have shown that CASPiE modules can also be used in high school settings, with in the informal setting of science fair projects for CPS schools.

Finally, the informal science community has a particular role to play here. As I mentioned, my discussion draws mostly from university examples. But universities have much to learn about the translation of research into forms accessible to the public from the informal science community. That is why I was particularly enthusiastic last year when Dr. Linda Marton of Foreman High School invited us to assist in their After School Matters program, which is supported specifically by Abbott. This linkage continues into next year and from this work we expect to have a clearer picture of how a university STEM partner, UIC, can use the ASM context as a means for bringing research into the broader context within K-12 settings.

(i) Higher education policy and practices

The final area of activity where UIC should be active as a member of the K-12 STEM system is with its own courses, curricula, and programs. Earlier I mentioned that, at least in mathematics and in natural sciences, the courses taken by pre-elementary education majors have become an environment where content is taught using reformed pedagogy. The institutionalization of some aspects of this by the University is a direct result of the linkage that we have established between our teacher preparation programs and our future students. After all, every student who graduates from high school was taught for 13 or more years by university-trained teachers, and at UIC NSF Course Curriculum and Laboratory Improvement program has impacted some of these future teachers.

While reforms have begun to occur in some teacher preparation programs, a gap remains for the general student population that finishes CPS intent on a STEM career. Data from the CCSR (Roderick 2006) shows that fewer than 30% of graduating seniors in 1998, 1999, 2002 and 2003 enrolled in a four college within a year of graduation, and only 35% of those from the 1998 and

1999 cohorts had graduated within six years, meaning that a stunning 90% of graduating seniors did not complete a four year degree in that time span.

These numbers have spurred many changes within CPS, including focused attempts to increase retention to graduation, to address specific problems that prevent college-bound students from matriculating (such as simply completing the FAFSA, which is hardly a simple process), and economic challenges. UIC, for its part, has begun to look at its own retention of students, which now hovers at about 50% of all entering first year students. Part of this comes from learning more about the students themselves, an a recent NSF “Science Technology, Engineering, and Mathematics Talent Expansion Program (STEP)” grant has begun to affect STEM students in general and STEM teaching in particular. Much more needs to be done on the campus, and a Provost-level working group has been established to be more systematic in examining the critical supports needed for wider success in STEM majors.

2 (a) What are the major problems that limit the performance of students and teachers in STEM?

If we consider the logic model presented earlier, there are several things that can occur that limit the performance of teachers and students in STEM. These occur in the context of the systems itself, within schools, within classrooms, and with students themselves. The simplest answer to this question is “quality of instruction.” But it is all too easy to hear that and think that this can be fixed by providing better teachers, or better textbooks, or better buildings. Instead, we need to consider how schools actually work and to recognize that systematic issues must be addressed so that quality instruction can be used by teachers.

Systematic barriers to reform are those that prevent the identification, adoption, and sustenance of effectiveness in STEM teaching. Some of these occur at the level of the K-12 administrative units such as state boards or district management teams. Inconsistency, including a sense that particular changes are only temporary, also contribute to a reluctance on the part of teachers and students to engage fully in changes. Also, the systems present in higher education to teach STEM students and to prepare future teachers may be antiquated, based more on a tradition of reproducing the professoriate than in working with diverse learners. Faculty who take pride in staying abreast of the latest research in their field will instead fall back on personal empiricism when thinking about their own teaching, dismissing the relevance of educational research to their own practice.

Within schools, a culture of rigor, relevance, and openness to learning are all needed for effective STEM teaching. However, there are many cases where the culture of the school may not value rigor for all subjects and for all students. Similarly, engaging curricula are often neglected, despite strong evidence that students will work much harder and remain in school if they know why content is valuable for people’s lives, including those of themselves and their community. Safety for students and for learning is needed, and when safety is compromised, learning is sure to suffer. Finally, schools need to have the equipment, including appropriate technology, needed for current curricula.

It is important that we be honest that teachers are sometimes a challenge for effective learning. Often this is because of gaps in their training, not their own goals. For example, lack of content knowledge, lack of pedagogical content knowledge, and a lack of experience with contemporary STEM research trends can all lead to instruction that is ineffective and stagnant. Many of the reasons for these challenges come from both a shortage of time with students to focus on math and science content and a shortage of time for professional learning and preparation for their math and science instruction. For example, researchers found that it was not uncommon for CPS teachers and administrators to struggle and fail to set up school schedules with required amounts of protected instructional time for middle grade math and science lessons. Many of these same teachers also were not able to debrief with a content expert in math or science coach who visited their classrooms—there was not time in their schedule to fit in a 15 minute reflective conversation with the coach following the observed or co-taught lesson. On the other hand, teachers that are given the time and support for ongoing professional development, reflective practice involving strong school-based teams, and deep engagement with trends in current STEM research can begin to overcome these challenges quickly.

Finally, we need to understand better ways to motivate students. Because of the emphasis on the economic necessity of increasing the number of students in the STEM pipeline, students often are not given the opportunity and encouragement to experience the wonder and joy of doing STEM. These opportunities are necessary for continued and deeper engagement that lead to a growth mindset (Dweck) . Similarly, students may be led to believe that discoveries/payoffs come easily and they are not helped to see the relationship between hard work and satisfaction. Another UIC project, led by Marty Gartzman, is developing materials for double period algebra that melds solid mathematics with careful attention to student motivation. An interesting perspective on this was recently provided by a student-led project, Voices of Youth in Chicago Education (http://www.voyceproject.org/. Using surveys, ethnography, and review of statistics, students from several high schools and community organizations examined multiple dimensions of teaching and the challenges of retaining and supporting students. Four areas of focus: rigor, relevance, effective teaching, and safety and security, were highlighted. When these are compromised, the VOYCE findings suggests student outcomes suffer .

2 (b) What are the most important and effective components of the National Science Foundation (NSF) funded programs (including the Math and Science Partnership Program, the Robert Noyce Teacher Scholarship Program, and the Graduate STEM Fellows in K-12 Education Program) that UIC has implemented in partnership with Chicago Public Schools?

This question will be addressed in four parts. First, I will recount some of the outcomes of the NSF-funded *Chicago Urban Systemic Program* (NSF DRL-0085115), a systemic change grant that has spawned many different efforts in the district and with its partners. Then, I will discuss the work that occurred in our GK-12 programs that impacted how we understand partnerships through the agency of STEM graduate fellows. Finally, I will present the plans that we have for a new Noyce Teacher Scholarship program, building upon a previous effort, and the ways in which our *Chicago Transformation Teacher Institutes* draw from and expand upon the different activities we have established in the past.

The Chicago Urban Systemic Program (NSF DRL-0085115)
The CUSP design supported a comprehensive math and science district reform effort focused on teacher professional development on content knowledge and around the use of specific math and science standards-based curricula. To strengthen content knowledge, elementary school teachers enrolled in university programs that gave them the subject matter content to apply for and receive State of Illinois endorsements to teach math and science in middle grades classrooms. Evaluation of this project resulted in extensive formative and summative research reports and several national conference presentations. See http://research.cps.k12.il.us/cps/accountweb/Evaluation for a partial list of and access to these reports. The CUSP final report to NSF (Feranchak, 2006), documents the following outcomes of the program:

- Developed district mathematics and science infrastructure capacity. The CPS plan for mathematics and science improvement—the Chicago Math and Science Initiative (CMSI)—was formulated through CUSP. CMSI has continued in the district after the cessation of CUSP funding. During the project period, CPS significantly increased its support for mathematics and science improvement from $5.2 million ($2.2 million from NSF) in 2002 to $15 million in 2006 ($2.8 million from NSF). Since the cessation of CUSP the district has continued its support, including a substantial part of the HSTP (see below).
- Improved professional development offerings and greater numbers of teachers served. By the end of the grant period, over 6,000 teachers per year were receiving direct professional development in mathematics and science. This represents a 106% increase in teachers served annually over the initial year. During the 2005-06 school year 2,560 elementary teachers from 268 different schools attended 37,000 person-hours of CUSP mathematics professional development. In the following year (after CUSP ended), 2,237 elementary teachers from 290 different schools attended a total of 24,677 person-hours of grade-specific, curriculum-specific mathematics professional development. In several hundred cases, this allowed teachers to receive certification for middle school math or science, significantly decreasing the number of uncertified teachers in those classrooms. And recent data show that the vast majority of individuals who have obtained a math endorsement (>90%) have done so through this program, as is also the case for the the majority of those who got endorsements in science.
- Improved student achievement. The 6-year change from the beginning of CUSP in 2000 find higher gains in the percentages of CPS elementary students, compared to percentages of Illinois students statewide, who met or exceeded state standards on Illinois state tests (ISAT) in mathematics and science. More importantly, student achievement gains in schools implementing one of the district-supported standards-based curricula for the second year in 2004-05 were greater than in other district schools (both those in their first year of implementation and those not implementing at all).

UIC Graduate Fellows in K-12 Education (DUE-9997537) and Scientists, Kids, and Teachers (SKIT): A GK-12 Partnership with the Chicago Public Schools (DGE-0338328).
These two successive GK-12 fellows programs represent a very important place wherein UIC STEM faculty were able to forge important relationships with the CPS through the specific activities of STEM graduate students working in middle and high school mathematics and science. The initial grant enabled us to take existing outreach programs and to add graduate fellow support to some of the schools that were involved. This included, for example, a partnership between UIC and Crane High School, part of the CPS Math Science Technology

Academy (MSTA) program that paired specific high schools with different support systems within UIC. In this program graduate fellows brought their content knowledge to questions of teaching high school chemistry, environmental science, and physics, assisting teachers in new ways to engage students (Wink et al 2004) that drew on the graduate student's expertise in studying ecosystem engineering. At the same time, a research program for the program allowed us to characterize systematically some of the ways in which STEM graduate students encounter the environment of the urban classroom (Christodoulou et al 2009).

The second GK-12 project took a very different approach to the placement of graduate students. Here, the different placements were specifically targeted at schools that were participating in aspects of the Chicago Math + Science Initiative, which was at that point emerging from the work on CUSP and related programs. CMSI targets school-based change in different ways. For example, fellows worked in bringing the Beissinger / Pless cryptography program to the National Teachers Academy (NTA), a district professional development school. In other cases, support of specific high school science curricula identified for district support within CMSI was aided by Fellows in schools and STEM faculty participation in professional development sessions. Thematically, then, the program focused on helping the district and its schools make change in projects that the district was already implementing, making SKIT into more of a responsive, not an intrusive, influence on schools.

One of the best examples of a partnership that was furthered through the SKIT program was in the work of computer scientist Tom Moher and his graduate students. Moher is a learning sciences researcher with a focus on the development "embedded phenomena" in teaching. Within this approach, the classroom becomes the locus of a technology-enabled science experience, including studies of earthquakes, the solar system, and most recently an environment, *WallCology,* that simulates the process of learning about animal populations. In the SKIT program, his graduate students were able to carry out an iterative process of implementation and research in conjunction with two CMSI-associated schools, NTA and Dawes Elementary School. Besides general information on the ways in which embedded phenomenon can be implemented well (Malcolm et al 2008), they also developed materials to support the specific learning outcomes of *WallCology* (Moher et al 2008).

The second GK-12 project, by design, included a plan for sustainability associated with funding support from CPS or other external partners. Early in the program, funding for Fellows to work at NTA was obtained as part of the district support for UIC's partnership in that school. In this case, the specific benefit of Fellows for teachers implementing reformed CMSI-designated curricula was demonstrated. This became important shortly afterwards when the CPS brought forth its plans for the High School Transformation project. In their response to that project, Loyola University and UIC included a plan, funded by the district, for graduate assistant support of the reformed curricula in the first three years of high school science at eleven CPS schools. Thus, a key outcome of the SKIT grant has been the establishment of an ongoing, independent support and rationale for graduate students within university / district partnerships.

Robert Noyce Scholarship Program (DUE-335748) and UIC-CPS Noyce II Program (DUE-833089.

These two implementations of Noyce Scholarship programs are led by Carole Mitchener of UIC's College of Education. The first program targeted career changers who planned on teaching in middle school mathematics or science (MGS / MGM students) or high school mathematics. MGS/MGM offered career-changers a three-year induction and mentoring experience while they earned teacher certification and a masters degree. During that time, they taught fulltime for three years in a high-need school in Chicago. MGS/MGM adopted the idea that it was crucial that very early in their preparation, teachers experience the relevance of the practice-based approach to professional development discussed earlier, and to appreciate it as one that they could continue, and build from, throughout their teaching careers. MGS/MGM sought to achieve this largely by devoting much of the second year of the curriculum to supporting each beginning teacher in an extended action research inquiry into his/her own practice in his/her own classroom. Ninety-one individuals received stipends and all completed their degree and all but one completed the required teaching. What is perhaps more important is that, as of 2008, 73 of them had completed either three or four years of teaching, suggesting that the program is successful at both preparing and inducting teachers. This success reflects the lessons learned through the accompanying research effort that examined how teacher identity is built around "a vision for a quality and inclusive science curriculum implicating science content, teaching methods, and relationships with their students" (Proweller and Mitchener 2004). Another important outcome of the program with implications for future work is that eight of the original program's scholars have now moved into CPS math and science leadership positions. This significantly strengthens the relationship between UIC and CPS.

The Phase II Noyce project continues work begun in the previous Noyce grant with secondary mathematics teacher candidates and expands its potential impact with the addition of an enhanced mentor program for new Noyce recipients. This new mentor program involves previous Noyce awardees and inducts new ones into a Noyce mentoring network. Second, the project extends the Noyce applicant pool by adding three new science certifications and introducing a one-year M.Ed. program option for secondary science, which is available for secondary science teacher candidates in biology, earth and space science, environmental science, chemistry and physics. The project supports the recruitment and retention of career-changers with strong STEM backgrounds and STEM undergraduates who want to teach in high-need areas in CPS. These goals will be attained by awarding stipends based on academic merit, with attention to diversifying the teacher workforce and a commitment to serving high-need schools. Over a three-year period the UIC-CPS Noyce II project is offering 40 recruitment stipends to students in UIC STEM secondary teacher preparation programs who commit to teaching in Chicago Public Schools. New teachers have the opportunity to conduct action research during their induction phase as they work to construct a defensible and inclusive practice.

Both Noyce programs provide new teachers learning opportunities to engage in extended action research projects (teacher inquiry) toward improving their classroom practice (Mitchener & Jackson, 2006). New teachers benefit when given an opportunity to examine their practice in relation to student learning over an extended time period. New teachers target an area for improvement and with support from a professional learning community make needed changes. Using student learning data as a guide, beginning teachers work at reducing discrepancies between what they learned about good practice and what they implement in their classrooms. Action research projects are then shared with the larger school community.

The Chicago Transformation Teacher Institutes (NSF DUE 0928669)
The Chicago Transformation Teacher Institutes (CTTI) is our new Math Science Partnership teacher institute program, funded earlier this month with support of funds allocated to NSF through the American Recovery and Reinvestment Act. In this case, the CTTI is an additional and essential part of existing system-wide reform efforts, not a new effort in itself. Thus, I will describe the context of the CTTI within the wider CPS High School Transformation project, since the two are intimately linked.

The CPS HSTP project was started in 2005-6 by the Chicago Board of Education with extensive support from the Board and the Bill and Melinda Gates Foundation with its largest ever single grant to a school district. One prominent strategy within the HSTP is a whole-school support program focused on the work of *Instructional Development Systems* (IDS). An IDS is a provider of comprehensive professional and materials development spanning grades 9-11 with a coherent program in mathematics, science, or English (*e.g.,* Wink et al 2008). Teachers and administrators in the IDS schools then receive:

- Rigorous curriculum options with innovative, nationally recognized and research-based materials.
- Supports for teachers using these curriculum options, including intensive coaching, professional development, networking, and in-school planning coordinated by a school lead in the subject.
- Direct leadership support for principals.
- Formative and summative assessment systems responsive to the specific curricula but also aligned carefully with the state-wide Prairie State Academic Examination (PSAE), a two-day exam in the 11th grade that comprises the ACT and subject-area tests including in science and mathematics.

The IDS program began with 14 schools implementing the ninth-grade curriculum in 2006-07; these schools are now implementing the tenth- and eleventh-grade curricula. Another 11 schools formed a second cohort that began in 2007-8 and a third cohort of 20 schools have joined in 2008-9. The science IDS's are all based at universities (IIT, Northwestern, Loyola / UIC) that are part of the CTTI. The CTTI mathematics participants (UIC and DePaul) are also involved in HSTP and other district high school teacher support programs.

All of the math and science IDS programs focus on a strategy to *implement,* not develop, reformed curricula. All six of the math and science IDS partners are using curricula developed in part with NSF support (*Cognitive Tutor, Agile Mind, CME* in math and curricula from BSCS, the American Chemical Society, It's About Time, and Northwestern University's environmental science curricula in science), or enhanced under the specific direction of inquiry-based teacher education programs (Glencoe biology and chemistry, in conjunction with IIT and the Field Museum). Thus, they respond to the district's own initiative to identify and support reform curricula.

The HSTP-IDS program has now established a full set of supports for grade 9-10-11 science and math. This includes a set of assessments to support teachers in formative assessment of students and also to be used in a summative manner at the end of the course. In all cases, the curricula and assessments are to point to increasing student success on the Illinois *Prairie State Achievement Exam,* given in April of the junior year. The first cohort of IDS-supported students have just taken the PSAE in Spring, 2009, and the outcomes for those students and for subsequent cohorts will be a key evaluation metric for the program overall.

From CUSP and HSTP to CTTI.
The significant impact of the CUSP program on the district, including its contribution to the formation of CMSI and the conceptualization of HSTP, means that the district and its university partners have much more experience in how to support school change. For example, a key component of the HSTP IDS is the adaptation and implementation of curricula identified by CPS. A similar approach will be used within CTTI.

It is important to note that CTTI is not a replacement for CUSP or HSTP. Rather, CTTI is an essential *new* initiative to carry through on the work of CUSP and HSTP by completing the district's strategy for high school science and mathematics (with 12^{th} grade strategies) and enhancing the work of teachers in grades 9-10-11. This new program, though, is based on leaders who are *on the staff of the schools themselves*, giving schools the capacity to carry out their own course implementation strategies and in-school planning to address challenges and to identify new opportunities.

During the program CTTI will have 160 teachers in four cohorts each of 20 science and 20 math teachers. They will come from 20 different schools, chosen through an application process with specific commitments required from the school. CTTI teachers will implement effective school-based changes in 12^{th} grade curricula even as they continue to participate in and impact the curricula in grades 9-10-11.
The CTTI teacher program will include two components in addition to networking programs:

a. **Coursework** in three areas essential to strong high school instruction: mathematics, physical science, and life and environmental science. The courses provide for increased content knowledge by teachers, including how the content is found in the contemporary issues and current research. It also supports growth of deep knowledge required for strong cross-curricula work.
b. **Workshops on leadership and teaching** that provide increased skills in how to use content to understand classroom practices, including in instructional design, selection of classroom materials, pedagogy, and assessment of student knowledge. Leadership workshops, developed from the Urban Education Leadership program, enhance the ability of teacher-leaders to support stronger teams within schools' departments and are developed with a program that already works on a parallel effort with CPS school principals, allowing for close alignment of the development of teachers, teacher-leaders, and administrators (Monk 2008).

This work is embedded in research and institutional change strategies that also drive the CTTI research. In particular, we have adopted a logic model (Newmann et al 2000) wherein **deep content knowledge + pedagogical skills + leadership training** for teachers changes **school capacity** to implement and support innovative math and science curricula. In turn, this affects **teacher practice** and improves **student outcomes.** Taken together, the teacher program and logic model let us formulate a key research question for our work: *What are the effects of providing teacher content and content-specific pedagogical training and leadership development on the elements of school capacity, teacher practice, and student outcomes?*

It is also expected that the CTTI will impact the ways in which higher education institutions work with the CPS and, especially, with the students who come from CPS high schools. University faculty, prior to teaching CTTI courses, will themselves receive training on reformed pedagogy, to align CTTI courses and their other college teaching with the practices we know to best support student learning of science and mathematics. The longer term impact on the Universities will occur as part of the discussion of what it means to have students emerging from high schools that, until now, have few graduates directly prepared for University study. The CTTI faculty will be charged as change agents that acquire enhanced understanding of the potential (and obstacles) inherent in rigorous high school courses. This understanding will then become the basis of advisory materials they will generate for campus recruitment and retention programs. Thus, these faculty become the means by which CTTI high schools re-envision outcomes for their students to include Chicago 4-year institutions and, conversely, become the means by which Chicago universities re-envision what they can do to provide more equitable access to CTTI high school students.

Finally, the CTTI program was conceived of as a research project from its start. Thus, the key research question of our work is articulated into multiple areas of inquiry. In association with the logic model presented earlier (Figure 2), these areas of inquiry will be:

1. **Teachers' experiences in program.** CTTI expects teachers to attend courses (Outcome 1), gain content knowledge and leadership skills (Outcome 2) and then apply what they learn through team work at their school (Outcome 4) that will improve instruction in grade 9-10-11 courses (Outcome 5) and will yield revised and/or new challenging grade 12 courses (Outcome 6).
2. **Student experience and performance.** Students taught by CTTI teachers are expected to achieve more at in grade 9-10-11 courses (Outcome 5) and enroll in and achieve in revised/new grade 12 courses (Outcome 6). Their preparation in CTTI taught courses should also support their college readiness shown through test scores and success in courses at CTTI universities (Outcome 7).
3. **Institutional change.** The CTTI university partners will share knowledge of math, science and leadership with schools through high quality courses (Outcome 1). The district and its schools will create the policies and practices to allow teachers to work together productively at school meetings (Outcome 3), to improve instruction (Outcome 5), and to change grade 12 courses (Outcome 6). The work of these teachers (Outcomes 4-6) in turn, changes and sustains their schools. Universities will learn from the CTTI project how to better serve entering CPS students (Outcome 7) and may attract some of the CTTI teachers into their regular graduate programs (Outcome 1).

2(c) Are there common lessons learned or replicable elements across UIC's various science and math programs, including those funded by NSF?

Experiences with STEM education reform in Chicago over the past decade suggest several lessons. Some of these have been summarized before (Roderick et al 2009; Wenzel et al 2009). But key points include:

- Invest in **people and relationships**. Even when people change roles and positions, the knowledge and skills that are supported by programs and trusting relationships travel with them.

- Work with **existing products**. A key idea behind most of the reform efforts is that the development of new materials can take years and several iterations. Earlier work in STEM K-12 education has, especially at the high school, provided many materials that are sufficient for reform of STEM education. New materials are needed, but much quicker change can be accomplished by implementing those quality products that do exist.
- Work with **existing research**. In almost every case I have discussed, the reform effort drew on extensive prior research. This is absolutely essential in a complex system, where prior research can identify those conditions that can dramatically affect the outcomes. This can range from specific questions of learning—how do students understand what is on a computer screen?—to system-wide questions—what does distributed leadership mean to change in a school?
- Don't leave out the **principal**. The principal is a key figure in setting up a school with adequate time for instruction and for teachers' professional development and reflection.
- Incorporate as appropriate **K-12 data on student performance** throughout the outreach and research work of the university. Thanks to the outcomes of CUSP and the hard work of Bret Feranchak and others in CPS's Office of Research, Evaluation, and Accountability, data is now available on student outcomes in many different areas. Improving the use of this data in our programs is now the next step, with of course appropriate privacy and confidentiality safeguards.
- **University-based systems** must be developed for program coordination. The history of reform at many of the institutions relied necessarily on the efforts of small teams or even single individuals. However, this is not sustainable and partnerships now require coordination among different units within the university. Many of these are already established: the Center for Science and Math Education at Loyola; IIT's Institute for Math and Science Education; Northwestern's Office of Science, Technology, Engineering, and Math Education Partnerships; and UIC's Learning Sciences Research Institute. This should be the norm in the future.

2(d) How do you or can you help to disseminate these findings to other cities and regions of the country?

In this case, there are three levels to my answer. The first is simple: to make use of existing scholarly channels, including peer-review journals and conferences. It is easy to believe this will occur, but only if it is the case that funding agencies, such as the NSF, insist on full use of the existing literature as the basis of education reform. But direct person-to-person communication is also necessary, especially to support collaboration. In Chicago, a very early success in the development of multi-institutional communication was done through an Illinois Board of Higher Education grant to establish a collaborative of institutions associated with teacher preparation and undergraduate STEM teaching. This gave rise to an annual series of conferences, entitled "Excellence in Teaching Undergraduate Science and Mathematics: National and Chicago Perspectives." These bring national plenary speakers and local STEM education reform participants together three times a year to discuss new ideas, report on progress of ongoing projects, and to maintain connections that drive many other STEM education reforms.

The second level of answer is something that the NSF has answered well in many ways. That is by having large systemic change programs such as the MSP's, the GK-12 Fellows programs, and the Noyce Teacher Scholarship programs *required* to share information through annual conferences and through NSF-associated web sites such as MSPNet. In this case, the sharing of ideas and outcomes at this level—not quite social networking, but close—permits rapid dissemination of preliminary findings to those who need the information most quickly. It is interesting to me that one of the features of MSPnet is that it is intrusive, with reminders of information and activities now provided to me weekly. Similar work occurs with GK-12 and I am pleased to learn that the same is occurring for Noyce.

The third level of possible dissemination is one that I have largely left out until now. It is through the actions of the states and their individual boards of education. These organizations are each independent, as befits our Federal system. But their importance as partners in STEM education reform cannot be underestimated. Improved communication about efforts nationally and locally will, most logically, require that state boards both be told what is going on and that they listen and act accordingly. Federal mandates to do this in association with block grants may be timely.

3 (a) What is the most important role a university such as your own can play in improving K-12 STEM education in your own community and/or nationally? How can universities help facilitate and build partnerships with other stakeholders, including the private sector and informal education providers?

I will take this question in two steps. First, we need to remember that whatever universities can do, it has to be in the context of a reform system. Second, I will note particular examples of how particular areas of strength for universities can be developed and used.

The most important thing universities can do is demonstrate that existing schools can move from low to high performance in math and science by assisting in organizing the adult learning in the school around what we know about effective STEM instruction. This requires partnership between universities and school systems that ordinary preparation programs do not require. Simply put, the principal and teacher leadership of academic departments must work together with universities to change instructional practices in each school, which requires collaboration around such fundamental issues as curriculum, instructional approaches, common formative assessments of students at collaboratively-set checkpoints, and so on. This kind of approach should be foregrounded in teacher preparation work so that new teachers are ready for it, but teacher preparation is itself a weak lever for improving school-wide performance since new teachers are novices who should be ready to work in a reformed environment but not expected to create it. If you put one of those novices into a school properly organized for STEM success, that teacher will thrive and get the job done. Thus, the same linkages that improve school practice also provide a place for new teachers to work effectively, greatly improving the likely outcomes of teacher preparation work.

As to what universities may do in specific ways, my opening review shows nine different areas of work in which universities can work in improving K-12 education. I hope I have provided part of an answer to this in the examples I cited in those areas. But there are other components of our work that are not captured well there, since they represent the effect of systems or units within the university. I will cite a few of those now, drawing on other institutions in the Chicago area that, I believe, exemplify how universities can systematically link their work to K-12 STEM education. Five specific ways in which this can be done are:

- The creation and use of a **university coordinating office** for STEM education.
- Close linkage of K-12 STEM education work to the **undergraduate mission** of an institution.
- Use of **laboratory-based research on education** in STEM education reform work.
- A consistent focus on addressing **emergent professional development opportunities** in a flexible and responsive way.
- Development and sustenance of **deep connections between university STEM and education programs** that bridge colleges within universities.

Northwestern University provides an example of a how a **university coordinating office** can facilitate the work of the university in K-12 STEM education, through its Office of Science, Technology, Engineering, and Math Education Partnerships (OSEP). OSEP uses its expertise in curriculum, technology, and program design math (STEM) research projects with NU researchers. These partnerships provide several benefits to the community that would not exist without this innovative form of collaboration for better programs, increased competitiveness, and especially leveraged resources through their ongoing connections of Northwestern faculty and researchers with a network of schools and informal educational institutions.

DePaul University shows how the **undergraduate mission of a university** can be incorporated as a foundation for K-12 STEM outreach, specifically by supporting strong community based relationships with schools to support, enable, and sustain K-12 innovation. The mathematics and science faculty there have a deep commitment to teacher education, reflecting DePaul's recognition that strong school-campus partnerships are vital to their success as a university. Hence, they have an NSF STEP grant that partners with community colleges to address transition issues, and they also provide their own incoming students with strong bridge programs to enable college success. At the same time, as we have seen, DePaul's activity as a leader of the *Algebra Initiative* and, now, in the CTTI, enables them to bring their own expertise in STEM and STEM education to support change in K-12 settings.

The Department for Math and Science Education of IIT points to the role of "big picture" thinking about science as a foundation for STEM education reform. The work of Norman Lederman and his colleagues in studying the ways in which the nature of science does, or does not, translate into classroom practice has fundamentally altered the discussion of what to teach in science, and also how to teach it. This is an excellent example of the role that **laboratory-based research on education** can translate into practice, including specific attention to the ways in which teachers shape and utilize their own concepts of the nature of science. IIT's program includes a doctoral level program that is just now graduating the first of a set of students trained in both educational research and the deep philosophical underpinnings of science, math, and education; this group is sure to have an impact on the future of K-12 STEM education in Chicago.

Loyola University Chicago, with the Center for Science and Math Education led by David Slavsky, is an example of how a university can become a key provider of **emergent professional**

development opportunities in specific support of state and district policies and needs. For example, as the HSTP was beginning the possibility of teaching a “physics first” curriculum was set aside, at least for a while, because of the lack of trained physics teachers in the district schools. Loyola moved immediately to the task of creating a university course-based program that would fill this gap, using state teacher development funds.. This built upon the many years of CSME work in support of the Chicago CMSI middle school program, enabling Loyola to be especially responsive to pressing needs. CSME also incorporates a full research unit within its programs, giving it specific strength in studying change in schools in a way that immediately affects practice.

Finally, I suggest that UIC provides specific examples of the gains that can be had when there are **deep connections between university STEM and education programs**. Within this testimony I have cited several examples of NSF grants that have come to UIC to enable our work in K-12 STEM education. What may not be apparent is that, with no exception, all of those grants have a PI, co-PI or senior personnel that is a STEM faculty member, like John Baldwin, Tom Moher, or myself, and someone from our College of Education, such as Maria Varelas, Carole Mitchener, or Steve Tozer. These are not just collaborations of convenience; rather, they reflect many years of work together, presenting a model for the fluid and productive interaction of different units on a research university campus. It is only natural, then, that a unit like the Learning Sciences Research Institute has been created to provide an interdisciplinary setting for further work by many of these researchers.

What is the single, most important step that the federal government should take to improve K-12 STEM education?

The most important single step is to ensure that funding mechanisms are aware of the strengths of different partners so that new projects draw on those strengths and, where necessary, address weakness. This should be targeted at what we know are the critical issues in schools: (a) demonstrating measurable increases in student learning by (b) improving classroom instruction through (c) improving each school's internal capacity (systems, procedures, and adult learning) through (d) improved teacher and administrative leadership in each school. This is the specific model of the CTTI (Figure 2), in reverse. It represents, we feel, the most cost-effective and scalable lever for change over a ten year period. Leadership issues are critical here, since virtually all principals nationwide will turn over in that ten-year period. Thus, developing leaders to carry forward reform in the short- and long-term is vital, and the federal government, especially through the MSP and Noyce programs, is already moving ahead on that task.

There are different ways federal support can impact the partners in this effort. For example, for universities, the federal government should support (ideally through NSF) university projects that develop teacher knowledge and K-12 school improvement using new knowledge developed by university researchers. This support draws upon what universities can do well on their own and emphasizes that within K-12 STEM education. This includes teacher education, preparation, and research both in classrooms and in laboratory settings. Ensuring that more of what occurs in K-12 education makes use of those areas of strength is essential, and clearly this is a central theme within the NSF Math Science Partnership program.

Districts and schools, in contrast, possess strengths of policy, instructional support, and teacher support. It is often difficult for them to use these strengths productively and consistently over the extended time required for systemic change. Thus, federal support for longer term-projects that implement rigorous, research-based changes in schools would be an important component of supporting change. Linking this to what is known to enable change—leadership, reflective teaching, use of reformed curricula—should also be expected.

The creativity and vision of informal science partners, including museums, industry, and after school programs, give them strength in the vital step of creating new environments to engage students, teachers, and families in the excitement of cutting-edge science. The role of informal science, including careful research on informal science settings, is much-neglected as a means of translating research into accessible forms.

Finally, as I have suggested at different points, the federal government needs to support work over extended time periods, something that is already done, for example, in the Long Term Ecological Research centers. We should collect data over 10 – 20 years to provide broad, district level data on curriculum, and initiatives to give us the data we need to make strong claims.

Coda

I would like to close with two items that have not yet been discussed in this testimony but that I think are essential to our work and to the reform of STEM K-12 education.

The first point is to return to the central role of relationships over time to the reform of any program, especially within a large and complex system such as an urban K-12 district. In this, individuals matter, and I want to tip my hat in particular to the role of Dr. Marty Gartzman in many of the efforts I have discussed. He is trained in biology but also worked for many years as a project manager in the UIC Institute for Math and Science Education, the group formed around the TIMS effort that, later, became one of the foundations for the Learning Sciences program. In this he developed deep connections with K-12 schools and many dozens of teachers. He helped design our first systematic efforts to reform teacher education at UIC and to start our GK-12 program. Then, he was tapped to lead the CPS' effort in its Office of Math and Science, managing some of the most effective work in CMSI and beyond. More recently, he has returned to UIC in a special role to help coordinate our work in K-12 and, especially, in high schools, having now helped to start our campus' first charter school, which is drawing many of our health professional units into educational innovation for the first time. The point here is that our effectiveness in many areas depends on the skills and relationships of Dr. Gartzman. Recognizing and valuing the role of such change agents, should not be overlooked.

The second point is that all of our work comes from a shared belief in STEM education as vital to the future of our nation and its people, especially the children who will be seeing our country through to its tercentennial and beyond. Technological, medical, and environmental challenges loom, and they will be addressed in this period by the STEM workforce we are training today. This is very much the philosophy behind the *America Competes Act*, which carries through on many important ideas already. But even as we agree on that I want to remind us that learning about science and mathematics is also important to the life of every person, especially in a democracy. I want to recall that, 100 years ago this Fall, John Dewey, who I proudly note was an active participant in the life of the Hull House settlement that is now part of UIC's campus, gave an address to the American Association for the Advancement of Science entitled "Science as Subject-matter and as Method." In it he outlined, somewhat tongue-in-cheek, the seeming gap between the rich, connected learning expected of students in the humanities and the dry, rote learning of the sciences. He argued, though, that the learning the *methods* of scientific inquiry is equally important to learning the content, and not just for the sake of science and technology. Thus, as he wrote for the conclusion for his address:

> If ever we are to be governed by intelligence, not by things and by words, science must have something to say about *what* we do, and not merely about *how* we may do it most easily and economically…Actively to participate in the making of knowledge is the highest prerogative of man and the only warrant of his freedom. When our schools truly become laboratories of knowledge-making, not mills fitted out with information-hoppers, there will no longer be need to discuss the place of science in education.

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Education

University of Chicago	S.B.	1980	Chemistry
Harvard University	Ph.D.	1985	Inorganic Chemistry

Professional Experience

New York University: Chemistry

1985-1992	Assistant Professor

University of Illinois at Chicago: Chemistry

1992-2000	Associate Professor
2000-present	Professor
2000-2005	Acting Head and Head
2006-present	Director of Undergraduate Studies

University of Illinois at Chicago: Learning Sciences

2006-present	Program Faculty
2007-present	Director of Graduate Studies

Publications most directly related to current testimony:

1. "Synthesis and Characterization of Aldol Condensation Products from Unknown Aldehydes and Ketones: An Inquiry-Based Experiment in the Undergraduate Laboratory," by Nicholas G. Angelo, Laura K. Henchey, Adam J. Waxman, Donald Wink, James W. Canary, and Paramjit S. Arora,* *J. Chem. Educ.*, 2007, *84*, 1816-1819.
2. "Inquiry-based and research-based laboratory pedagogies in undergraduate science" by Gabriela C. Weaver,* Cianán B. Russell & Donald J. Wink, *Nature Chemical Biology*, 2008, *4*, 577-580.
3. "Evaluation of the Center for Authentic Science Practice in Education (CASPiE) model of undergraduate research," by Donald J. Wink* and Gabriela C. Weaver. Commissioned paper for National Academy of Sciences Board of Science Education, 2008: http://www7.nationalacademies.org/bose/Wink_Weaver_CommissionedPaper.pdf.
4. "Bringing Standards-based Chemistry Instruction to an Urban School District," by Donald J. Wink, Patrick L. Daubenmire, Sarah K. Brennan, and Stephanie A. Cunningham, *Chemistry and the National Science Education Standards*, 2nd Ed., 2008, American Chemical Society: Washington, DC. http://portal.acs.org/portal/fileFetch/C/WPCP_010699/pdf/WPCP_010699.pdf.
5. "Fostering Pre-Service Teacher Identity through Student-Initiated Reflective Projects," by Donald J. Wink, Julie Ellefson, Marlynne Nishimura, Dana Perry, Stacy Wenzel, and Jeong-hye Hwang Choe, *Feminist Teacher*, 2009, *19*, 31-46.

Publications in other areas

6. "Developing a New Model to Provide First and Second-Year Undergraduates with Chemistry Research Experience: Early Findings of the Center for Authentic Science Practice in Education (CASPiE)," by Gabriela C. Weaver,* Donald Wink, Pratibha Varma-Nelson, Fred Lytle, Robert Morris, William Fornes, Cianán Russell, and William J. Boone, *Chemical Educator*, 2006, *11*, 125-129.
7. "Connections between Pedagogical and Epistemological Constructivism: Questions for Teaching and Research in Chemistry," by Donald J. Wink, *Foundations of Chemistry*, 2006, *8*, 111-151.

8. “Pennies and Eggs: Initiation into Inquiry Learning for Pre-service Elementary Education Teachers,” by Donald J. Wink* and Jeong Hye Hwang, *J. Chem. Educ.*, 2008, *85*, 396-398.

9. “Inquiry and Connections in Integrated Science Content Courses for Elementary Education Majors,” by Maria Varelas, Roy Plotnick, Donald Wink, Qian Fan, and Yvonne Harris, *J. Coll. Sci. Teach*., 2008, *37(5)*, 40-47.

10. "Structure and Reactivity of Alkynyl Ruthenium Alkylidenes" by S. Y. Yun, M. Kim, D. Lee,* and D. J. Wink, *J. Amer. Chem. Soc.*,2009, *130*, 24-25.

Current Support

1. “Chicago Transformation Teacher Institutes,” PI on this *ca*. $5,000,000 grant to five Chicago-area institutions of higher education in partnership with the CPS. July 1, 2009-June 30, 2014.
2. “Science Approach A: Inquiry to Build Content,” Chicago Board of Education High School Transformation Project, January 1, 2006-June 30, 2010. I am a co-PI on this *ca*. $3,000,000 grant to provide comprehensive curriculum and professional development to Chicago Public Schools. Loyola University Chicago is the lead institution (David Slavsky, PI). The UIC subcontract will be approximately $900,000.
3. “The Center for Authentic Science Practice in Education,” National Science Foundation, Chemistry Division, August 16, 2005-August 31, 2009. I am a co-PI on this $2,400,000 grant. Purdue University is the lead institution. The UIC subcontract is for $300,000 over five years.
4. “Scientists, Kids, and Teachers (SKIT): A GK-12 Partnership with the Chicago Public Schools,” National Science Foundation, Division of Graduate Education, January 1, 2004-December 31, 2008, $1,979,787. I am the PI.
5. “Research on Student Understanding of Solution Phenomena in College Chemistry,” National Science Foundation, Division of Undergraduate Education, September 1, 2008-August 31, 2010. I am the PI.

Synergistic Activities

- Co-director, UIC ASCEND program, and NSF STEP grant to support students at the University of Illinois at Chicago in STEM majors. Includes networking on campus with major student support groups and programs to support students in early participation in research (Lon Kaufman, PI).
- Secretary and Councilor, Division of Chemical Education, American Chemical Society. Member of executive committee for 5000 member Division and also *ex officio* member and secretary of the Board of Publication for the *Journal of Chemical Education*.
- Editorial Advisory Board, Education Division, American Chemical Society *Chemistry in the Community: 6th Edition.*

Former Advisors: Undergraduate: Prof. William Evans, University of California at Irvine; Graduate: Prof. N. John Cooper, University of Pittsburgh

Collaborators outside of UIC (2004-2009): Miami University: Stacey Lowery Bretz; William Rainey Harper College: Julie Ellefson Kuehn; Kennedy-King College, Sharonda Benson; Harold Washington College: Dana Perry, Mike Davis; College of DuPage: Susan Shih, Mary Newberg, Carolyn Dockus; Moraine Valley Community College: Ewa Fredette; Truman College: Yvonne Harris; Olive-Harvey College: David Zoller; New York University: Paramjit Arora, James Canary; Northeastern Illinois University: Veronica Curtis-Palmer, Ana Fraiman; IUPUI: Pratibha Varma-Nelson; Purdue University: Gabriela Weaver, Fred Lytle; Georgia State University: Jerry Smith; Chicago Public Schools: Michael Lach, John Loehr; University of West Georgia, Sharmistha Basu-Dutt, Gail Marshall; American Chemical Society, Angela Powers, Cynthia Mickevicus, Terri Taylor. Michigan State University: Diane Ebert-May.