EnLiST: Entrepreneurial Leadership in STEM Teaching and Learning
Preparing Science Teacher Leaders for the 21st Century
It takes a whole village to raise a child

A P-20 approach to transforming STEM education and strengthening the STEM pipeline
EnLiST: Entrepreneurial Leadership in STEM Teaching and Learning

Fundied by the National Science Foundation, EnLiST is a partnership between the University of Illinois at Urbana-Champaign (Illinois) and a number of core partner school districts, including Champaign Unit 4 School District, McLean County Unit District 5, Thornton Township High School District 205, Urbana School District 116, and Western Community Unit School District 12. EnLiST also collaborates with a substantial number of affiliate school districts across the state.

The EnLiST partnership aims to build the capacity of a new generation of science teacher leaders who, armed with cutting-edge content knowledge, a strong pedagogical repertoire, and entrepreneurial spirit, mindset, and skills can effectively contribute to the transformation of science teaching and learning in their classrooms, schools, and districts. EnLiST aims to improve the quality and quantity of science learning for all students, and increase their engagement and success in the sciences.

EnLiST Teacher Fellows include high school physics and chemistry teachers, middle school physical science teachers, and elementary school teachers. Fellows engage with the partnership for three years, during which they participate in a set of intensive residential summer institutes on the Illinois campus. The institutes focus on disciplinary science content knowledge, as well as interdisciplinary applications; reform-oriented pedagogy; and entrepreneurial leadership. Fellows continue to engage with EnLiST throughout the academic year.

EnLiST Fellows are provided with support and resources to leverage individual, group, and institutional initiatives at the classroom, building, district, and cross-district levels. These initiatives provide opportunities for EnLiST Fellows to engage in leadership roles as they collaborate with colleagues throughout the partnership to initiate and implement transformative curricula and instructional projects, as well as pedagogical innovations, which are designed to significantly impact student learning in the sciences.

Since 2009, the EnLiST partnership has seeded, nurtured, and saw to fruition a substantial number of innovative and transformative initiatives. These initiatives span the gamut from localized, classroom or building level projects spearheaded by small groups of teachers to systemic building, district, and cross-district projects with sustained impact. The following pages feature many of these initiatives, which serve to showcase the levels of teacher innovation and richness of student experiences created and facilitated by a robust partnership that draws on resources from across the P-20 STEM community.

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The EnLiST Co-PIs

Fouad Abd-El-Khalick
Professor and Department Head, Curriculum and Instruction

Raymond Price
Professor, Industrial and Enterprise Systems Engineering

Mats Selen
Professor, Department of Physics

Patricia Shapley
Professor, Department of Chemistry

Judy Weigand
Superintendent, Champaign Unit 4
The EnLiST partnership spans 6 colleges, 10 departments, 3 units, and 17 school districts... and relies on the expertise of 183 professionals.
“Working in contexts that are (or justifiably perceived to be) resource-deprived, entrepreneurial STEM teachers succeed in creating innovative and transformative learning opportunities or environments, both within and beyond their own classrooms, such that the quality and quantity of students’ STEM learning experiences and outcomes are markedly better than the actual or perceived norms of their milieu.”

The EnLiST summer institutes

Jan Gaffney, Joe Muskin, Ray Price, Mats Selen, Pat Shapley, Anita Martin

Pat Shapley, UIUC chemistry professor

The EnLiST summer institutes are the cornerstone of the National Science Foundation Math Science Partnership. From its beginning in 2009, the partnership has provided an intensive two-week content-based workshop for teachers of middle school physical sciences, and high school chemistry and physics teachers.

To ensure meaningful and sustained professional development, EnLiST participants began with a three-year commitment of attending the summer institutes on the University of Illinois campus, and used that training to establish school-based leadership and opportunities for classroom innovations. Participants who completed these responsibilities emerged from the experience as EnLiST teacher leaders.

During the institutes, teachers received high-quality professional development in science content, pedagogy, and leadership, graduate credits for completion, and a leadership certificate from the University of Illinois.

Through five years of summer institutes, EnLiST gave its cohorts of participants opportunities to integrate newly-learned activities and content into their own curriculum. Patricia Shapley, a University of Illinois professor in chemistry and EnLiST Co-PI, engaged Core teachers with topics that included principles of chemistry and inquiry-based activities.
Topics addressed in the Core chemistry institute included the structure and properties of water and aqueous-phase chemistry; measurements in chemistry; structure, properties and particle size of materials; forensic chemistry, polymers and biopolymers; atmosphere and gas-phase chemistry; bio-molecules: sugars, fats, and proteins; and everyday chemistry.

Cascade teachers experienced chemistry workshops that were tailored to the grade level of the teacher, with activities delivered in a “predict, observe, explain” format. Teachers were given time to discuss how these activities might be deployed in their own classrooms.

Chemistry faculty employed active learning methods throughout the institute. EnLIST teachers were engaged with chemical concepts and thinking through guided inquiry activities. Teachers then developed novel activities that they would use in their own classrooms.

Mats Selen, a University of Illinois professor in physics who also is the EnLIST Principal Investigator, instructed the Core physics institute, which focused on the science of the Global Positioning System (GPS). Teachers completed hands-on labs to study a variety of basic physics concepts including gravity, acceleration, electricity, magnetism, the speed and properties of visible light, interference of microwaves, the observable effects of special relativity, and atomic spectroscopy.

Each teacher took home a wireless data acquisition system and a
Selen’s Cascade physics workshop included hands-on activities in energy transfer and states of matter. During the workshop, EnLiST participants created “slime” that exhibited qualities of both a liquid and a solid, and experimented with the effects of liquid nitrogen on a variety of materials, from conductive metals to nonconductive acrylic and rubber.

Teachers learned engaging new ways to bring learning experiences about the states of matter and conservation of energy into the classroom. These experiences had teachers riding skateboards through the halls of the Loomis Laboratory to understand Newtonian motion, and plunging their hands in water to learn how humans perceive temperature differentials.

Additional professional development was provided by an institute in Nano-Technology, hosted by NanoCEMMS, the Center for Nanoscale Chemical-Electrical-Mechanical Manufacturing Systems.

EnLiST participants were guided by Joe Muskin, NanoCEMMS educational coordinator, and other NanoCEMMS staff, as they manufactured electrical diodes, polymer balls, and kaleidoscopes, and learn how to use lab equipment such as precision pipettes.

Participants were given full access to the University’s level-3 clean room, where they experience the process of photolithography as they etch wafers of silicon using chemicals and light.
Participants also construct and programmed small, mobile robots, and learned the process by which silver nanoparticles can disinfect clothing and isolate cancer cells for safer, more effective chemotherapy.

ENLIST recognized these experiences and curriculum enhancements required additional training in order for systemic innovations to take hold in partner school districts. As such, Raymond Price, an ENLIST CO-PI, and Janet Gaffney, administered an entrepreneurial leadership institute.

At the ENLIST institute, teachers met their counterparts in other cohorts to plan collaborative, vertical projects that could be implemented during the academic year. A culmination institute provided additional opportunities for discussion about innovations that occurred during the prior year, and time to plan additional projects and synergies.

Response to these summer institutes were extremely positive. Across all summer institutes, 98% of teachers rated their overall experience as successful. Most teachers (91%) agreed or strongly agreed that the institutes improved their knowledge and understanding of the target topics related to science, pedagogy, and/or entrepreneurial leadership.

Additionally, ENLIST participants valued the sense of community that was built during the entrepreneurial leadership institutes, and enjoyed the time to reflect, share and collaborate with other teachers.
The pedagogy institute, led by EnLiST project director Anita Martin, provided participants with opportunities to reflect on the content knowledge instruction they received during the physics and chemistry institutes.

The course gave EnLiST teacher leaders an overview of best practice as described in the reform-oriented instructional literature, and introduced them to professional development frameworks.

It also served as a catalyst for EnLiST fellows to engage in leadership activities within their districts.

Part of the course’s expectation was that teachers engage in project-based learning as an effective teaching strategy. To this end, EnLiST collaborated with a Champaign County engineer to identify problems faced by the county, and solutions to those problems.

EnLiST participants visited Boneyard Creek, and a construction foreman explained design choices. Students worked on a project-based design unit that met their district’s curriculum standards in science.

An essential component of the entrepreneurial leadership goals of the EnLiST project, this course built bridges of communication between classrooms, and across school districts.

The culmination of the Pedagogy Institute challenged EnLiST teacher leaders to create a new professional development opportunity that would benefit their entire district.

Some teacher leaders implemented their professional development plan in their district, and shared their results at the EnLiST annual poster seminar.
EnLiST Initiatives
The Urbana School District achieved success with its STEM Coach, Tina Lehr, who spearheaded the development of new curricular units and generated new awareness about STEM initiatives in this district.

As a STEM coach and an EnLIST teacher leader, Lehr brought parents, students from K-8 together for Urbana STEM Nights. For this and other successful initiatives, district administration and the EnLIST Leadership Team again partnered to co-fund this important position.

To ensure district support for the STEM coach position after the life of the EnLIST, the EnLIST initiative gave full ownership of this vital position to the district, with recommendation that the STEM Coach become a broader resource for all grade levels in the district.

In her second year as STEM Coach, Lehr bridged initiatives that were developed by EnLIST Teacher Leaders in the district’s six elementary schools and one high school. In light of those accomplishments, the district promoted Lehr to District STEM Coordinator, a position based in the district’s central office.

Lehr and Anita Martin, EnLIST Project Director, in spring 2013 launched a new systemic initiative at Thomas
Paine Elementary School that collaborated with the school’s STEM committee to provide extensive professional development for teachers around alternative energy sources. The project involved a peer-mentoring model where even younger students taught concepts in alternative energy sources to older students in K-5.

For this exciting new initiative, teachers created energy-related projects, which students presented at a school-wide science fair in May 2013.
Cross-building effort creates new outdoor learning space

This cross-building life experience in landscape design was the product of a collaboration between Tina Lehr, Urbana STEM Coach, and Alicia Burge, a Core I teacher leader and Urbana High School teacher, and the students in her AG course. Students worked together on a new design for the middle school’s outdoor courtyard, located in an open-air space in the center of the building.

The project’s goal was for students to create a comprehensive plan for an outdoor classroom area by conducting extensive studies of local plant species and soil, drafting proposals that included blueprints, and presenting their strategy to a panel of stakeholders including building and district administrators, and grounds keeping personnel.

Students then remodeled a greenhouse formerly used for storage to create a fresh, new outdoor environment that was conducive to learning. To execute this project, high school students sacrificed their lunch and study hall periods to travel between the high school and middle school.

The project required students to level the ground to install a flagstone pathway connecting the two courtyard entrances. Attention to sun and shade led students to select hearty plants that thrived with minimal maintenance.

The courtyard is now used as an outdoor learning environment.
Reaching out with entomology

Beneath the high ceiling of Booker T. Washington STEM Academy (BTW), nearly 60 young students buzzed with excitement. Some were too enthralled to sit, while others squirmed in their chairs. But their attention is rapt, and they learned from a shared experience: giant grasshoppers have invaded the STEM lab!

Tara McGill, a UIUC graduate student in entomology, volunteered to work with Pat Shapley, a UIUC chemistry professor and EnLiST co-principal investigator, to build on the existing science curriculum with engaging entomology lessons.

Shapley’s model involved training high school students to teach lessons, and David Bergandine, University High School (Uni High) science teacher, selected students to teach entomology lessons.

Uni High student volunteers brought live insects from the UIUC entomology department to Shalonda Carr’s class at Martin Luther King Elementary in the Urbana school district.
Carr, an EnLiST Teacher Leader, planned a lesson on animal habitats and worked with McGill to enhance the lesson with live Madagascar hissing cockroaches. “Their habitat is a rainforest, but they live their entire life on that one log,” McGill said.

The outreach grew to BTW, Champaign Unit 4 school district, and included lessons in insect taxonomy, anatomy, and life cycles.

Undergraduate entomology students from UIUC guided elementary students through lessons about collembola, a tiny insect which is vital for a balanced ecosystem. A separate lesson involved transporting a beehive from the UIUC pollinatarium to the classroom.

Additionally, McGill brought two boxes of large lover grasshoppers, and conducted a behavioral study related to the insect’s diet. “These students are having genuine conversations and they are really trying to communicate their thoughts because they want to learn about what’s going on and ask questions of their fellow classmates,” McGill said.

The Entomological Foundation awarded McGill’s lesson, “How do insects beat the heat,” first place in the competition for science project ideas at the Entomological Society of America’s 2012 conference in Knoxville, Tennessee.
Betabrain, a collaboration between McLean County Unit 5 and EnLIST, takes its name from the idea that the brain is constantly improving. In technology terminology, it’s always in “beta.”

Headed by David Brown, a faculty member in science education at UIUC, and Loren Baele, McLean’s director of technology, along with EnLIST teacher leaders Stacie Threlfall, Blair Broker, April Schermann and Nate Bostic, betabrain is a set of student challenges and online resources focused on engineering design principles.

The challenges were initially presented to students in grades 6-12 at the first annual betabrain science competition in the spring of 2012. Student teams challenged themselves with physics-oriented tasks to move a ball from one table to another without touching it, using only materials such as inflatable balloons, buckets, duct tape, string and dowel rods.

When a team completed a challenge they moved to a more advanced level, where the challenge was similar but the difficulty was increased. The EnLIST teacher leaders pooled resources from the community, by soliciting donors who provided prizes, including an Apple iPad, for a raffle for students who completed all of the challenges.

This challenge day provided motivation for students to investigate science ideas of motion, force, and energy. Online resources provided prior to the challenge day were woven into the science curriculum over the course of the semester.

The creators of the 2013 betabrain challenge day, marshaled more resources...
and engaged chiropractors, cheese makers, and civil engineers to create challenges focused on chemistry, earth science, and biological sciences as well as physics and engineering principles.

While the 2012 challenge incorporated one middle and one high school, the 2013 betabrain challenge brought together nearly 400 students from all of the district’s four middle schools and two high schools in team-based challenges located throughout Normal Community High School.

The newly-reworked betabrain challenge tasked students to make a load-bearing structure out of index cards that could hold the weight of a brick, develop a wind-powered cart that could zoom across a table, design a parachute and capsule that could save a potato chip from a two-story fall, and more.
In an underserved suburb of Chicago, EnLIST Teacher Leaders Sue Hokkanen, and Sharon Bird, in collaboration with Eric Mooney and Lael Dubose, worked together to garner interest and support for STEM activities spanning multiple content areas.

For this initiative, a group of sixth through eighth-grade students took on an engineering and ROV (Remotely Operated Vehicle) competition sponsored through the Shedd Aquarium in 2012.

Colin Powell students brainstormed and designed a submersible robot to perform tasks associated with the competition. The community provided access to the city’s pool, which allowed students to test their designs.

The Shedd competition involved the use of high-level mathematical concepts and computer programming and also was inclusive of special needs students. A remarkable feat for their first try, students clinched fourth place with their first underwater robot.

It was not just a success for the team, but the entire community, which served as motivation for the 2013 competition.
Chris Dryer, an EnLiST Teacher leader, saw that his Danville High School students were struggling with obsolete probeware. Knowing that properly-equipped labs make an enormous difference in inspiring high school students to pursue post-secondary STEM degrees, he worked with the Danville School foundation to acquire state-of-the-art lab equipment.

Danville School Foundation President Bob Richards reached out to community members who had supported innovative science opportunities for students in the past. Richards received donations ranging from $2,000 to $9,000 each, and pulled in a total of $38,000 in contributions. The Einstein project invested that money into university-grade Vernier Labquest probeware for Danville students.

In order to make the most out of the new equipment, EnLiST partnered with Dryer to provide Danville science teachers with a two-day professional development training centered on updating teacher’s skills.

Barbara Hug and Lynn Burdick facilitated the training by examining Danville High School’s science curriculum and creating relevant training on the new Vernier probes.

In addition, EnLiST supported the substitute teacher costs and registration materials for four teachers to attend a one-and-a-half day Vernier probeware training in Indianapolis, IN.

Several of Dryer’s students who previously were not considering going to college, thanks to the Einstein project, are now planning to attend universities, and potentially medical school.
East Peoria high school chemistry students, 2nd graders collaborate

Jay Bowman

This cross-district EnLIST project involved elementary school teachers in the Peoria School District collaborating with Jay Bowman, an EnLIST Teacher Leader, in East Peoria High School. Bowman created a project that involved his high school chemistry students reaching out to the district’s feeder elementary schools, utilizing the peer mentor model in teaching second grade students.

High school students taught second grade students the relationship between temperature and pressure. Students used a vacuum pump in a visual demonstration that enabled second graders to more clearly understand weather patterns.

Bowman plans to work with high school students who are currently working in grade schools as part of the High School Teacher Cadet Program, to help students prepare meaningful science lessons to younger students.

The future of this project will benefit the elementary school students and high school students as they both engage in a quality learning experience through the science peer mentor model.
Creating positive learning environments in chemistry classes

Creating Positive Classroom Environments in High School Chemistry is a localized project created by Champaign Unit 4’s Bryan Foli, George Stanhope, and Tom Grove, and is supported by EnLiST. The collaborating team emphasized the importance of positive learning environments and promoted value-driven curriculum in chemistry classes.

Foli, a Core II teacher leader discussed behavior and its effect on the classroom environment with his colleagues, who presented his ideas to students. This discussion made students more conscious of their actions while in the chemistry classroom, and how they might affect the learning and work of others.

Teachers were encouraged to pursue positive behaviors, and not to let problems upset or defeat a positive mindset. In addition, the collaboration aimed to reverse ordinary classroom discipline techniques that rewarded misbehavior by applying additional energy, and reduced energy input when students behaved appropriately.

The collaborators energized the chemistry learning process while making students directly responsible for their own behaviors and actions.
Drones for schools initiative

Matthew Schroyer, Paul Leidig, Mats Selen, Rich Geiger, David Bergandine, Eric Butler, Zanne Newman, Katie Snyder, Tara Bell

Drones for Schools (DFS) is a broad-reaching, cross-discipline, cross-district initiative launched by EnLiST leadership that brings lessons in robotics, physics, chemistry, computers, and natural sciences to K-12 classrooms. The DFS initiative augments STEM learning by providing professional development around the components of small, unmanned aircraft systems (UAS), along with support equipment and training to high schools. High school students learn about the STEM concepts behind unmanned aircraft, more commonly known as “drones,” as they construct one capable of monitoring their local environment. DFS provides elementary students the chance to fly smaller aircraft as they learn about the basics of flight and robotics. The initiative is led by Matthew Schroyer, the communications specialist and social network analyst for the EnLIST grant, who created the DFS initiative with the assistance of EnLIST Co-Principal Investigator Fouad Abd-El-Khalick. Schroyer develops drone technology, guides students through the underlying STEM concepts, and engages new and existing school partners in the initiative. Paul Leidig, an engineering graduate student, teaches engineering principles and provides students a link to the wider world of engineering design. Individualized DFS projects are currently taking place in five schools: Tuscola High School, University High School, Urbana High School, Stratton Elementary School, and Booker T. Washington STEM Academy. EnLIST has provided aerial robotics to its partner schools, along with associated educational materials and manpower, with plans to expand the curriculum.
During the multi-day GPS collaboration, ESL (English as Second Language) students from Urbana High School met with the multicultural and multilingual students from King Elementary to explain the Global Positioning System of satellites, and how coordinates and waypoints help with the task of mapping and navigation.

This lesson first included a team-building exercise to get students comfortable with working with each other. Subsequent lessons involved mapping locations, drawing, writing and defining geographical terms, and mapping potential groundwater sources at King Park. Students used handheld GPS units to gather data, and worked together, to determine coordinates of previously determined locations.

High school students were challenged with creating a developmentally appropriate lesson for fourth grade ESL students, and completed their own research by creating and narrating videos and sharing them with the elementary students.

High school students culminated their involvement in this initiative by reflecting about communication and teaching and learning strategies. They then created a presentation and display at Urbana Middle School’s STEM night that showcased these lessons in GPS technology.
This localized project debuted in the Minooka School District as a collaboration between Minooka Jr. High School’s Megan Heng, a Core II teacher leaders, and ExxonMobil, who set out with a goal to encourage students to explore math and science applications using real world problems.

Twenty-two eighth-grade students and two seventh-grade students were carefully selected based on academic achievement and teacher recommendations to explore the topic of energy efficiency by designing, implementing, and presenting energy-saving projects to the school staff and administrators.

Some student-produced efforts included calculating average temperatures within the school to determine how temperature regulation could save money, creating energy efficiency by injecting helium in a sealed window, and investigating retention properties of roofs by considering the use of mulch, sod or dirt.
Physics teacher Jeremy Davis of the Rantoul Township High School created a project to increase student engagement in STEM by combining forces with EnLiST, NanoCEMMS, the UIUC Physics Department, the Opheum Children’s Museum and Eater Jr. High School. Davis started with the goals of expanding his STEM networks and adjusting the current curriculum to be more student-driven and more focused on student engagement, to engage students in a higher level of learning that aligned with the district’s curriculum standards.

Some of Davis’ projects included 3-D printing, kaleidoscope construction, bridge building, egg drop, and scientific measurements at a theme park.
For this EnLIST initiative, a Core I high school physics teacher teamed with three elementary teachers to engage high school science students with kindergarten and first grade students in science.

Kindergarten and first grade students wrote letters asking high school students about space. Working on this data, high school students interviewed the younger students to assess their understandings and naïve conceptions of key concepts in earth and space science.

High school students then developed lessons to address the younger students’ misconceptions about the seasons, day and night and phases of the moon.

Based on the results of these interviews, the high school students, under the supervision of participating teachers, built lessons and activities specifically targeted at helping elementary students understand those concepts. Research shows that both those who teach and those who are taught in such mentoring relationships develop better understandings of science concepts.

The second project involved a high school chemistry class who taught a third grade class about the water cycle in the rainforest. High school students authored textbooks for third graders demonstrating aspects of the water cycle, appropriate for elementary students. These successful initiatives were continued by the STEM Coach in the Urbana School District.

Beth Chamberlain exhibited strong characteristics of an entrepreneurial STEM teacher leader. In addition to teaching high school science courses in a traditional setting, Chamberlain sought to make science learning accessible to younger students in formal and informal settings by creating a science roadshow and a two-week summer science camp for elementary students.

The Science Road show involved designing and implementing science lessons, delivered by her Danville high school physics students to elementary students in the district. At the Science Road Show, younger students explored five different science inquiry investigations. Meanwhile, elementary teachers observed high school students teaching meaningful science content, and using effective instructional practices for younger students.

Chamberlain also developed a summer science camp, which employed high school students as science camp leaders who played an integral role in preparing the camp. These students led the camp’s experimental opportunities and related science concepts to a younger generation.

High school students gained leadership experience while strengthening their scientific awareness. The YMCA and the Boys and Girls Club, who were partners in this innovation, also left a positive impression the community.

Based on the directors of both summer programs, Chamberlain’s science camp is one of the most popular summer programs in the area. She attributes its success to her EnLIST experience, and her incorporation of hands-on science activities to generate high levels of student engagement.
The Bouncy Balls collaboration brought 15 Urbana Middle School students to teach 75 Booker T. Washington STEM Academy students about polymers and the science behind balls and ramps. This innovation leveraged resources across two school districts and the University of Illinois to give middle school students the opportunity to serve as science teacher leaders, and gave elementary students a unique and tangible inquiry-based science lesson. UMS students received specialized training and became intensely familiar with the background science material and best practice.

Joe Muskin, from the Center for Nanoscale Chemical-Electrical Mechanical Manufacturing Systems (NanoCEMMS), helped teach the manufacturing process to students. The elementary students then proceeded to pour their unique polymer mix into the molds and then placed the molds in a vacuum to remove air from the chemical mixture.

The balls were then cured in a kiln in the BTW STEM lab overnight. UMS students returned to BTW to remove students’ polymer balls from molds and educate students about the properties and mechanics of balls. Students engaged in an inquiry activity where they measured the composition of the balls to learn why they bounced differently. Students also experimented with balls and ramps to understand how their polymer balls behaved compared to other balls.
Composting collaboration links middle, elementary science classes

Beth Koplinski, Julie Anders-Becker, Tara Bell

What began as an innovative cross-classroom project exploring where food comes from evolved into a transformative learning experience for elementary and middle school students in Champaign, Ill. Beth Koplinski, an elementary science teacher at Booker T. Washington STEM Academy (BTW), and Julie Anders-Becker, a science teacher at Edison Middle School, initiated the collaboration.

Anders-Becker already had prepared a composting bin with her students as part of their ecology curriculum, while Koplinski sought assistance to execute a science unit on the origins of food. In a meeting after their EnLiST summer institutes, the two teachers decided to collaborate and combine their classes, with middle school students assisting 70 eager kindergarten students in building composting bins.

With 70 kindergarten students to teach at one time, organizers were initially concerned with how to manage the lesson. However, with seven or eight kindergartners to every student volunteer, Edison students reported that their BTW pupils were extremely attentive and easily absorbed the lesson on compost. Koplinski said it also instilled in her students a sense of wonderment about what science could hold in future grades.

“We want our kids to see that learning doesn’t just stop in kindergarten,” Koplinski said. “Once they become eighth graders, they can be a STEM person and they can come back and help.”

Anders-Becker reported that the partnership effectively tapped into the human capital of her students, who she said quickly adapted to the role of science teacher. This was the same even for students who had not been high-performers, but sparked a renewed interest in science and “stayed on task.”

She plans to continue the partnership with her students at Edison by returning to teach BTW students about uses for the compost and planting seeds in the spring.
EnLiST partnered with Scott Willenbrock, from the UIUC physics department, to work with Thornton Township District 205 to make transformative STEM opportunities through innovative, redesigned units for green energy courses.

Willenbrock engaged Thornton teachers in a two and a half day professional development centered on solar and wind energy scientific principles, as well as materials and student investigation options.

Students investigated different types of wind and solar energy sources in the green energy course, which culminated in a field trip to Argonne National Laboratory, one of the U.S. Department of Energy’s leading national laboratories for scientific and engineering research.

In addition, students researched how to engineer their own wind turbine system.

It has been EnLiST’s goal to empower this district to make a systemic transformation that would truly impact students’ attitudes and interest in science at the high school level, and to instill the confidence required to continue to take on college-level science courses.

This initiative has grown in scope from the third year of EnLiST, and is now impacting curriculum in physics, earth science, and environmental science at all three Thornton Township High Schools.

Truly transformative change at the district level in Thornton Township occurred through perseverance and compromise between Thornton teachers and administration in collaboration with multiple UIUC colleges and units.
Realizing the rising importance of the "E" in STEM education, along with upcoming science standards that emphasize engineering practices, engineering graduate student Paul Leidig partnered with Uni High physics teacher Beth Westfall to create a general science course with a focus on engineering principles for their "subbies" (accelerated seventh and eighth grade students).

Course investigations for the first semester included such challenges as developing a car and a racing scenario around the car, re-designing prosthetics using engineering design principles, and designing a device to prevent audio earbuds from becoming tangled.

For the second semester, collaborators integrated engineering principles into an earth science-focused course. This course included atmosphere and weather topics, where students were engaged with Kid Wind, a project-based kit focused on wind turbine properties.

Students investigated the most efficient blade designs for wind generators. Another project used Google Earth software to learn about plate tectonics. In the final segment, students studied water in an engineering context.

Leidig and Westfall are presently engaged in the design of an engineering course for Uni High seniors with the collaboration of UIUC engineering faculty.
Anita Martin, EnLiST Project Coordinator, assisted Champaign Unit 4 teachers to integrate art into their STEM curriculum.

Martin provided eight hours of professional development as part of a semester-long course where Booker T. Washington STEM academy teachers engaged in developing additional STEM interdisciplinary units.

The professional development day centered on BTW teachers receiving an overview of the District’s Visual Arts standards and engaging in an art inquiry activity.

BTW teachers learned how to compose music using the software program Garage Band, and discussed the increased learning opportunities when students create music themselves, and then connect the subject matter to music.

Finally, teachers learned how to incorporate the visual arts/performing art standards into their BTW STEM Academy Content Integration template using vertical and horizontal articulation.

The final discussions focused on the big picture of a STEM vision, to individual content standards, and then to step back towards the school-wide vision of STEM education at a premier, state-of-the-art STEM Academy.
Western Interactive Learning Design courses enriches rural community

In the Western WILD (Western Interactive Learning Design) initiative, UIUC Faculty and the EnLiST Team partnered with the Western Community School District to provide courses that turned the local environment into an enriching STEM experience.

These courses -- WILD for Economy, WILD for Ecology, and WILD for Equity -- are three systemic additions to the Western Community School District curriculum. Serving as mentors to the Western Staff, UIUC Faculty helped administrators and teachers define a focus around local ecosystems, encompassing lessons in energy, water, and soil.

In these three Western WILD courses, the students of the Western School District were introduced to a new problem-based learning environment. In one of the classes, students were challenged to formulate a plan on how to extend the growing season to meet the demand for local fresh foods, year-round.

Students formulated ideas, generated different prototypes, tested their products and evaluated their individual prototypes’ effectiveness. These courses encouraged the students to develop an entrepreneurial way of thinking and approaching problems.

Students collaborated to make homemade hydroponics systems for tomatoes and strawberries. They also designed, constructed and deployed rain collection systems and water heaters.
Content experts team up with middle school science teachers

Kristin Camp, Tom Johnson, Katie Cummins, Brian Fields, Heidi Bjerke, Jennifer White

At the request of Champaign Unit 4 School District, EnLiST tapped into UIUC faculty to enhance science course offerings at the district’s three middle schools.

Out of this collaboration came exciting new courses on sound, light and electricity, oceanography, and space science in grades seven and eight.

EnLiST found that school districts needed content experts help teachers keep up-to-date with developments in specific areas, and to help them capitalize on the most relevant “big ideas” in science.

Content experts also were vital in guiding teachers to determine what new knowledge and skills should be integrated in the science curriculum, and to bring innovative and exciting ideas for inquiry-based labs or demonstrations to the classroom.

UIUC experts were on-hand for part of the week-long process of drafting a curriculum outline, which the teachers continued to flesh-out during the remainder of the summer and into the fall semester of the next school year, piloting the courses as they developed them. In addition, the faculty provided additional support to teachers throughout the following year, as teachers launched their new pilot courses.

An oceanography unit included lessons on the shapes and features of ocean basins, the currents that circulate water around the globe, and the patterns of biological activity that those currents support.

This unit was designed from a collaboration between Tom Johnson, the head of the department of geology at UIUC, UIUC Physics Professor Brian Fields, physics education doctoral student Katie Cummins, and the Champaign Unit 4 middle school science teacher cadre.

Cummins provided professional development on ways to use smartphone or computer technology to make measurements, and view simulations and videos.

For the final project in the course, students designed a simple and perfectly functional audio speaker. This project used a performance-based assessment, in addition to a formal written assessment, which combined the concepts of sound and electricity taught in the unit.

Finally, a unit on space science by Fields expanded teacher’s knowledge of the universe including star evolution, solar systems, and Big Bang theory.

This unit focused on students’ naïve conceptions on phases of the moon, gravity, tides and the formation of planets.

Topics for all the courses created in this initiative were selected based on the most current draft of the Next Generation Science Standards (NGSS).
The EnLiST Partnership continues to facilitate the building of innovative cross-institution and cross-district collaborations that leverage expertise and resources from multiple stakeholders along the P-20 STEM education system to improve science teaching and learning for precollege students. One such unique collaboration represents a powerful inter-generational teaching and learning network that brings together active scientists and graduate students from the University of Illinois campus, and science teachers and students from the University of Illinois Laboratory High School (Uni High) and their counterparts in elementary schools in the Champaign Unit 4 and Urbana 116 school districts.

Pat Shapley, an EnLiST Co-PI, developed this unique collaboration to provide inquiry-based science learning activities to elementary classrooms, while providing enriching opportunities for high school students. Now in its third year, Shapley’s partnership trains 20 volunteer Uni High school students each year alongside EnLiST teacher leaders in the context of the EnLiST professional development workshops.

Shapley, a professor of chemistry, builds on the existing science objectives in partner elementary schools by crafting inquiry-based activities that demonstrate core science concepts and processes. Uni High volunteers teach the activities to the K-5 students and foster problem solving skills three times a week at Booker T. Washington STEM Academy in Champaign and Martin Luther King (MLK) School in Urbana.
In one activity, Uni High volunteers challenge elementary students to get a bulb lit starting with familiar components—a battery, wires, and a light bulb. This simple activity first allowed student to manipulate the objects, attempting to solve the challenge on their own. But then, it provided high school volunteers an opportunity to explain how simple electric circuits work in a manner understandable to elementary students, which entails finding simple metaphors and ways to represent some abstract ideas.

Switching batteries and measuring resultant changes with lab meters introduced notions of electrical force and voltage. More advanced lessons give students the opportunity to test their newly acquired knowledge on LED strips that show different colors depending on voltage. Another lesson involves testing natural materials for insulating qualities, and interpreting those qualities via graphs, while other lessons demonstrate concepts about magnetism and interstellar impacts.

“They feel like scientists because we’re not having them memorize anything, we’re not having them read a bunch of stuff in a textbook,” Shapley said of the elementary students. “We’re not telling them science is hard. In fact, we’re telling them that science is interesting and easy and in fact they are scientists and they can be scientists.” Indeed, the younger students often show signs of adopting traits from their high-achieving teaching volunteers, who served as role models. Indeed, a major aim of this intergenerational network is to enable the younger students to start developing an identity as ‘science folks.’

Uni High science teacher David Bergandine reported the partnership had tangible benefits for his students. Uni High volunteers gained experience as professional teaching assistants. The positive experiences volunteers had teaching science to young students motivated some Uni High students to consider a science teaching career.

“The prestigious Uni High proved to be essential to the partnership, as it was able to grant students the privilege of a flexible schedule. “Being in a setting like this allows a little more freedom on the part of the kids to explore,” Bergandine said, “and it’s not quite as regimented an atmosphere as you might find in other schools.” Despite this key difference, EnLiST Teacher Leaders are already exploring the systemic adoption of this model among additional schools, given the success of the partnership.

While the full benefit of this EnLiST partnership may not be realized for years, the achievements attained thus far prompted EnLiST leaders to expand the program. EnLIST hired a UIUC graduate student to assist administering lesson plans and materials, while teachers at Uni, BTW and MLK are networking to bring UIUC scientists into the partnership to teach more advanced science concepts. Long-term goals of the partnership involve seeding neighboring high schools with similar peer-teaching programs, with elementary students eventually becoming volunteer teachers as they advance into high school.

Ten UIUC chemistry faculty have committed to teaching units at the schools in the upcoming year.
Inspired to build on their EnLiST training, Alyssa Mayer and Janelle Weinzierl initiated an independent study at UIUC in the summer of 2012 to integrate reading comprehension strategies in STEM, while helping Booker T. Washington STEM Academy (BTW) in Champaign meet new Common Core expectations in English Language Arts (ELA).

As part of the independent study, Mayer and Weinzierl researched existing teaching comprehension strategies, re-envisioned and mapped the academic year of instruction at BTW, and sought out texts that satisfy Common Core requirements, support existing STEM units, and allow for a variety of reading strategies.

As a result of their efforts, BTW principal Asia Fuller-Hamilton and STEM coordinator Martha Henns worked with BTW STEM Specialist Tara Bell and UIUC’s Barb Hug to create a school-wide professional development series to bring bottom-up support and collaboration with K-5 teachers.

In September 2012, the group planned and delivered several bi-monthly, after-school development workshops to all K-5 staff. During these workshops, teachers identified texts to satisfy ELA Common Core standards, reading strategies, and STEM curriculum goals to improve student achievement.

The end product of these workshops was a template that K-5 teachers completed to serve as a curriculum planning tool for subsequent school years. The template integrated quarterly STEM themes and reading strategies at BTW with the ELA Common Core standards, in order to identify the ideal fiction and nonfiction texts.

“Students need a meaningful context for acquiring ELA skills and strategies. The outcome of this project will be a coherent and strategic plan for integrating ELA throughout the day,” said Weinzierl.

These texts are now used within both STEM and reading instruction time in all K-5 classrooms at BTW.
Geotech engineering brings STEM learning down to earth

Previous to this collaboration, second grade students of Booker T. Washington (BTW) STEM academy studied rocks, as required by the district curriculum.

To incorporate the Next Generation Science Standards (NGSS), this collaboration between UIUC faculty and BTW developed a 2-week geo-technology unit to cover the content usually taught in the rocks unit.

Geotechnical engineers, an engineering graduate student, and BTW second grade students and teachers joined for a two-week geotechnical engineering module.

This project allowed students to explore principles of geotech engineering by working with raw materials, learning about surface area, and observing examples from the field. Students created a model wall in the final design project, which was tested to learn about the strength of the design.

There is a curriculum of Elementary Geotechnology units commercially available but the team was unimpressed with the content and pedagogical practices, and developed new curriculum highlighting the NGSS and incorporating open inquiry and project-based learning as instructional delivery methods.

They showcased these curricular materials at NSTA’s STEM Expo in St. Louis, MO in the spring of 2013.
EnLiST fostered a collaboration with Thornton Township High School, who reached out to all feeder middle schools in the area, to provide more than 30 experiments and investigations in general physics concepts including projectile motion, planetary motion, force, and gravity.

Physics teachers from all three high schools and their students utilized football stadiums, soccer fields, and practice fields as large areas to conduct a day of physics lessons. More than 400 middle school students, which represented one third of all sixth through eighth graders in the area, attended.

Students learned about projectile motion as they used potato cannons and launched rockets. They also completed electric circuits, worked with photovoltaic cells, and experimented with liquid nitrogen.

EnLiST teacher leaders are striving to increase middle school student interest in science.

EnLiST continues to support innovations across district boundaries, including those across and within the three buildings that comprise the Thornton Township District.

These innovations engage former and present EnLiST teacher leaders and provides continual support for endeavors that transform and augment opportunities for students in science teaching and learning.
A Core I High School teacher leader from Rantoul Township High School initiated a cross-district collaboration with the Champaign Unit 4 school district to update the classic "egg drop" experiment.

This collaboration involved three, fifth-grade teachers from Westview Elementary School in Champaign Unit 4, who conducted an egg drop experiment each year with students, but faced recurring challenges and shortcomings.

The original egg drop project consisted of a single experiment to design projectiles to protect eggs that were dropped from a significant height.

The EnLiST partner teachers redesigned the activity to eliminate previous concerns, while increasing the rigor of the project and raising expectations by combining the scientific process of trial and error methodology and the manipulation of variables based on results from previous trials.

EnLiST teacher leaders continue to discuss how to improve this innovation in future years. One such idea teachers are pursuing is to extend the innovation into a contest across all 11 schools in Champaign and Urbana districts, which has the potential to foster a long-term, friendly competitive relationship between the districts.

Most importantly, Champaign Unit 4 has integrated the egg drop innovation into the standard curriculum for grade five, and has the potential for incorporation in the curriculum in other districts.
The Champaign school district sought to substantially increase the number and quality of their high school science course offerings, with the aim of increasing a single science course graduation requirement to two required science courses. EnLiST capitalized on this opportunity and initiated a collaborative effort, which engaged EnLiST high school physics teachers, other collaborating teachers, the district science curriculum coordinator, a UIUC physicist, and two EnLiST Co-PIs to envision the framework for the initial course in the multi-course series. EnLiST continues to develop modalities to draw on resources from across the P-16 STEM education system; in this case enabling high school science teachers and university disciplinary science experts to work jointly over an extended period of time to develop innovative, state-of-the-art science courses. Collaborating with the Department of Atmospheric Science at UIUC, a new earth science course was designed that included an immersive learning assignment: an expedition to study rivers and geology in a nearby county. A new space science course focused on stellar evolution, asteroids and comets, galactic collisions, and astrobiology, by eliciting assistance from a UIUC astronomy professor. The third new course, titled “Physics and Chemistry of Modern Technology,” filled a gap in the science curriculum for students who completed a general science course but were not ready for an advanced placement or honors course. The new course taught the core science concepts behind modern transportation, communication technology, and energy efficient homes. Finally, a new course collaboration resulted in physics department heads at both high schools to reinvigorated their 13 year-old honors physics course. The partnership created a new model of science course development in Champaign Unit 4.
For this all-school STEM inquiry project, Urbana STEM coach Tina Lehr and EnLIST project director Anita Martin facilitated a three-month professional development opportunity to provide all teachers at Thomas Paine Elementary in Urbana with inquiry-based investigations around alternative energy.

From this professional development, teachers planned and initiated a two-week inquiry unit centered on alternative energy and the three Rs: reduce, reuse, and recycle.

This offered many opportunities for students to engage in open and guided inquiry, using formative assessment strategies as the units unfolded.

Upon completion of the two weeks, each classroom of students became teachers for other grade levels.

Kindergarten students taught fifth grade students, first grade students taught third grade students, and second grade students taught fourth grade students.

The peer mentoring model had been used in many EnLIST initiatives, but this was the first where younger students taught older students in the same school.

Projects included such unique opportunities as a play...
that communicated the importance of soil and its components for crop production, an underwater remotely operated vehicle (ROV) was built by kindergarten and fifth grade students, who then modified the vehicle with nets and magnets to collect garbage and thus solve a pollution problem for local streams and ponds.

Teachers gave students the opportunity to deploy their vehicles in a three-foot deep pool that had been saturated with organic and non-organic waste, to determine how well the designs worked.

Other projects included solar and wind-propelled cars, wind maps of the playground, soil creation using components (clay, compost), cause and effect machines, solar cookers, and animal environments and habitats.

The STEM day was covered by local media, including a local newspaper and multiple broadcast news stations.
Jay Hooper, an EnLIST Teacher Leader, revised the classic structure of his AP Calculus class at Centennial High School in Champaign by flipping the class such that the lectures became homework, and the students collaboratively solved problems during class time.

Hooper noted the traditional structure of the class, which relied on a lesson that was reinforced with homework, had disadvantages.

In calculus, students generally had several questions after attempting to complete their homework, not all of which could be addressed in a class period reserved for lecture.

Hooper concluded that it would be more effective to assign a lecture as homework outside of the classroom, while reserving in-class time for solving problems. To do this, he created podcasts of all his lectures and as homework students were to view the podcasts and completed a resource book in which they compiled their notes for the semester. This changed the dynamics of the class and the research-centered flipped classrooms support such a shift. However, it rarely occurs due to a large time commitment to develop the system of online lectures.

Hooper collected student reflections of the course, written to the next year’s class. Students wrote that the course format was “amazingly helpful,” and was “pretty convenient because there were many available resources including friends.” Students also appreciated being able to work at their own pace and repeat lectures as needed. They advised future students be confident in their knowledge, find a hard-working study group, and not to become frustrated with the difficult course material.

The quality of work produced by Hooper’s students improved from previous years.

High school teacher flips calculus classroom

Jay Hooper
The mission of KIKS is to facilitate opportunities for kids to inspire other kids in science, using a trickle-down effect where secondary students will work with upper elementary students, who then will work with lower elementary students.

This peer-mentoring model includes video conferencing to share current events in their science class, and to share evidence-based claims.

Elementary students also visit the middle school to conduct inquiry-based labs and to report claims and evidence to support their investigation.

Three elementary grades and two seventh-grade classes participated in the innovation. One investigation included squid dissection (pictured) that seventh graders taught second and fourth-grade students after their squid unit was completed at the middle school. The long-term vision of this collaboration was to assign four feeder elementary schools to each middle school teacher.

Overlapping curriculum in middle and elementary schools determined the concepts that were shared. Most middle school science teachers have a science degree, or have taken more science coursework, and are able to share their expertise by pairing with elementary science teachers who don’t have the same content knowledge.
Two EnLIST Cascade teachers, Katie Hickey Snyder and Zanne Newman, created a project titled “Micro STEM University,” where fourth and fifth grade classes met daily for an hour with 30 students from the third through fifth grades.

These students, including minority and ESL populations, became leaders in their classrooms to create an exciting environment for all students in the school to experience STEM.

Because their project did not fall within the normal parameters of the Microsocieties Magnet School, the idea was met with resistance.

However, teachers used what they learned in the EnLIST institutes to marshal resources, thereby providing an engaging environment for many underserved students, which offered a potentially life-changing event.

STEM learning opportunities included manufacture of “nano-gold” particles, with the assistance of Joe Muskin and his NanoCEMMS laboratory at the University of Illinois.

Students also created polymers and designed bridges in an engineering outreach.

In addition, students took command of emerging technologies such as unmanned aerial robots, through EnLIST’s “Drones for Schools” program, and piloted an unmanned aerial vehicle to learn about sensors, robotics, and flight.
Moon Goons fly through science lessons

Katie Hickey Snyder, Zanne Newman, UIUC "Moon Goons", Matthew Schroyer
Mats Selen

To continue the Stratton Leadership and Microsociety Magnet School, Zanne Newman and Katie Hickey Snyder sought to increase the number of "drones" related activities after a successful collaboration with EnLiST’s "Drones for Schools" program.

Mats Selen, UIUC professor of chemistry, provided a link to several engineering undergraduates who had received a prestigious grant to conduct experiments on NASA’s zero gravity jet. The engineering students established a student organization at UIUC, and called themselves “Moon Goons.”

The Moon Goons grant called for experimenting with a method to land an unmanned aircraft, commonly called a “drone,” in microgravity conditions. This is a difficult task that is only made possible with a combination of software and mechanical solutions.

Part of the NASA grant required that Moon Goons perform community outreach to get students excited about STEM careers. With coordination from EnLiST’s Matthew Schroyer, and Stratton’s Katie Hickey and Zanne Newman, Moon Goons visited Stratton on two consecutive days to teach about artificial intelligence, computer vision, physics, and more.

This two-day experience was documented by local news outlets, including the News Gazette and the CBS affiliate WCIA.

Moon Goons will conduct their experiment in Houston, Texas aboard NASA’s "Vomit Comet" during the summer of 2013, and will return to Stratton to share what they learned from their experiment.
Students go green with biodiesel production

When high school sophomore Ana Hernandez proposed her science fair project about biodiesel emissions, she had not planned on launching a suite of biodiesel processors for other Chicago Public Schools and The Museum of Science and Industry. Fueled by physics teacher Brian Severs’ innovation and a desire to change the world, the Whitney M. Young Magnet High School student teamed up with four classmates to do that and more.

With skills garnered from a University of Illinois sponsored grant, EnLiST, Sievers coached Hernandez and the student team into developing an outreach project beyond the classroom and into the community. The students called themselves Whitney Young Biodiesel HEROS – or Helping to Engender Renewable Organic Energy Sources.

Armed with buckets, panty hose, and vats of used cooking oil, the students have filtered more than 1,200 gallons of used oil into more than 130 gallons of golden biodiesel to fuel anything from a go-cart to a VW Jetta. They have collaborated with engineering professors and graduate students at the University of Illinois in Chicago and plan to visit Argonne National Laboratory, one of the U.S. Department of Energy’s oldest and largest national laboratories for science and engineering research. At Argonne, the team hopes to conduct an analysis of the composition of their biodiesel to evaluate its specifications and performance.

While the research component is crucial, Sievers said his training as a fellow in the Entrepreneurial Leadership in STEM Teaching and Learning (EnLiST) initiative helped hone his networking skills, which have landed the HEROES group new connections and research partners.

“Through his management with EnLiST, we saw Brian developing the collaborative and leadership skills that enable him to facilitate the development of other teachers along these entrepreneurial lines,” said Fouad Abd-El-Khalick, the head of the department of Curriculum and Instruction at the University of Illinois, and a co-principal investigator of EnLiST. “His projects now feature increasingly wider networks of collaborators with more ambitious goals and enriched experiences and engagement for his and others’ students.”

He is an UIUC graduate of mechanical engineering, and a Core I teacher leader in the EnLiST initiative, funded by the National Science Foundation. His
past EnLiST projects have included humanitarian efforts for Haiti. He continues to brainstorm ways to enhance quality of life, incorporating students as key players.

“Brian is sharing his ideas and his expertise with other teachers, other students, other districts, and other organizations,” said Anita Martin, EnLiST project director. “He won the Lexus Eco Challenge in 2009, helped Mother McAuley students win it again in 2010, taught at Whitney Young to help those students win it, and now has moved on to other initiatives.”

In addition to research, the students added a service component to their efforts by supplying local farmers with the clear-burning fuel. They also donated biodiesel to run the “Fresh Moves Mobile Produce Market,” an outfitted CTA bus, which brings fresh produce to urban areas of Chicago that lack access to fruits and veggies. The club’s initial donation was 105 gallons, with hopes of increasing that amount.

“This project is also about community service as much as it is research,” Sievers said, adding that the students built a full-scale biodiesel production system for the Museum of Science and Industry. “The students unveiled their display and spent the day informing visitors about how to make biodiesel, the benefits of biodiesel, and demonstrated how to make biodiesel in a 2-Liter bottle.”

Other public interactions include presentations at the Peggy Notebart Museum, where the Biodiesel Club designed an art-board display describing their project.

“This group of high school students is learning that they and alternative fuels, like biodiesel, can make a difference in the environment,” Sievers said. “A new generation, a new fuel.”
Mats Selen, a professor of physics at the University of Illinois, recently slid a wheeled cart the size of an iPhone across his desk. The device bounced off of his hand, and a running line of his computer screen blipped upward.

“I found some stuff that I thought was really exciting that I never imagined doing before,” Selen said. “By great luck, it worked really well.”

While playing with the blue cart looked like a great deal of fun, as principal investigator of the EnLiST National Science Foundation grant, Selen was serious about the implication to physics education. Inspired by creating instructional materials for the EnLiST physics summer institutes for K-12 STEM teachers, he realized there was a need for versatile equipment to teach physics both inside, and outside of the traditional lab setting.

The device, called IOLab (for Interactive Online Laboratory), is about the size of a smartphone, is equipped with three wheels so that it can be moved along a tabletop or track. Its movements are recorded by a suite of sensors packed into the device, including an accelerometer, a Hall probe, a force probe, a gyroscope, sounds and light sensors, pressure and temperature sensors, and a high-gain amplifier, all of which can be used in conjunction with educational software to teach basic physics lessons out-of-the-box.
But a number of expansion ports on the device allow the physics cart to be upgraded with a near limitless number of sensors and detectors for future lessons. The gadget links wirelessly to a PC, which receives and graphs the data in real time for physics students. Once fully developed, students will be able to purchase the inexpensive device at a university bookstore, allowing them to bring a complete physics lab to their dorm or home office.

That kind of flexibility can open up new frontiers in physics education. For example, students can conduct a number of simple lab activities and learn about Newtonian motion at home, which can lead up to a more complex laboratory exercise on campus. This online preparation tactic – known as "pre-lecture" – was developed by Gary Gladding, Tim Stelzer and Selen at the University of Illinois as part of their “smartPhysics” course development for Macmillan publishing.

Giving students the opportunity to participate in lab activities as part of their lecture preparation “opens up a whole new world as far as interacting with students in class,” Selen said.

The IOLab device can also provide a valuable hands-on component to online courses and MOOC’s (massively open-online courses), and having the convenience of an inexpensive, all-in-one physics lab also lowers barriers for teaching university-level physics at high schools.

Selen’s initial motivation to lower barriers and seek out fun ways to enhance physics education came from his experience teaching the EnLiST institutes. The collaborative effort to develop the device and associated course material serves as a case study of the entrepreneurial spirit that EnLiST encourages. Selen credited the initiative for providing the inspiration to step outside of his comfort zone and make this kind of work possible.

"In particular, working with (EnLiST CO-Pls) Ray Price, Pat Shapley, and Fouad Abd-El-Khalick has been a great opportunity for me to learn how other people teach, to learn to teach better myself, and to become motivated to improve the way we teach physics here in the department,” Selen said.

With support provided by Macmillan publishing, about 70 of the devices have been made so far. Selen and his colleague Tim Stelzer have an NSF/TUES grant to investigate the pedagogy enabled by IOLab, and several studies have already been carried out at the University of Illinois, Parkland College and Millikin University.
In its efforts to nurture entrepreneurial STEM teacher leaders, the EnLiST project strives to engage EnLiST Fellows in ever expanding collaborations and learning networks that cut across science content areas and classrooms, as well as school levels and buildings, both within and across the EnLiST partner school districts.

This aim is a major focus of the program’s Entrepreneurial Teacher Leadership (ETL) summer institute, where Fellows were afforded opportunities to organize around, and lead, collaborative and innovative projects to help transform science learning for students across school building and grade levels.

In this context, Matt Sly, an EnLiST Core I teacher leader and high school science teacher at Urbana School District 116, pioneered a project between his students and the kindergarten and first grade students at Urbana’s Leal and Prairie Elementary Schools.

High school students interviewed their K-5 counterparts, using flip cams, to discover misconceptions about the sun, earth, and moon.

Capitalizing on opportunities made possible through the EnLiST project, Sly teamed up with LaDonna Helm, Sandra Deville and Joyce Raney—EnLiST Fellows and teachers at the two elementary schools—to align the timeframe and units during which their students learn about earth and space science. Next, Sly tasked his high school students with helping their elementary counterparts learn about some key concepts in this science domain throughout the span of the shared units.

High school students created simple hands-on activities to address K-5 students’ incorrect understandings about space.

This helped elementary students learn about many of the target astronomy concepts that were not easy to comprehend, given the developmental level of elementary students. So, Sly’s students had a challenging task ahead of them.

Sly was excited to see how his students’ understandings and creativity would come through as they attempted to figure out the best approach to work with elementary students: “From my perspective, it was interesting to see the way kids came up with their own models, with their own games, and with their own ways of engaging kids mentally and physically.”
To make the material relevant and meaningful to elementary students, high schoolers needed to represent the concepts at a level that was developmentally accessible to the kindergarteners and first graders. This meant Sly’s students first had to figure out their target audiences’ background knowledge.

With support from EnLiST, the high school students used Flip cameras to interview their elementary counterparts about their ideas related to the earth, sun, and moon.

Sly supported his students as they analyzed these ‘data,’ making sure to address some of the high schoolers’ naïve concepts in astronomy along the way.

“I probably included some things that I normally wouldn’t have spent time on; content wise, and I think that was actually very beneficial because this project allowed me to clear up some misconceptions that my kids had that I wouldn’t have even thought to question it had I not spent time on getting them ready to teach kindergarten or first grade students,” said Sly.

Teaching to the kindergarten and first grade students has also given the high school students a real audience. Previously, Sly relied on hypothetical audiences and situations. “Finally it was a real audience and it held [my students] accountable to that. I liked watching the kids’ creativity come out a bit more than maybe I would have seen otherwise, because they were making it for a different audience. It wasn’t a fake audience of kindergarteners; it was real.”

The elementary students and their teachers were quite engaged with the activities that the high school students developed.

Equally important was the fact that the latter students realized that the best way to learn something is to try to teach about it to others.

In effect, both elementary and high school students were engaged with science teaching and learning, which brought about more favorable attitudes toward science and deeper science learning for all concerned.

“Obviously, EnLiST was the motivating force behind this project,” said Sly.
Beth Chamberlain, a chemistry, physics, and engineering teacher who also is the Science Department Co-Head at Danville High School, embodies the essence of what it means to be an entrepreneurial STEM teacher leader. In addition to teaching science to high school students in the formal setting of her school, Chamberlain and a long-time EnLIST Fellow, constantly seeks opportunities and resources to make science learning accessible and engaging to younger students in informal settings. This is particularly significant because science teaching and learning receives little attention in the greater majority of elementary classrooms across the nation.

One of Beth’s projects is a science summer camp for the YMCA and Boys and Girls Club in Danville, Illinois. Each summer the camp features a mystery theme, such as the “Case of the Kidnapped Cookies,” whereby kids use and, thus, learn science in order to solve the case. Throughout the mystery, kids get to learn about core biology, chemistry, physics, and engineering concepts through exciting, hands-on activities, such as finger printing, extracting DNA from strawberries, and doing simulated “spatter analysis” with ketchup.

Chamberlain has orchestrated her science summer camps for over a decade in two different towns. Originally, she offered the camp in a rural community in partnership with a local chemical plant. When Chamberlain relocated to Danville, the camp idea came with her, but not the sponsorship. She worked diligently to nurture connections in the community, and was successful in securing new avenues of financial support for her camps through grants and partnerships with local organizations, such as the YMCA and the Boys and Girls Club, in addition to EnLIST and several businesses in the community. The camp has grown to include over 100 elementary school students each summer, who partake in all activities at virtually no cost to them. But the science learning opportunities do not stop with the younger students: High school students also are tapped to engage with the camps. They are offered the opportunity to serve as camp counselors, which enables them to better develop their own understandings of science concepts and hone their scientific inquiry skills as they facilitate the engagement of elementary students with camp
investigations."
The summer camp, like all of Chamberlain's projects, places a strong emphasis on inquiry-based learning and hands-on/minds-on activities to promote learning in both formal and informal settings. This style, along with her ability to meaningfully engage and connect students with science at all academic levels, makes Chamberlain's efforts particularly effective.

She is simultaneously successful in improving elementary students' understandings of scientific concepts, enhancing their attitudes toward science, and bolstering their problem solving skills, as well as enabling high school students to apply their science learning and partake in significant service to their community.

Chamberlain's leadership and efforts bring science to kids who otherwise would have limited opportunities to experience the power of understanding and thrill of solving problems. She is an exemplary leader who works diligently and marshals resources to provide equitable access, and nurture a future generation of individuals capable of contributing, to the scientific and engineering enterprise.
Alexander Scheeline, 
Bach Fuge, 
Kathleen Kelley

Cellphone spectrometer brings invention back to science classrooms

Professor Alexander Scheeline in the Department of Chemistry at the University of Illinois is one of the Senior Personnel on the EnLiST project. Along with a number of colleagues in the Department of Chemistry, he has been pivotal to the development and delivery of the EnLiST Chemistry Summer Institute; a two-week intensive learning experience for EnLiST Fellows who teach high school chemistry.

A hallmark of the EnLiST Institutes is the creativity and entrepreneurship that science faculty bring to the task of engaging EnLiST Fellows with learning experiences that are both accessible and cutting-edge, while providing for ways to enable teachers to take such learning experiences back to their students. Professor Scheeline is in no short supply of both creativity and entrepreneurial skills when it comes to working with students and teachers.

Professor Scheeline at the University of Illinois likes to think that science is very similar to music. In explaining the similarity between the two, he presents the analogy of attempting to learn a Bach fugue. When practicing, you get to the point where you are good at playing most of the fugue, except for a select 20 seconds. What do you do? You practice the section that needs work. “You run towards the problem,” Scheeline said.

“The same thing is true of research, especially in the chemical sciences. Most things you understand. What you want to do is break down the things you don’t understand.”

This perspective permeates the way Professor Scheeline approaches teaching. For about 30 years, he has taught spectrometry as a part of the field of analytical chemistry. “I tried for 25 years to teach students the concept of stray light and they could mouth the words, but they had no clue what it was,” says Scheeline.

In May of 2008, Professor Scheeline went to teach a class of students in Hanoi, Vietnam as a result of a collaboration of the Department of Chemistry at the University of Illinois and the Department of Chemistry at the Hanoi University of Science. He was shocked by the squalor he saw; their resource base was thin, aside from a new set of lab benches.

While these conditions were not initially a problem for this particular visit as he was teaching quantitative analysis, the next year Professor Scheeline was supposed to return to teach instrumental analysis. “I thought, ‘how in the world am I going to teach instrumental analysis to students who have never had...
their hands on an instrument?”
To Scheeline, the answer seemed obvious: to have the students build a simple instrument in order for them to understand how it works. After deciding on the topic of spectrometry, he set out to find the materials to make a cheap spectrometer. For the light source, he put together a LED light and a three-volt battery, like the ones found in car key fobs for 88 cents apiece. By this time, Kathleen Kelley was an EnLiST teaching assistant, and it was she who figured out the elegant, connector-free battery/LED assembly. In addition, the diffraction gratings and cuvettes necessary are cheap and easy to find. From there, the only missing component was a cheap photodetector. Fortunately, in this day and age, the problem can be solved easily enough. Scheeline had noticed during his visit to Vietnam that many students had cell phones, and many of those cell phones had cameras. Unique to this undertaking, he also developed software to supplement the spectrometer. “If you don’t have the software, you have this data, which ends up being a bunch of pretty pictures, but what do you do with it?”

While this financially savvy spectrophotometer is not the most accurate instrument, its obvious flaws inspired him. “One of the reasons it’s hard to teach about modern instruments is that while they have all the flaws the old instruments have, it’s hard to see the flaws because they have been reduced to such low levels. Here, that’s not a problem.” It is this failure that allows students to discover concepts and limitations of analytical chemistry and spectrometry for themselves. Scheeline saw this phenomenon when he went to a summer outreach program at Clark Atlanta University in 2009.

When a high school student in the program saw the room light affecting the results of the cell phone spectrometer, she realized there was a problem. Due to the fact that the inner workings of the instrument were exposed, rather than the usual design of having a spectrometer enclosed in a box, she discovered the concept of stray light on her own.

This use of an instrumental flaw, dubbed a ‘creative failure’ by Scheeline, acts as a teaching tool that forces students to problem solve. Science should be more than simple memorization and regurgitation; it requires creativity. Professor Scheeline put his spectrophotometer toward this very use during the 2009 and 2010 EnLiST Chemistry Summer Institutes.

Scheeline believes that creativity “is one of the things that is missing in American education these days, because if you’re teaching for a multiple choice test, you cannot teach creativity. Here, you say, ‘here are some parts, go play,’ you’re teaching creativity!” In bringing creativity back into the classroom, building the spectrometer themselves can help develop skills required for inventing. Even if the students only create what has already been invented, the thought process of developing ideas is represented.

The importance of this project also extends past the classroom. For instance, the use of cheap instruments in the classroom can act as a leveler that paves the way for a more egalitarian scientific field. “The ideal thing, of course, is to open the pipeline to everybody rather than just the stereotypical upper middle class that has been dominating American science for the past couple of generations,” says Scheeline of his hope for the future of the field. He has already had the opportunity to see how the cell phone spectrometer is a step in the right direction. In getting the word out about this project, Scheeline was contacted by a high school teacher in Camden, New Jersey with limited resources wanting to bring this project to his students.

As a direct result, the morale of teachers improved along with the self-confidence of students. By giving students the opportunity to do things themselves, teachers are affording them the chance to gain a sense of self-efficacy; it becomes something that they can say, ‘I can do this myself.’ In his words, “the first person singular really matters to most people.”

In addition, Professor Scheeline has always been very open with sharing his developments with others and making this particular resource available to science teachers across the nation. From the beginning, he was always open to collaboration and other’s input. In relation to the software that he wrote, he always knew that it would one day become an app for a cell phone.

When Dave Bomberg asked about adapting the idea to the Android phone, his response was to go for it. His approach is to “join the crowd, have fun with it.”
If the EnLiST summer institutes are the cornerstone of the Partnership, the annual dinner and poster seminar is the capstone experience.

Each year, EnLiST teacher leaders return to the University of Illinois to present the fruits of their collaborations and systemic initiatives.

EnLiST teacher leaders display posters which feature their innovations in a “walk-through” format, which encourages conversations around science teaching and learning.

The poster seminar gives teacher leaders an opportunity to re-connect with their peers, and exchange valuable information about the successes and challenges of their collaborations.

Throughout the years at EnLiST, the poster seminar has provided a showcase for the substantial innovations which feature creativity, strong leadership, and transformative impact on student learning.

The EnLiST family
In recent years, the EnLiST annual poster seminar has expanded to include multimedia presentations, including e-Posters. These electronic versions of traditional poster boards are displayed on Smart Boards, giving both EnLiST Teacher Leaders and members of the public a demonstration of pivotal learning technologies.

EnLiST teacher leaders walk away with a stronger sense of their STEM community, and a renewed perspective on the possibilities of transformative change in science teaching.
Teacher leaders continue their conversations on STEM education and leadership during the annual dinner. Principals and other essential administrators from school districts throughout Illinois join in this conversation, as well as STEM leaders from the University of Illinois community.

For 2012, Paul Ritter, president of the Illinois Science Teachers Association who was ranked the third-best science teacher in the world by the United Nations, spoke to more than 150 science teachers, administrators, university faculty, and EnLiST partners about the impact of science teaching on students’ lives.

Amir Abo-Shaeer, an engineering teacher who founded a nonprofit organization to fund a new engineering wing onto his Los Angeles high school, addressed the EnLiST family in 2011. Carol Frericks, the superintendent of the Western Community Unit School District in Barry, IL, spoke in 2010.

Fouad Abd-El-Khalick, the head of the Department of Curriculum and Instruction at the College of Education, and a Co-Principal Investigator for the EnLiST grant, also spoke about the latest impacts and accomplishments to come out of EnLiST partner school districts.
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