STEM Smart: Lessons Learned From Successful Schools

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Program Descriptions

The session title appears in parentheses when different from the program description title.

EFFECTIVE INSTRUCTION

EQUAL ACCESS TO QUALITY STEM EXPERIENCES

SUPPORTIVE INFRASTRUCTURE FOR STEM LEARNING

Deeply Digital Student Engagement and STEM Learning with Models and Probes

Background

The Concord Consortium is a nonprofit R&D organization in Concord, Mass., dedicated to transforming education through technology. Our free, deeply-digital tools and learning activities capture the power of curiosity and create revolutionary new approaches to science, math, and engineering education that bring out the inner scientist in everyone. Since 1994, we have been pioneers in probeware, models and simulations, data collection with mobile computing, online assessment and teacher professional development, and the nation's first online high school.

The Molecular Workbench is a software suite providing visual, interactive computational experiments for teaching and learning science, including a full set of simulation engines enabling students to explore the atomic and molecular world firsthand, a wide ranging suite of curricula from biology to chemistry to physics, and in-depth assessment capabilities that provide an in-depth view of student understanding.

Our High Adventure Science activities engage students with unanswered questions in Earth and space science today, exploring cross-cutting ideas such as feedback loops and complex systems in the process.

Our Evolution Readiness series of activities helps elementary school students learn about the underpinnings of natural selection using a curriculum involving models, simulations, and hands-on, in-classroom activities.

Our Engineering Energy Efficiency curriculum makes use of digital tools and real-time data collection via probes and sensors to teach students concepts of energy and energy transfer and help them apply these concepts in an engineering curriculum as they design, build, and test model solar houses.

The Geniverse project weaves the central concepts of genetics together with a rich narrative thread and a game-like framework to help introductory high school biology students understand the central dogma of biology and appreciate the practices and concepts that underlie modern bioinformatics and DNA science. Students experiment with fanciful dragons, designing and performing experiments, solving carefully designed challenges, and employing important scientific practices such as scientific argumentation.

In our SmartGraphs mathematics and physical science curricula, students use deeply digital tools to build essential skills and understanding about critical concepts such as graphing and graph interpretation. SmartGraphs technology provides instructional scaffolds to help students explore difficult to learn concepts.

Technology Enhanced Elementary and Middle School Science (TEEMSS) 2 is a physical science curriculum for grades 3–8 that utilizes computers, sensors, and interactive models to support investigations of real-world phenomena.

Documented Results

The above projects and many more from the Concord Consortium are designed with research-based concepts at their core and with the support of measurable student learning gains as the primary goal. For many of the above projects, research studies are still ongoing. Some completed or in-process research results are below.

Selected examples

- The TEEMSS 2 curriculum was found to have potentially positive effects on general science achievement for elementary school students in grades 3–4, and is listed as an effective curriculum in the prestigious What Works Clearinghouse.
- In a Rhode Island study, teachers completing a professional development program and students using a series of Molecular Workbench activities embedded in courses showed statistically significant improvements in content knowledge on a Molecular Concept Inventory (MCI). Though students had broad exposure to many topics within the courses overall, student gains on the MCI were related to the number and content of the Molecular Workbench activities they completed.
- Students completing High Adventure Science curriculum units significantly improved their scientific reasoning and their scientific argumentation ability, by 0.64 standard deviation (SD) for the "Modeling Earth's climate" investigation, 0.77 SD for the "Will there be enough fresh water?" investigation, and 0.85 SD for the "Is there life in space?" investigation. The improvement occurred in all four elements of scientific reasoning and argumentation—claim, explanation, uncertainty rating, and uncertainty rationale—and students retained or even further improved their scientific argumentation after High Adventure Science investigations were finished.
- For the Evolution Readiness curriculum, a comparison of item maps revealed that two implementation cohorts of fourth-grade students had a more complex understanding of selected concepts in natural selection than students in the pre-implementation cohort, performing statistically significantly higher (effect sizes of 0.46 and 0.33 SD) on an assessment of these concepts.
- Students using a series of SmartGraphs activities related to the motion of objects, a standard topic taught in eighth/ninth-grade physical science classes, demonstrated greater gains on a test focused on seven motion-related learning goals than students in a control group studying the same topics using the same textbooks, and the difference was statistically significant at the $p<0.05$ level.

Potential Applications

Concord Consortium activities are designed for use in a wide variety of classrooms and many are, by their nature, adaptable to a broad set of delivery mechanisms and conditions. They are often optimized for 1:1 computing scenarios, but teachers frequently find they can be presented effectively in groups or in whole-class instruction. Many can also be adapted well to informal settings, especially those involving hands-on, inquiry-based exploration or data collection and analysis.

Many activities provide Universal Design for Learning scaffolds and/or dual language capabilities. Additionally, many can also be customized by the teacher to suit particular topics, classrooms, or curricular demands. This capability permits their use with a diverse set of classroom applications and student populations.

For More Information

All of our curricula and activities can be used free of charge. Activities, information about our research focus areas, additional projects, and lists of our published research results can be accessed at our website, http://concord.org. This website also provides an opportunity to subscribe to free newsletters and mailings describing our ongoing work, as well as opportunities for teacher participation in current and upcoming research and testing of educational technology for science, math, and engineering.

Framework Vision for Science Education and Implications for *Next Generation Science Standards*

Background

The *Next Generation Science Standards* (NGSS) are a set of science education standards being developed based on a vision for science education established by *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas,* published by the National Research Council in 2012. Publication of the framework was the first of a two-step process to produce a set of *Next Generation Science Standards* for voluntary adoption by the states. The NGSS are currently being developed by a team of writers including researchers, education policy specialists, scientists, and classroom teachers. The development is being coordinated by Achieve and 26 lead states.

The first draft of the NGSS was released to the public for comment in May 2012. The writing team is currently responding to the comments of the public and expert groups that reviewed the draft. Another public review is currently scheduled for late fall with the final standards expected in 2013. These standards describe student performances at the intersection of the three dimensions of science described in the framework, and they are designed to provide assessable performance expectations for all students.

Understanding the framework and NGSS is essential to implement meaningful changes in science teaching and learning. The potential for the framework's vision to be fully realized hinges largely on the quality of the NGSS and practitioners' understanding of the intersection of the three dimensions of science described in the framework. The framework's vision takes into account two major goals for K–12 science education: (1) educating all students in science and engineering and (2) providing the foundational knowledge for those who will become the scientists, engineers, technologists, and technicians of the future. The framework principally concerns itself with the first task: what all students should know in preparation for their individual lives and for their roles as citizens in this technology-rich and scientifically complex world (NRC, 2012).

The framework is designed to help realize a vision for science and engineering education in which students, over multiple years of school, actively engage in science and engineering practices, utilizing crosscutting concepts and core ideas to make sense of scientific phenomena. Instruction that focuses student learning on the three dimensions may be accomplished in a number of ways, but what should be clear is that separating the doing of science from the knowing of science, as many current state standards imply, is not consistent with the framework's vision.

Models of professional development and implementation of instruction provide teachers with meaningful ways to understand and use the three dimensions of science as described in the framework. The Utah Partnership for Effective Science Teaching and Learning uses a model built on this concept to provide teachers with the tools for effective instruction at the intersection of the three dimensions. During the past four years, this partnership has provided teachers with instructional models for using the crosscutting concepts, disciplinary core ideas, and science and engineering practices. The models help elementary teachers make sense of the science needed to understand core ideas specific to matter, energy, and forces. Reducing the ideas down to a few core ideas that have utility across all of science helps teachers improve instruction. When students develop a deeper understanding of a few core ideas, they are able to make sense of novel phenomena. Focusing on core ideas requires eliminating ideas that are not central to the development of science understanding. Core ideas should be both foundational in terms of connections to many related scientific concepts and have the potential for sustained exploration at increasingly sophisticated levels across grades (NRC, 2007).

Students are able to make sense of scientific phenomena when they are able to develop causal relationships, supported by evidence, of observed phenomena in defined systems. The crosscutting concepts organize a set of familiar touchstones for students to use in their sense making and evidence gathering. Students utilize these crosscutting concepts in the process of gathering and using evidence for the science and engineering practices. The practices engage students in gathering and using information from investigations and other sources, developing and using models, constructing explanations and communicating arguments that support these explanations.

Insights into the vision of the three dimensions of science described in the framework, the implications for the NGSS, as well as the professional development that will lead to successful implementation of the vision for science education are critical for the education system to make changes consistent with the framework. The ongoing discussion specific to implementing the NGSS and the implications for professional development, STEM education, and instructional materials is necessary but not sufficient. Models of classroom instruction will be necessary to move the vision forward, and teachers need to embrace the proposed changes for science education. Successful implementation requires coherence of all the components of the education system working in logical ways to support the new vision.

References

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National Research Council. (2007). *Taking Science to School: Learning and Teaching Science in Grades K 8.* Committee on Science Learning, Kindergarten Through Eighth Grade. Richard A. Duschl, Heidi A. Schweingruber, and Andrew W. Shouse, Editors. Board on Science Education, Center for Education. Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

For More Information

The framework is available to download at: http://www.nap.edu/catalog.php?record_id=13165
Information about the NGSS is available at: http://www.nextgenscience.org/
Taking Science to School is available at: http://www.nap.edu/catalog.php?record_id=11625

Illustrative Mathematics

There is a clamor of activity inside districts and state departments of education as they gear up to implement the *Common Core State Standards* (CCSS); many well-intended people are working hard to "align" their materials to the CCSS. However, as the CCSS clearly states, "These standards are not intended to be new names for old ways of doing business." The *Common Core State Standards* are profoundly different from most state standards documents, but those differences are not always obvious to teachers, curriculum developers, assessment writers, teacher educators, or policy makers.

The goal of Illustrative Mathematics is to clarify the meaning and intent of the *Common Core State Standards* by publishing tasks and tools that support implementation of the CCSS. Illustrative Mathematics is a growing community of mathematics teachers, mathematics educators, and mathematicians that provides leadership and guidance by illustrating the mathematics that students should experience in a faithful implementation of the CCSS.

There are almost 500 published tasks linked to individual standards and clusters in the CCSS. The contributors to Illustrative Mathematics are building sets of tasks that, taken together, fully illustrate the intention, depth, breadth, meaning, and faithful implementation of the CCSS; our goal is to have 2,000 tasks in the next 2-3 years. While not every set will exhibit every characteristic, we want sets of tasks that illustrate a standard to lend themselves to teaching and learning as well as assessment, tasks that drill into the related knowledge and skills, and tasks that probe conceptual understanding. Our goal is that every task in the set has a specific purpose and reason for inclusion. Eventually, tasks will also be arranged into progressions across grades illustrating important streams and connections that define structures such as those described in the progressions documents.

Illustrative Mathematics is chaired by William McCallum, one of the lead writers of the *Common Core State Standards*. We currently have over 6,500 registered users; over 200 have contributed directly to the development of tasks thorough writing, reviewing, or commenting on tasks. But Illustrative Mathematics is more than a place where people come to view and work on tasks. It is the meeting place of a growing, discerning community building professional norms and expertise in task analysis and refinement. And in the future, that work will grow to include all aspects of teaching and learning mathematics that support students in doing mathematical work.

For More Information
The public face of Illustrative Mathematics is a website: http://illustrativemathematics.org/.

SimScientists: Effective Instruction and Assessment

Background

A series of national reports urge science education to go beyond emphasis on basic science facts to support science learning that results in deep understanding of scientific ideas and an ability to engage meaningfully in the practices of science (Bransford et al., 2000; Duschl et al., 2007). Inquiry practices—asking questions, finding ways to explore them empirically, investigating and evaluating competing alternative models, arguing from evidence—are judged to be severely lacking in the enacted U.S. curriculum. The report, *Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics,* emphasizes the need for instruction that is inquiry-based and problem-centered and that engages students in the practices of science. Strong instruction should be accompanied by a supportive system of assessment that links classroom, district, and state reports of science learning progress.

The National Science Foundation (NSF) has funded projects that have produced suites of simulation-based assessment and instructional resources along with research evidence of their feasibility for classroom use, utility for instructional decision-making, and technical quality as evidence of complex science learning. These research and development projects form the SimScientists program in WestEd's Science Technology, Engineering, and Math program. (See http://simscientists.org.) The projects have conducted field tests in five states (including Nevada) to document their feasibility, utility, quality, and impacts on learning.

A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas and the draft *Next Generation Science Standards* seek to focus on fewer, deeper learning goals. Systems thinking and model-based learning are identified as key resources for reformulating science education (NRC, 2011, 2012). The cross-cutting concepts of Systems and Models are recommended for application to life, physical, and Earth science so that students develop the kinds of organized knowledge structures held by experts. Also highlighted is the scientific practice of developing and using models to visualize, study, understand, and communicate about systems.

The NSF-funded Calipers I and II projects have developed simulations to assess complex science learning. The Foundations of 21st Century Science Assessment project has conducted research on the value of static, animated, and interactive environments for providing evidence of students' skills in using inquiry strategies. Related SimScientists projects have extended the use of science simulations to support instruction and to build coherent sets of science assessments that could be used at classroom, district, and state levels.

All of the SimScientists modules incorporate research-based learning principles: meaningful problems, application of science knowledge in active investigations, formative assessment, and articulation and reflection. The science simulations present students with rich authentic environments that present simplified models of complex systems in the natural world such as ecosystems or watersheds. The simulations are dynamic and can show processes that may be otherwise unobservable and cannot be directly manipulated because they are too large (earthquakes) or too small (chemical reactions), too fast (hurricanes) or too slow (plant growth or erosion). The simulations are designed to represent the cross-cutting structures of all systems—components, interactions, and emergent system behavior. For example, consumers and producers are components in all ecosystems. They interact to transmit energy and matter throughout an ecosystem. Interactions among the component organisms result in emergent population levels that can vary under changing conditions. Because simulations can be manipulated to test predictions such as the effects of changes in numbers of organisms or environmental conditions on population levels, students can demonstrate their abilities to engage in the inquiry practices of science by actively conducting investigations. In addition, as students conduct inquiry by using simulations, data can be collected automatically to trigger individualized feedback, provide links to further instruction, and generate reports on learning progress.

Figure 1 shows screenshots from embedded modules of a terrestrial ecosystem for middle school. In the left screenshot, students are asked to draw a food web showing the transfer of matter and energy between organisms based on observations of feeding behaviors in the ecosystem. When a student draws an incorrect arrow, a feedback box coaches students to observe again by reviewing the animation and then to draw the arrow from food source to consumer. Feedback addresses common misconceptions. The right screenshot shows coaching for investigations of population changes due to variations of nonliving and living factors.

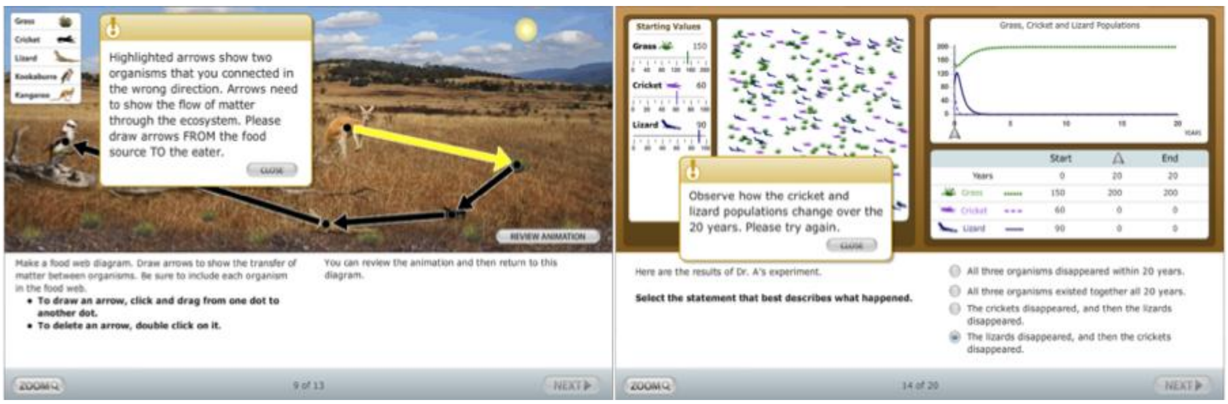

Figure 1. Screenshots from two *SimScientists* Ecosystem curriculum modules.

Simulations can also expand the ways students show what they know by offering a range of response formats "beyond the bubble," such as hot spots, drag and drop, drawing, operating sliders, and generating graphics, tables, and visualizations. This greater range of ways to show science phenomena in action and the allowance of multiple ways to respond offer great promise for reducing language demands and increasing access for students with disabilities and English learners (Quellmalz, Timms, & Silberglitt, 2012).

In the Calipers II project, assessments were developed that shared common specifications and simulation environments to provide sets of assessments for classroom, district, and state levels that were vertically linked. At the classroom level, simulations form the bases of curriculum-embedded assessments to monitor progress. The curriculum-embedded, simulation-based assessments are intended to be formative—to provide feedback and additional instruction (in the form of graduated coaching) as needed. The same simulation environments host end-of-unit benchmark assessments intended for summative information about student proficiency on science content and practices. Suites of simulation-based modules were developed for middle school life and physical science systems. A new project is developing sets of simulation-based signature tasks, derived from the same designs. These shorter simulations could function as components of district or state science tests. Another NSF-funded project, Human Body Systems, is extending the use of simulations to high school biology.

For More Information
Simulation-based curriculum and assessment modules are available for use by districts and states. More information can be found at http://simscientists.org and by contacting Edys Quellmalz (equellm@wested.org) at (650) 381-6427.

Using Learning Trajectories to Unpack and Interpret the Common Core Math Standards

Background

The state-led Common Core State Standards Initiative represents the leading wave of a sea change in public education aimed at putting United States education and students on par with those of leading countries—intensifying educational standards, improving coherence among the state education systems, improving instruction, and developing and deploying new approaches to curriculum and in-class and summative assessment. Educators across the country are discovering that the *Common Core State Standards for Mathematics* (CCSSM) represent major changes from "business as usual": fundamental changes in depth of content, as well as earlier introduction of major blocks of content, compared to previous state standards. The need for sustained coherent professional development to support CCSSM implementation is widely acknowledged.

The CCSSM are based on the concept of learning trajectories (LTs)/progressions—using LTs to support instruction and standards. They offer a rare large-scale opportunity to focus on improving the "instructional core" through emphasis on conceptual growth across the grades, and linking learning research to instructional practice. LTs lay out paths by which student reasoning builds to increasingly sophisticated levels. Beginning with students' prior knowledge, they are most important for identifying the intermediate states of understanding that students are likely to traverse, through instruction, on the way to achieving rich goals of mathematical understanding.

The Turnonccmath project is a response to the urgent need to interpret the CCSSM within a LT framework. Drawing on our research team's experience in student learning research and in developing and representing LTs and standards, we have created a set of learning trajectory-based resources aimed at teachers, professional development staff, and teacher educators.

In turnonccmath.net, we identify 18 LTs to cover all the K–8 CCSSM. The LTs are mapped onto the CCSSM hexagon map developed by J. Confrey, A. Maloney, and the GISMO research team of NC State University. Each of the 18 learning trajectories for the CCSSM is accompanied by a detailed *descriptor* document containing a structural overview of the LT, the full set of standards for that LT, and descriptors that "unpack" the standards into the learning trajectory, using several elements:

- *Conceptual Principles* pertaining to the standards topics within an LT
- *Student Strategies, Representations, and Misconceptions*
- *Meaningful Distinctions* among different closely-related topics, representations, and concepts, and *Multiple Models* for approaching problems and tasks
- *Coherent Structures* of related sub-topics or repeating themes of the LT
- *Bridging Standards*, where necessary, to support transitions between standards that were not specific or detailed enough to support instructional implementation of some standards in the CCSSM

At presentations and professional workshops for audiences that have included teachers, school principals, and state curriculum supervisors, Turnonccmath team members have encountered a uniformly enthusiastic response to the resources we currently have available. With 10 or 15 minutes to explore the site, workshop participants have responded that the site is easy to navigate, rich with information, and comprises resources that they intend to use repeatedly in their instructional preparation or professional development presentations.

The highly positive reception to the current version of turnonccmath.net demonstrates the potential usefulness of these resources across the community. We are now extending and deepening turnonccmath.net's resources. A major aim is an iterative improvement model, through which the usefulness of the turnonccmath.net resources can be improved to meet particular implementation support needs (for teachers, professional development, and teacher educators) through a combination of Web analytic and face-to-face approaches (currently under development). The suite of resources will eventually include (1) stand-alone presentations (both PowerPoint and video) for use by any interested educators, (2) customizable lists of research and practitioner references, and (3) student work examples mapped to the LTs and standards.

For More Information

See turnonccmath.net to explore the current version of resources available.
Contact Alan Maloney (alan_maloney@ncsu.edu) for further information about project progress, and to discuss participation in user group evaluation of the resources.

Video-rich, Web-based Professional Development to Improve Science Discussions

Background

Perhaps the greatest challenge required by the *Next Generation Science Standards* is the creation of coherence—coherence in order to develop deeper learning from grade to grade, and coherence in the support systems of curriculum, assessment, and professional development.

To help students develop scientifically sound ideas and practices, curricula need to support deep restructuring of their knowledge. This requires that the core ideas of science are addressed with coherence from one grade to the next. Moreover, it requires alignment among curriculum, assessment, and professional development.

Many National Science Foundation-funded projects, including The Inquiry Project at TERC, are engaged in creating curriculum coherence through careful study of how learning progresses. The Inquiry Project curriculum is based on elaboration and refinement of the grades 3–5 portion of a learning progression for matter, and focuses sharply on the core idea of matter and its component ideas of material, weight, volume, and transformations of matter. The curriculum carefully builds the foundation for students' later understanding of matter at both the macroscopic scale, visible to the naked eye, and the microscopic scale, where matter appears as discrete particles. The curriculum emphasizes progressive deepening of understanding across grades, the integration of mathematics into the science content, and a focus on inquiry and scientific practices.

A complementary project, Talk Science, provides scalable, Web-based professional development designed to help teachers facilitate productive science discussions. The professional development is explicitly aligned with the Inquiry curriculum, providing coherence and near transfer between teacher learning, and what and how they teach.

To strengthen classroom science discussions, teachers deepen their understanding of science content, study video cases of discussions taking place in other classrooms, and develop nine strategies to support productive talk. They engage in guided independent study, try out ideas in their classrooms, and participate in grade-level study-group meetings in order to share their progress.

The Inquiry and Talk Science team comprises diverse expertise: teachers and their students, school leaders, science educators, scientists, cognitive psychologists, socio-linguists, curriculum developers, Web developers, and researchers. Of special importance were the teachers who openly shared their classrooms and practice.

Documented Results

A longitudinal study was conducted to compare the learning of students who used the Inquiry Curriculum with those who did not. This informed further refinement of both the curriculum and learning progression. Students who had the curriculum made more progress in moving from perception-based to model-mediated understanding of materials and matter. The report is available at http://inquiryproject.terc.edu.

The Talk Science research is still underway. It focuses on the process of teacher learning and the changes in discussion patterns evidenced in science classrooms. Four key areas are considered: (1) classroom discourse practices, (2) teachers' participation in study groups, (3) teachers' understanding about the role of discussion in science classes, and (4) teachers' facility with the scientific ideas in the curriculum. Preliminary analysis of the data suggests that teachers are able to bring more productive talk moves into their classroom discussions, especially when the curriculum incorporates science discussion.

Over the past seven years, the Inquiry Project curriculum and Talk Science professional development have been implemented in urban, suburban, and rural classrooms. Approximately 50 classrooms in Massachusetts and Vermont use the curriculum. The materials were revised based on the research findings and feedback from the classroom.

Potential Applications
The Inquiry Project curriculum and guides for grade-specific implementation workshops are openly available for school and district use at http://inquiryproject.terc.edu.

The Talk Science Professional Development Program is also openly available at http://inquiryproject.terc.edu. This program is designed to work in conjunction with the Inquiry Project curriculum, providing just-in-time support. Links to the Talk Science cases are embedded in the Inquiry Project curriculum so that teachers have easy access to these resources as they teach. The program is most successful when supported and recognized by district or school leaders. There are cases, however, where grade-level teams have successfully organized and facilitate their own study.

Many of the Talk Science strategies are applicable to other curriculum areas and may be helpful for cross-discipline professional development purposes.

For More Information
Please contact Sue Doubler (sue_doubler@terc.edu).

Leadership Institute for Teachers (LIFT)

Background

Our research focuses on university/public school partnerships to develop effective mathematics programs for all students. Through National Science Foundation funding, New Mexico State University (NMSU) has engaged in the Gadsden Mathematics Initiative (GMI), Scaling up Mathematics Achievement (SUMA) and currently the Leadership Institute for Teachers. Through our research efforts, we better understand what it takes to build viable sustainable learning systems and how to support English language learners in mathematics achievement.

The MC^2-LIFT project is a five-year research partnership between New Mexico State University (NMSU) and five southern New Mexico school districts. Mathematicians, education faculty, and school leaders collaboratively design the MC^2-LIFT project. Each LIFT cohort comprises about 30 mathematics teacher leaders who develop their knowledge and understanding of K–12 mathematics and the leadership skills for improving teaching and learning.

The goals of the project are to:

- Increase teacher leaders' knowledge of K–12 mathematics and expand and enrich pedagogical practices through blended courses that are team taught by mathematicians and math educators.
- Develop intellectual leaders who understand what students should learn and who can differentiate instruction in their own classrooms and support other teachers to meet the needs of diverse learners.
- Implement LIFT Institute Learning in their classrooms and schools with mentoring from the School Support Team.
- Build and sustain viable partnerships between mathematicians, education faculty, and school districts.

MC^2-LIFT provides participating teachers and math coaches with two years of coursework involving intensive summer study, as well as a follow-up academic-year program that includes application of their learning in their school or district settings. Each semester and during the summer, pairs of courses are designed and team taught by NMSU mathematicians and educators, blending mathematical concepts with knowledge and skills in pedagogy and leadership. Cohort members work together for two years and have the opportunity to earn a Master of Arts degree in teaching mathematics. Teacher leaders come from elementary, middle, and high schools or serve as math coaches in a school district.

The cohort members, as teacher leaders in the LIFT program, gain a new lens for learning mathematics by studying how concepts progress through the K–12 continuum, connecting within and across grade levels in the LIFT institutes. They are developing a deeper understanding of mathematical concepts through engaging in rigorous math tasks to strengthen mathematical thinking and reasoning, sense making, communication, and math connections in the LIFT program. Then, by developing a range of models and strategies to represent mathematical ideas, teacher leaders support other teachers at their respective schools to differentiate their instruction and to meet the needs of diverse learners in their classrooms. The LIFT coursework is developed from the premise that effective mathematics teaching requires a deep understanding of mathematics, pedagogy, and pedagogical content knowledge to advance K–12 students' learning and achievement.

Principals also engage in professional learning during MC^2-LIFT courses for gaining an understanding of how to foster a collaborative culture for teaching and learning mathematics on their campus. Principals and teacher leaders are developing a shared vision for the teacher leaders' roles in their classrooms, schools, or districts, communicating expectations for professional learning among school staff and gauging the progress that their schools are making toward student learning goals. The LIFT School Support Team helps to connect the university institute experiences to the school site and classroom. LIFT utilizes these school-based team structures for supporting professional learning throughout the year. The School Support Team provides onsite ongoing mentoring for teacher leaders and utilizes extensive feedback in shaping support at the campus, connecting research and practice, and informing course development.

Documented Results

The Gadsden Mathematics Initiative helped us to understand essential components of a dynamic district model for significantly improving mathematics achievement for all students. As a result of the GMI, these key components were integrated into a building-capacity model for mathematics teaching and learning. The model was subsequently implemented through a partnership between NMSU and a school district in the desert southwest. The SUMA research project focused on the ways in which the systemic model should be modified to ensure its effectiveness in a large urban district with relatively high numbers of English language learners. The project also examined which components of the model had the greatest effect on student achievement. The results of this research project contribute to a broader understanding of systemic mathematics reform in five specific areas: (1) how to build the capacity of the district system-wide, (2) the importance and nature of professional development, (3) the effective use of data to drive improvements in student achievement, (4) instrumentation to document classroom learning environments, and (5) developing viable partnerships.

The lessons learned in the SUMA research are applied in the LIFT. The MC^2-LIFT program has designed unique graduate coursework and mentored K–12 teachers using a variety of models, including peer observations and lesson-study. Through these methods, teachers have been able to modify their teaching methods and practices to improve their own effectiveness as educators, which have increased student academic achievement.

At Monte Vista Elementary in Las Cruces, it has become evident that collaborating with teachers at the school level and providing an in-depth understanding of mathematical concepts can effectively support student learning. Monte Vista Elementary achieved a grade of "A" for two consecutive years on the state report card, but more importantly the students are engaged and excelling in mathematics. The multicultural educators presenting in the workshop will share methods that are implemented both in their classrooms as well as school-wide, to support all students' achievement in mathematics particularly English language learners.

For More Information

Please contact Cathy Kinzer (cakinzer@nmsu.edu).

Living in Relations

Background

The long-term goal of the Living in Relations project is to improve science learning and school achievement for NativeAmerican children. Data from our project's studies of children's understandings of biology indicate that Native American children begin school with an advanced understanding of biology compared to their non-Native peers. This finding is also supported by early positive performance on standardized tests. However, this early overachievement is not sustained and leads to significant under-representation of Native American students in STEM fields. Understanding why and how this happens is a central purpose of our research. To do this, we explore the ways in which culture, cognition, and development are intertwined and impact teaching and learning, particularly at the epistemological level. In partnership with local Native American communities, our research team develops innovative science learning environments that build on students' cultural ways of knowing to develop robust, engaging, and empowering learning environments for Native American students. While our work explores these issues in Native American communities specifically, our findings are applicable to other non-dominant students.

Documented Results

We have demonstrated a wide range of converging cross-cultural differences in knowledge, knowledge organization, and impacts on reasoning and sense making. For example, our studies have shown that Native American children are more likely to reason along ecological lines closer to that of complex systems than non-Native American youth. Further, when learning environments recognize these strengths, complex forms of inquiry are accessible in previously unengaged ways. We have also shown that when science learning environments incorporate the following design characteristics, Native American students' learning is significantly impacted. The design characteristics are: (1) use local, place-based instruction and hands-on experiences; (2) link community participation and practices with classroom learning; (3) premise on the idea that nature is not an externality, apart from humans, but rather that humans are a part of nature; (4) motivate and organize around a big idea, in our case the idea that everything is related and has a role to play in the universe (systems level or ecosystems thinking); (5) place science in an inter-disciplinary or holistic context and invite the learner to view phenomena from multiple perspectives and highlight the need for participation and leadership; (6) include community values, needs, language and experiences; (7) engage phenomena from a seasonal/cyclical perspective; and (8) actively explore and address relationships and tensions between Native American science and Western science.

Potential Applications

There are far reaching applications of our work particularly in the development of curricula and in teaching practice. Further, our research practices have had significant impacts on building local Native community capacity and increasing the number of Native people pursuing advanced degrees in disciplines related to our research.

For More Information

Contact Megan Bang (mbang3@uw.edu).

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Science Foundation Arizona (SFAz)

Background
Over a period of several years, Science Foundation Arizona (SFAz) has successfully partnered with key leaders to establish the Arizona STEM Network to drive access to effective STEM education for all Arizona students by creating a culture of achievement. As part of this work, SFAz has led a number of projects focused on implementing and sustaining Engineering Pathways, a model that links student experiences across education sectors (K–12 through postsecondary) to engage and excite students about STEM career opportunities, prepare students for rigorous college coursework, and support acquisition of meaningful career knowledge and skills leading to program degrees and credentials, and completers performing in the workplace.

SFAz initially partnered with Cochise College, using SFAz and National Science Foundation's Advanced Technological Education (ATE) funding, to more fully develop its Engineering Pathway into a proven model. Over a period of time, Cochise College has introduced strategic activities/programs across the Pathway Model, including:

- Career Exploration
  - Math/Science Experience (4th–8th grades): A one-day, on-campus experience with 50 organizations serving 1,160 students in 2011.
  - STEM Exploration (9th–10th grades): Four days of targeted activities enrolling 46 students during 2010–11, up from 40 the previous year.
  - Classroom speakers and university visits (11th–12th grades): 12 classroom presentations, with 30 – 35 students visiting Arizona State University (ASU).
- Math Education
  - Summer Math Academy (7th–8th grades): On-campus summer camp for students improving math skills, with 29 students in summer 2011.
  - ITV Consortium Math Outreach: Using technology to connect college with local high schools to support offering of Pre-calculus and Calculus I courses to high school students, with 12 students enrolled in 2011–12, up from 10 the previous year.
  - Professional Learning Council: Instructors/support staff from across education sectors participating in research-driven inquiry focused on improving student success in math and along the Engineering Pathway.
- Early College
  - Running Start Academy (RSA): On-campus early college experience for "ready" high school students focused on engineering (technical and transfer) courses and targeted student support strategies. Initial high school junior enrollment in the RSA program in fall 2011 was 35 students, double the enrollment compared with fall 2010. Female enrollment was also up to 55% from 28% in the prior year.
  - Industry engagement to support curriculum development and provide meaningful intern opportunities for high school students.
  - Curriculum opportunities include traditional and hands-on learning around preparation of future engineers and/or technicians.
- Transfer Education
  - Established STEM degree pathways with universities.
  - Member of ASU's Motivated Engineering Transfer Students (METS) program, funded by the NSF, to support community college/university transfer students in engineering.

- Industry engagement to support curriculum development and provide meaningful intern opportunities for college school students, with eight students interning at a local technology company in a pilot program for summer 2012.

Preliminary Results

Junior and senior high school students qualify for the Running Start Academy through a math placement test at the college and are able to earn between 40 and 42 transferable college credits during their two years in the program, leaving them just 20 to 22 credits short of an associate of science degree in engineering. Findings over the course of two academic years show very strong student support for the quality of the program, and 87% indicated an interest in a STEM field of study. A follow-up survey in October 2011 of May 2011 Running Start graduates showed that of the 13 that responded, all were attending college either at Cochise College in a two-year program or at a university in a Baccalaureate degree program. Over 90% identified themselves as currently enrolled in a STEM major.

The applied technology program at Cochise College is a four-course program developed by Siemens Corporation offering students hands-on electro-mechanical and robotics experience toward a Level 1 technician certificate for an automated machine operator. Students taking the courses have been positive about the potential benefit to future employers. Active, involved employer support is intended to help Cochise College find internships for these students and recruit new high school students to this program. All students who have participated in the program said that the courses were useful and expressed interest in continuing their education at a university in an engineering program.

Potential Applications

SFAz is well positioned to lead and facilitate the expansion of a proven engineering pathway model and serve as a key resource to industry, K–12, and higher education leaders and educators. Working alongside Cochise College provides SFAz the opportunity to scale proven components to rural communities while also using its predictive analytics and measurements capability to inform future state and regional efforts. As a result, SFAz has already led the expansion of model pathway components to three additional rural community colleges—Arizona Western College, Central Arizona College, and Yavapai College—using one-year American Recovery and Reinvestment Act (ARRA) funding to expand STEM.

For More Information

Arizona STEM Network, led by Science Foundation Arizona: www.sfaz.org
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Cochise College: www.cochise.edu
Contact: Verlyn Fick, Ph.D., Vice President of Instruction/Provost
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Math, Engineering, Science Achievement (MESA) Program

Background

Co-curricular programs complement the formal curriculum and often have sessions outside of the regular school day. A review of evaluation reports from afterschool Science, Technology, Engineering, and Mathematics (STEM) programs, both co-curricular and extra-curricular, by the Afterschool Alliance found that students attending these programs had improved attitudes toward STEM fields and careers; increased STEM knowledge and skills; and had a higher likelihood of graduating and pursuing a STEM career.[1] Afterschool programs can provide a safe place for students to explore a STEM field, which contributes to student gains in intellectual skills and temperament to become a scientist.[2]

The Math, Engineering, Science Achievement (MESA) program utilizes a co-curricular program that supports educationally disadvantaged students by providing pathways for minority students to succeed in science, mathematics, and engineering disciplines.[3] MESA was started in 1970 as an inter-segmental program, administered through the California Public School System, Community College System, and California College System. Because of the success of MESA in California, the program has expanded to seven other states. MESA USA is a partnership of MESA programs in nine states: Arizona, California, Colorado, Maryland, New Mexico, Oregon, Pennsylvania, Utah, and Washington. MESA USA programs are based on the academic enrichment model originating in California. They include many of the following elements: SAT/ACT preparation, study skills training, hands-on activities, competitions, career and college exploration through field trips and guest speakers, parent leadership development, individual academic plans, and teacher training opportunities. Annually, students in MESA USA programs participate in a national engineering design competition.[4]

An exploratory study funded by the National Science Foundation examines the influences MESA activities have on students' perception of engineering and their self-efficacy and interest in engineering and their subsequent decisions to pursue careers in engineering. The MESA activities included in the study are field trips, guest lecturers, design competitions, hands-on activities, and student career and academic advisement. Focus group interviews were conducted in the 2010–2011 school year to better develop a survey instrument. The survey instrument, Engineering Self-Efficacy, Interest and Perception Survey (ESIPS), was developed and piloted with 166 students from MESA programs in Utah, Washington, and California.

Documented Results

The results of the grounded theory approach to analyzing the focus group responses produced eight disparate themes including (a) informal mentoring, (b) makes learning fun (c) time management (d) application of math and science, (e) feelings of accomplishment, (f) builds confidence, (g) camaraderie, and (h) exposure to new opportunities. We are in the process of conducting a factor analysis from the pilot study, which was conducted last fall and spring.

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[1] Afterschool Alliance. (2011, September). *STEM learning in afterschool: An analysis of impact and outcomes*.
[2] Crane, R., Thiry, H., & Laursen, S. (2011). *Broadening the view: First steps toward mapping the national landscape of out-of-school-time science education.* Presented at Inciting the Social Imagination: Education Research for the Public Good, Annual Meeting of the American Educational Research Association, New Orleans, LA, April 8–12.
[3] Kane, M. A., Beals, C., Valeau, E. J., and Johnson, M. J. (2004). Fostering success among traditionally underrepresented student groups: Hartnell College's approach to implementation of the Math, Engineering, and Science Achievement (MESA) Program." *Community College Journal of Research and Practice, 28*(1), pp. 17–26.
[4] MESA USA. Retrieved from http://mesa.ucop.edu/about/mesausa.html on February 17, 2012.

Potential Applications

As formal and informal learning environments are modified to appeal to a more diverse array of students, it is important to understand which instructional strategies appeal to diverse students and how the activities impact their self-efficacy, interest, and perceptions. The survey instrument was developed specifically to investigate MESA's effectiveness in recruiting and retaining underrepresented populations to degree programs within the STEM field. The results of the quantitative analysis produced eight themes that are being incorporated in the development of a survey instrument to support focused work with MESA. The approach used in this developmental effort may be applicable to investigations of the impact of other informal education efforts that have similar goals in serving students from groups that are underrepresented in engineering and interested in increasing participation of underrepresented students.

For More Information

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Mathematics, the Common Core Standards, and Language: Mathematics Instruction for ELs Aligned with the Common Core

Background

The need for research-based recommendations for mathematics instruction for English learners (ELs), aligned with the *Common Core State Standards* (CCSS), cannot be overstated. The recommendations focus on improving mathematics learning and teaching through language for all students, and especially for ELs. Although it is difficult to make generalizations about the instructional needs of all students who are learning English, instruction should be informed by knowledge of students' experiences with mathematics instruction, language history, and educational background (Moschkovich, 2010). In addition, research suggests that high-quality instruction for ELs that supports student achievement has two general characteristics: a view of language as a resource rather than a deficiency and an emphasis on academic achievement, not only on learning English (Gándara & Contreras, 2009).

Research provides general guidelines for instruction for this student population. Overall, students who are labeled as ELs are from non-dominant communities, and they need access to curricula, instruction, and teachers proven to be effective in supporting the academic success of these students. The general characteristics of such environments are that curricula provide "abundant and diverse opportunities for speaking, listening, reading, and writing" and that instruction "encourage students to take risks, construct meaning, and seek reinterpretations of knowledge within compatible social contexts" (Garcia & Gonzalez, 1995, p. 424).

Research shows that ELs, even as they are learning English, can participate in discussions where they grapple with important mathematical content. Instruction for this population should not emphasize low-level language skills over opportunities to actively communicate about mathematical ideas. Research on language and mathematics education provides several guidelines for instructional practices for teaching ELs mathematics (Moschkovich, 2010). Mathematics instruction for ELs should:

1) Address much more than vocabulary
2) Support EL's participation in mathematical discussions as they learn English
3) Draw on multiple resources available in classrooms (objects, drawings, graphs, and gestures) as well as home languages and experiences outside of school

What is effective mathematics instruction?

According to a review of the research (Hiebert & Grouws, 2007), mathematics teaching that makes a difference in student achievement and promotes conceptual development in mathematics has two central features: one is that teachers and students attend explicitly to concepts and the other is that teachers give students the time to wrestle with important mathematics. Mathematics instruction for ELs should follow these general recommendations for high-quality mathematics instruction—to focus on mathematical concepts and the connections among those concepts and to use and maintain high cognitive demand mathematical tasks, for example, by encouraging students to explain their problem-solving and reasoning (AERA 2006; Stein, Grover, & Henningsen 1996).

How can mathematics instruction align with Common Core State Standards?

First and foremost, teach mathematics for understanding! Students should use and connect multiple representations, share and refine their reasoning, and develop meaning for symbols. Mathematics instruction for ELs should align with the CCSS, particularly in these four ways:

1. *Balance conceptual understanding and procedural fluency.* Instruction should balance student activities that address important conceptual and procedural knowledge and connect the two types of knowledge.
2. *Maintain high cognitive demand.* Instruction should use high cognitive demand math tasks and maintain the rigor of tasks throughout lessons and units.
3. *Develop beliefs.* Instruction should support students in developing beliefs that mathematics is sensible, worthwhile, and doable.
4. *Engage students in mathematical practices*. Instruction should provide opportunities for students to engage in mathematical practices such as solving problems, making connections, understanding multiple representations of mathematical concepts, communicating their thinking, justifying their reasoning, and critiquing arguments.

CCSS Mathematical Practices:
1. Make sense of problems and persevere in solving them
2. Reason abstractly and quantitatively
3. Construct viable arguments and critique the reasoning of others
4. Model with mathematics
5. Use appropriate tools strategically
6. Attend to precision
7. Look for and make use of structure
8. Look for and express regularity in repeated reasoning

Recommendations for Connecting Mathematical Content to Language:
1. Focus on students' mathematical reasoning, not accuracy in using language.
2. Focus on mathematical discourse practices, not language as words, or grammar.
3. Recognize the complexity of language in math classrooms.
4. Treat everyday language as a resource, not as an obstacle.
5. Uncover the mathematics in what students say and do.

References furnished upon request.

For More Information
This summary was based on "Mathematics, the Common Core, and Language" Understanding Language: http://ell.stanford.edu/.

See http://people.ucsc.edu/~jmoschko/.

Seeds of Science/Roots of Reading: An Integrated Approach to Science and Literacy Instruction

Closing the achievement gap in our nation between native English speakers and English language learners will require educators to address the needs of the English language learners. Along with being the fastest growing segment of the school population, English language learners are also among the most academically vulnerable students in schools today (Wong-Fillmore & Snow, 2000). In science achievement, in particular, English language learners score significantly below their native English-speaking peers. The 2005 National Assessment of Educational Progress data shows only 28% of fourth-grade English language learners scored at or above basic level for science compared with 71% of native English speakers (National Center for Educational Statistics, 2005). Moreover, this achievement gap between native speakers of English and English language learners is persistent. The average science scores of eighth- and twelfth-graders identified as being English language learners did not change significantly between 1996, 2000, and 2004, remaining markedly below those of native English speakers (National Center for Educational Statistics, 2005).

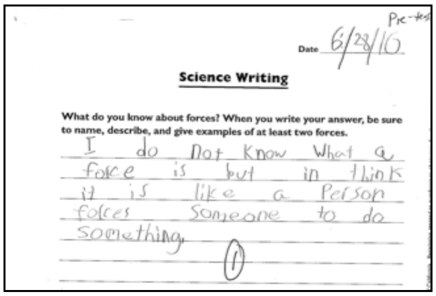
Background

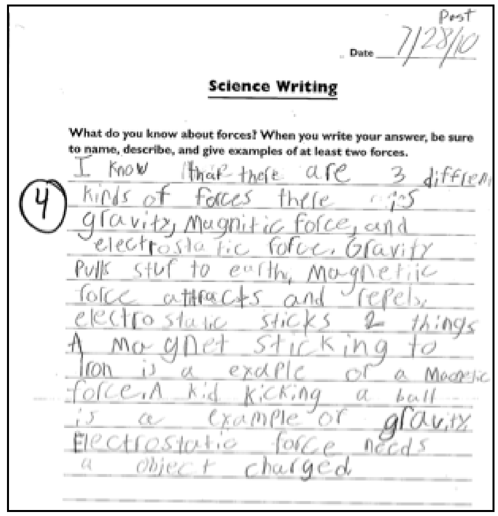
Seeds of Science/Roots of Reading (Seeds/Roots), developed jointly by the University of California, Berkeley's Lawrence Hall of Science and Graduate School of Education, set out to address this growing reality in our nation's schools. The Seeds/Roots curriculum program for grades 2–5 provides students with multiple ways to access science knowledge through a Do-it, Talk-it, Read-it, and Write-it approach. It engages students in deep forays in science learning, while increasing student skills in reading, writing, and discussing as scientists do. Explicit instruction on how to read and write science text and engage in science talk provides students with the support they need to successfully participate in all class activities. Finally, teachers are provided with just-in-time support and suggestions for strategies for accommodating the needs of English language learners in their classes.

Documented Results

More than 300 teachers and their students have participated in studies to test the efficacy of the Seeds/Roots curriculum units. An independent evaluator, the National Center for Research on Evaluation, Standards and Student Testing (CRESST) at UCLA, has conducted randomized control studies on two of the grades 2–3 units, one of the grades 3–4 units, and one of the grades 4–5 units. Looking across the studies, students using the Seeds/Roots curriculum have consistently outperformed students using business-as-usual, content-comparable science units on measures of science understanding and science vocabulary, with mixed results for science writing and science reading comprehension (Cervetti, Barber, Dorph, Pearson, & Goldschmidt, 2012; Duesbury, Werblow & Twyman, 2011; Wang & Herman, 2005). Analysis of the performance of English language learners in these studies provides growing evidence that the Seeds/Roots model of instruction provides greater access to science knowledge than typical science programs and helps English language learners develop academic language. In the study, we focused on grades 2–3 Seeds/Roots units, over 1/3 of the 89 classrooms had at least 30% English language learners. The English language learners in that study made equivalent gains on all science measures and most literacy measures to their English-speaking counterparts (Wang & Herman, 2005). Using results from the study focused on a grades 4–5 Seeds/Roots unit, Duesbury, Werblow, & Twyman (2011) found that English language learners in the Seeds/Roots classrooms outperformed a comparison group of English language learners in the areas of science understanding, understanding of the nature of science, and science vocabulary. Finally, in a random control study focused on the support characteristics of the Seeds/Roots teachers guides, teachers with access to just-in-time suggestions of strategies to use in accommodating the needs of English language learners employed more (and a broader range of) accommodation strategies than comparison teachers.

Taken together, these results provide a promising picture of the effectiveness of the Seeds/Roots program for use in our nation's increasingly language-diverse classrooms.


Pre-test
Date 6/28/10
Science Writing
What do you know about forces? When you write your answer, be sure to name, describe, and give examples of at least two forces.
I do Not Know What a force is but in think it is like a Person forces Someone to do something
(1)


Post
Date 7/28/10
Science Writing
What do you know about forces? When you write your answer, be sure to name, describe, and give examples of at least two forces.
(4)
I know that there are 3 differen kinds of forces there is gravity, Magnitic force, and electrostatic force. Gravity Pulls stuf to earth, Magnetic force attracts and repels. electrostatic sticks 2 things A magnet sticking to Iron is a exaple of a Magnetic force, A kid kicking a ball is a example of gravity Electrostatic force needs a object charged

Pre-and Post-Test Science Writing (before and after 3rd-grade ELL student participates in the Seeds/Roots Gravity and Magnetism unit)

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National Center for Education Statistics (2005). *Science 2005: Assessment of student performance in grades 4, 8, and 12*. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

Wong-Fillmore, L. & Snow, C. (2000). *What teachers need to know about language*. Washington, DC: Center for Applied Linguistics.

For More Information

For general programmatic information: http://www.scienceandliteracy.org
For research and efficacy data: http://www.scienceandliteracy.org/research/efficacy_studies
For information about purchasing Seeds/Roots: http://www.wirelessgeneration.com/ordersos

Career and Technical Academy Innovations in Teaching and Learning

Background

The Southwest Career and Technical Academy (CTA), an Apple Distinguished School, is a Clark County School District (CCSD) public magnet school in its fourth year of operation that has 1,400 students enrolled in 11 different career and technical education (CTE) program areas. The school is divided into two smaller personalized learning communities—the Design Academy and the Professional Service Academy. Within the Design Academy, the Southwest CTA offers the following areas of specialization: Entertainment Engineering, Fashion Design, Video Game Design, and Web Design. In the Professional Services Academy, the areas of focus are Culinary Arts, Hospitality, Travel and Tourism, Automotive Technology, Respiratory Therapy, Dental Assisting, and a Certified Nursing Assistant Program. Within the smaller learning communities, students who have common career interests share English, math, science, social studies, electives, and program classes. In the classroom, project-based learning activities simulate real-world experiences, preparing students for entry into the workforce, post-secondary training, or study at the college and university level. Teachers and students have access to laptops, computer labs, iPods, and iPads. Students extend their learning day through the integration of the Flipped Classroom method, teacher podcasts, ePubs, the use of Google Apps and other online resources for assignments and educational tools. Using innovative technology has impacted the academic culture at Southwest CTA because the school is providing an education that relates to the 21st century student.

Documented Results

With the increased access to technology and a forward approach to delivering digital content, the Southwest CTA has experienced tremendous academic success and growth in Adequate Yearly Progress (AYP) and district-wide benchmark common assessments.

- During its first year (2009–2010), the Southwest CTA achieved an AYP report rating of "Adequate." At the end of the second year (2010–2011), our school achieved an AYP report rating of "Exemplary." At the end of the 2011–2012 school years, our school was designated as "Continued Exemplary." The CCSD goal for ELA was 76.92% and SWCTA achieved a 96.02% pass rate. The CCSD goal for math was 81.51% and SWCTA achieved a 93.6% pass rate. AYP data is based on our junior class results on the required Nevada state English Language Arts, Math, and Science graduation exit exams.
- The Clark County School District has been working to develop district-wide benchmark common assessments in core subject areas, with the first area being math. These math assessments are given at the end of the first and second semester in Pre-Algebra, Algebra I, Geometry, and Algebra II. For the past three years, Southwest CTA has consistently scored above the school district average in all four subjects.

Potential Applications

All teachers and administrators have received formal training in project-based learning. Project-based learning supports cross-curricular projects. To succeed in the industry, students need to have (1) a solid skill set and practice in teamwork, collaboration, and communication (both written and verbal), (2) a professional work ethic, and (3) a desire to learn and research new ideas to add to their current knowledge base. Through our use of project-based learning, students collaborate in groups requiring communication inside and outside the classroom using intra-school e-mail, social media and mobile devices. They must also create unique and interesting projects and presentations to demonstrate their understanding of the material. Southwest CTA works hard to promote a natural curiosity in its students through the use of technology and the fostering of a highly collaborative environment. Students are given the opportunity to solve problems, investigate issues, and then create presentations that demonstrate an understanding of the issues and curriculum. The kinds of projects that prepare students for real-world experiences are the ones that take an actual problem that the students need to research, analyze, and create a solution for an individual, a business, a government agency, and various other entities.

One example of a STEM project at Southwest CTA is an 11th-grade guitar project in the entertainment engineering program. In collaboration with the math and physics teachers, students explore all aspects of STEM that are present in the construction and usage of the guitar. While exploring the relationship of math and science during the process of making a working instrument, students each design, fabricate, and tune their guitars to industry standards. The STEM guitar project was originally developed from a National Science Foundation grant in coordination with Fender Guitars and Purdue University and has been adapted successfully into woodshop, drafting, science, and engineering high school classes throughout the United States, as well as community college electives and after school programs as early as middle school. Schools can scale the project down by purchasing the complete kits and having teams of four or five students build one guitar using common hand tools. Teams can use the guitar to expand into areas such as music, marketing, manufacturing and entrepreneurship.

For More Information
Southwest CTA Website: http://swcta.net
Southwest CTA Student Showcase: http://swcta.net/showcase
The Buck Institute for Education (Project-Based Learning): http://www.bie.org
The National Science Foundation STEM Guitar Project: http://www.guitarbuilding.org

Creating a High Performing STEM School Culture

Background
DSST's (Denver School for Science and Technology) Stapleton High is the founding school in a network of public charter schools. DSST Public Schools currently operates five STEM open-enrollment charter schools, four middle schools, and two high schools, serving almost 2,000 students in Denver, Colorado.

Because we are charter schools, all of our students enroll through a non-selective, random lottery. As a result, our student body is very diverse: 50% of our students are low income and 70% are minorities. Our schools truly represent a cross section of Denver, the city we serve.

Documented Results
Last year, DSST Public Schools operated the highest performing middle school and high school in Denver. Within the state of Colorado, according to the Colorado Growth Model on the Colorado Student Assessment Program (CSAP) tests, our schools showed some of the highest growth numbers of all public schools. And at DSST: Stapleton High School, 100% of all five senior classes in the school's history have earned acceptances to four-year colleges. All of our students are prepared to study STEM-related disciplines in college, and we estimate that 40% of our students are choosing STEM fields after graduation.

Most importantly, DSST proves, without a doubt, that all students, regardless of race or income, can earn a rigorous STEM high school diploma and attend four-year colleges and universities. Preparing every student to succeed in a four-year college with the opportunity to study STEM is at the center of DSST's academic program. Our STEM program is centered on three pillars.

First, our schools are built on the premise that all students deserve access to a high-quality STEM education. A majority of DSST students enter well below grade level in the sixth and ninth grades and could never test into a magnet science program. Many students are conditioned to believe that science and advanced math "is an extra" and only for "smart kids." In our schools, these subjects are not extras, but core subjects for all students. All students have access to STEM college preparatory curricula.

Our second key belief is that schools must provide a rigorous STEM preparatory curriculum. We believe that the most important factor in a student choosing and ultimately completing a STEM degree is their preparedness to succeed at the college and graduate level.

Regardless of their starting point at DSST, all students are expected to pass three years of integrated science in middle school and more than five years in high school—and many students take more.Students take an algebra-based high school physics course in the ninth grade. This provides students with a lab-based class to practice, apply, and synthesize the math skills they are learning elsewhere. All ninth-grade students also take "Creative Engineering," where they learn the design process, how to conduct basic research, how to maximize and minimize constraints, and are hooked into engineering and the sciences as careers that improve the human condition. We are introducing an Engineering course in eighth grade this year that will increase the depth and rigor of engineering coursework in grades 8 and 9 by the end of next year. Students complete their high school requirements by taking a college-level physics class coupled with an engineering course or a college-level biochemistry class coupled with a bio-technology class. Math is also a critical component of a rigorous STEM curriculum. All DSST students are required to pass at least pre-calculus to graduate. In two years, we estimate that 85% of our students will pass calculus prior to graduation.

Lastly, we believe the success of any school must be rooted in a strong school culture that focuses on building character and creating an accountable environment that expects all students to be college ready. Students are challenged but supported in our schools. A peer-driven culture is reflected in each of our schools where going to college is cool and expected.

For More Information
Visit www.scienceandtech.org/ or http://dsstpublicschools.org/contact-us/.

e-Mentoring for Student Success (eMSS)

Background
Online professional development that provides content-focused mentoring is an optimal solution to support new teachers. While there are many different online professional development options available today, not all programs are the same. It is prudent to look to the recommendations and criteria outlined in the professional development and distance learning research and the research on mentoring to help guide the selection of an online professional development program that best meets the needs of beginning science, math, and special education teachers.

The e-Mentoring for Student Success (eMSS) program for beginning science, math, and special education teachers was developed based on the New Teacher Center's expertise, research and practitioner literature on professional development, online learning, and mentoring. eMSS offers a variety of science, math, and special education curriculum options for beginning teachers that are designed to support teachers' immediate short-term needs, inquiry into teaching practice, and understanding of content. eMSS is a year-long program that emphasizes the key structural features of an effective mentoring program.

Documented Results
Evaluation research on the eMSS program has shown that beginning teachers participating in eMSS have reported (a) a significant increase in preparedness in basic teaching and management skills; (b) that the eMSS components have enhanced their ability to teach science; and (c) that participation in the content areas improved their understanding of the content.

The mentors who participate in the program also report significant increases in feelings of preparedness to work with beginning teachers who teach challenging curricula, and the ability to be a content-focused mentor.

In addition, eMSS has been the focus of several dissertations, evaluation studies, and master's theses in which the following themes have emerged.

New Teacher Growth
Independent research shows that new teachers in eMSS increased their pedagogical-knowledge and pedagogical-content-knowledge understanding. New teachers are more confident in using a variety of strategies to influence how students learn math and science. The addition of using video of teaching practice as part of an observation cycle is a recent program enhancement also shown to impact new teacher development.

Meeting the Needs of New Teachers
All new teachers have needs that are unique to the early years in their careers, and this is even more evident in new special education teachers. New special education teachers in eMSS find support through relationships with mentors, pedagogical strategies, time management, and addressing the new teachers' emotional and psychological concerns. Mentors responsiveness supported a variety of new teacher needs.

Reflective Practice
Numerous studies identify the importance of reflective practice in teaching. The eMSS design utilizes varying levels of reflection processes. Making connection between the professional development in eMSS and the new teacher's classroom is a marker of effective professional development that impacts student achievement. The addition of using video of teaching practice as part of an observation cycle has deepened the level of reflective practice.

Mentor Growth
Mentors in eMSS are engaged in ongoing professional development to support the teachers they serve. eMSS is design to promote social knowledge construction through the interaction with the community, and eMSS has been shown to meet mentors' professional learning needs. Mentors in eMSS have a more focused level of support specific to STEM and special education.

Online Community Building
Vibrant and dynamic online communities of practice require support, nurturing, and topics that engage participants. The active facilitation in the design of eMSS has been shown to increase the quality of dialogue that impacts classroom practice, confidence, and leadership skills. Access of new teachers to an established online community builds their capacity for high-quality instruction and thus strengthens their content knowledge, and offers both personal learning networks and professional networks.

Retention
Retaining STEM and special education teachers in schools is difficult due to the challenges in finding qualified mentors. STEM teachers in eMSS have a retention rate of 80-95%, similar to in-person induction programs. A second retention study is currently underway.

Researcher Richard Ingersoll reports the STEM teacher shortage is not due to a lack of production but, rather, it is due to a lack of retention. He also reports that the strongest impacts on retention are a mentor in the same content area and collaboration time with other teachers in the same content area. In addition, his latest study indicates that induction programs with just a few components, such as those above, have a reduced impact on teacher retention.

Potential Applications
During the National Science Foundation (NSF) grant, eMSS scaled to over 1,000 participants successfully. Since 2007, eMSS has been a self-sustaining program. Currently, eMSS has projected numbers of new teachers approaching 1,000 with a growth plan and strategy to continue to grow and scale without a reduction in quality. In addition, eMSS provides (1) multiple entry points into the program to support new teachers, (2) support from a content-focused mentor, (3) access to a content-focused community of practice, and (4) access to Explorations—professional development modules designed for new teachers. As eMSS is an online nationwide program, geographic boundaries are not a barrier to support new teachers regardless of location and types of students being served.

For More Information
See http://www.newteachercenter.org/services/emss.

To discuss your state or district's support needs for beginning teachers of math, science or special education, email us at emss@newteachercenter.org or call 831-600-2200.

Implementing STEM Programs that Capture and Nurture Imaginations and Talents

Background

While the need for more experts and innovators in STEM fields is critical to the success of our nation and is increasing (National Science Board, 2012), the number of students pursuing and completing degrees in these fields is decreasing (National Academies of Science, 2011; National Science Board, 2012). Implementation of programs that will transform education and enhance the pipeline from grade school to university to the workforce is imperative (National Research Council, 2011). The Prime the Pipeline Project (P^3): Putting Knowledge to Work proposed a solution to this problem by designing, implementing, and evaluating the *scientific village* strategy for (1) increasing student interest in and success with the study of mathematics and science through engagement with teachers (as learners and collaborators) in the solution of challenging problems that mirror those faced by STEM professionals and that use workplace technologies, and (2) updating teachers in STEM fields.

Scientific Villages are communities of high school students and secondary school STEM teachers as learners; scientists from the university, business, or industry who design and lead the villages; and undergraduate STEM majors who serve as assistants to the scientists, mentors to the villagers, and role models for the students. Villagers (24 per village) work collaboratively on long-term projects/problems for a semester (9 sessions, 2 ¼ hours per session) and summer (10 sessions, 4 hours per session) in the labs at Arizona State University. The projects are of high interest, are similar to those faced by STEM professionals, and require application of STEM concepts and skills for their solutions. The approach during project engagement reverses the lecture-and-then-apply method of instruction. Rather, villagers bring to bear what they already know and gain information and direction at point of need. Four different villages were held each semester/summer. During the final session of each semester and summer program, villagers showcase their work for the community.

Connections Courses for Teachers, held daily in tandem with summer villages (an additional 2 hours per day, Monday through Thursday) and led by project staff, village leaders, and visiting scientists, provide teachers with (1) greater insight into big ideas in their content areas of expertise and sister fields, (2) experience with various types of assessment strategies, (3) methods for counseling students through the STEM pipeline, and (4) techniques for developing proposals to fund materials and supplies for implementing integrated content and project-driven learning in their classrooms.

The website for P^3 served as a communication portal for project activities and provided valuable information for participants, including access to technology support; links to STEM conferences, programs, and events in the Phoenix metropolitan area; and links to potential funders and grant development information. All village materials and products are available on the website.

Products include the *MATHgazines* and *MATHgazine Juniors* that continue to be produced every month with opportunities for students, teachers and families to solve and send in problem solutions to compete for STEMatician awards. The *Pipeline Story Book*, detailing village goals and projects, student and teacher recruitment and evaluation, and interviews with participants, is in production now. It will be available in print and uploaded as an e-book to the website. The project is also documented in the P^3 film, made by students under the direction of an Emmy-award winning filmmaker.

Documented Results

Evaluations showed that P^3 students completed significantly more STEM courses in high school, completed significantly more advanced courses in those fields, and had significantly higher GPAs than their controls. P^3 students were more likely to go to college and choose STEM or business majors—a significant increase over self-declared interest during their junior year in high school. Perseverance in majors in college is significantly higher for P^3 students than their controls. In interviews during and after P^3 students identified not only the great academic experiences, but also the confidence they gained from collaborating with new peers, teachers, and scientists, and working in the labs and other facilities of a large university campus. More than one-third of teachers stated that as a result of the P^3 experience, they are using long-term projects and investigations to enhance learning and exploration of new concepts with their students; 30% indicated higher expectations for their students' engagement and performance based on their collaborative work with P^3 students in scientific villages; 28% described their increased use of activities to develop students' critical-thinking and problem-solving talents; 28% identified an increased awareness of what interests and motivates students; and 21% cited several methods they had employed to foster collaborations among students. Teachers also gained skills in grant writing, with 40% attaining financial or technology support for implementation of project-driven programs in their classrooms. Awards ranged from $250 to $40,000.

Potential Applications

Based on the success of P^3, the Helios Education Foundation supported STEM in the Middle (SIM), targeting students in grades 5–8 and middle school teachers of mathematics, science, or technology (2010–2013). This is a Saturday morning program for both teachers (four Saturdays, 4 hours per session each semester) and students (Club STEM, seven Saturdays, 3 hours per session each semester) during the academic year, with an additional week in the summer for teachers. Students work on long-term, content-integrated projects. Like participants in P^3, Club STEM students are mentored by trained high school students and undergraduate STEM majors. The program for teachers focuses on the big ideas of mathematics and science developed in the middle grades and projects that facilitate student acquisition of those big ideas. In addition it focuses on the design, conduct, and analysis of assessment strategies; the development and offering of professional development programs with staff mentorship; and the production of proposals to fund needed resources. We are currently working on a program to engage elementary school students and their teachers in STEM explorations.

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For More Information

P^3, see http://primevillages.asu.edu/
SIM, see http://prime.asu.edu/ClubSTEM

NCTAF LEARNING STUDIOS

REINVENTING STEM EDUCATION

The world economy is rapidly outpacing America's development of STEM talent. Our students must learn more, do more, and create more. To meet this challenge, thousands of STEM professionals are ready to join forces with new and accomplished teachers to develop the next generation of innovators, entrepreneurs, and leaders we need to thrive in a global economy.

Tom Friedman has suggested that "We might be able to stimulate our way back to stability, but we can only invent our way back to prosperity. We need everyone at every level to get smarter." A century before him, John Dewey observed that "If we teach today's students as we taught yesterday's, we rob them of tomorrow." Getting smarter in schools means inventing a better way for teachers and STEM professionals to engage students in deeper learning. It's time to stop fixing the schools of the past so we can create the schools of the future—we don't have the time or resources to do both.

TEAM UP FOR 21ST CENTURY TEACHING

Learning Studios are innovation incubators that mobilize educators, business partners, and community leaders to remake STEM education for the 21st century. STEM professionals, teachers, and young people join forces in cross-generational teams that tackle significant community problems.

- **NCTAF** facilitates Learning Studio design workshops and develops well-structured partnerships among teachers, STEM professionals, and students who work together on year-long projects.
- **Studio students** become curious, thoughtful learners as they work on year-long inquiry projects with a team of four to six teachers and a STEM industry partner. Students develop the 21st century skills they need to truly prepare for college, careers, and life by learning STEM the way STEM is done: in hands-on, solution-focused teamwork.
- **Studio teachers** develop deeper content mastery in the sciences and engineering as they work with their STEM partners to design rigorous inquiry projects, and they become more effective teachers as they team up with colleagues to engage students in deeper learning.
- **Studio partners** discover how to translate their professional STEM expertise into well-structured and engaging student investigations, with coaching and support from accomplished Studio teachers who understand how children learn.

ABOUT NCTAF

The National Commission on Teaching and America's Future (NCTAF) was founded in 1994 to ensure that every child in America has access to quality teaching in schools organized for success. NCTAF is mobilizing educators, business partners, and community leaders to remake America's schools for the 21st century. We conduct research and develop demonstration programs to support deeper student learning with more effective teaching and higher impact community engagement.

Studios are research based. With grants from the National Science Foundation, MetLife, NASA, Gates Foundation, and Pearson Foundation, NCTAF has developed six core principles that we use to train and deploy teams of teachers and STEM professionals who have well-structured responsibilities for engaging students in deeper student learning.

Studios are partnerships. Working with NASA Goddard Space Flight Center, Northrop Grumman, Boeing, the U.S. Naval Academy, and others, NCTAF has launched sixteen STEM Learning Studios in nine high schools and six middle schools in four Maryland school districts. Over 100 teachers are collaborating with 21 STEM professionals on sustained investigations with approximately 1,500 students.

Studios are problem-focused. Similar to studios in other fields, NCTAF Learning Studios organize teachers, professionals, and students into teams that draw on their diverse skills and expertise to design innovative responses to complex learning challenges. Studio themes, which vary across schools, include trans-disciplinary concepts and "big questions" that teachers and students team up to address in real-world inquiry projects.

Studios are constantly evaluated. NCTAF trains Studio teams to participate in quarterly performance reviews, and we use outside evaluators to collect teaching effectiveness and student achievement data. We are seeing increased student engagement, with gains in STEM content mastery, higher order thinking skills, and collaborative problem-solving abilities. Teachers are gaining STEM proficiency, and STEM professionals are making higher impact contributions to student learning.

SNAPSHOTS

At Lindale Middle School in Anne Arundel County, a Studio team of teachers and students is working with the U.S. Naval Academy and Boeing to investigate "how air travel impacts our environment" – a problem especially relevant to the students whose school is located on the Baltimore-Washington International Airport flight path. Students examined flight pattern maps in math class and corresponded with airport officials in English class to gather authentic data on noise pollution. This Learning Studio built air quality sensors with the help of U.S. Naval Academy faculty that were placed around the school to collect real-time data. Students check air quality readings daily and raise a color-coded flag corresponding with E.P.A. air quality scales.

At Central Middle School in Anne Arundel County, two Studio teams (an 8th grade and a 7th grade) are investigating "the impact of our environment on water quality." In collaboration with a parent volunteer from the Annapolis Public Works Department and representatives of the Arlington Echo Outdoor Education Center, they are exploring design solutions for a rain garden to solve water runoff problems around their school. Teams of teachers and students are using Google Earth satellite images to measure and analyze their community's changing landscape over time, with a focus on understanding how housing developments and the expansion of paved surfaces around their school are affecting vegetation and runoff in their community. To help reduce erosion and water runoff into the Chesapeake Bay, the students decided to plant more than 100 trees on their school grounds – with assistance of a parent who works in forestry. In subsequent years, teachers and students will monitor the growth of these trees to catalyze Studio explorations of "Evolving Land Use" in the Maryland Earth Science curriculum.

Learn more at www.NCTAF.org
Follow us on Twitter @NCTAF
Contact us at 202.429.2570

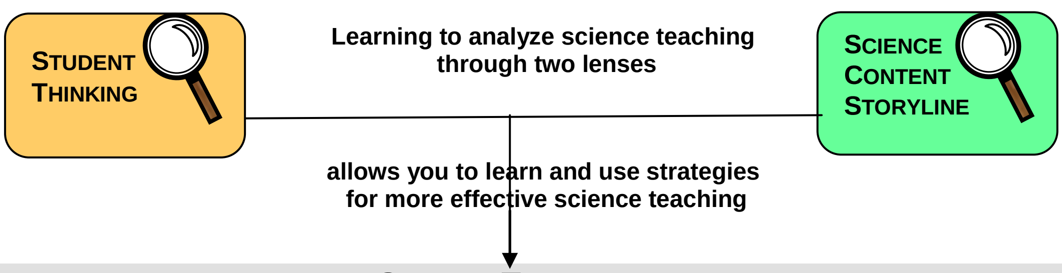
NCTAF National Commission on Teaching & America's Future

PD that Makes a Difference for *Students*: Science Teachers Learning from Lesson Analysis (STeLLA)

Background

The STeLLA professional development program engages fourth-, fifth-, and sixth-grade teachers in using two powerful and often neglected lenses to analyze videocases of science teaching: the Student Thinking Lens and the Science Content Storyline Lens. Focusing on deep analysis of these two lenses and associated teaching strategies, teachers learn to be more analytical in planning, enacting, and reflecting on their practice. Through this analysis work, they deepen their science content knowledge, develop as analytical practitioners with rich pedagogical content knowledge about the subjects they are teaching, and improve their planning and teaching practices. Most importantly, the one-year intensive program improves their students' science learning. In short, this is a professional development (PD) program that makes a difference in terms of *student* learning.

STeLLA Two Lenses Conceptual Framework



SCIENCE TEACHING

STRATEGIES TO REVEAL, SUPPORT, AND CHALLENGE STUDENT THINKING

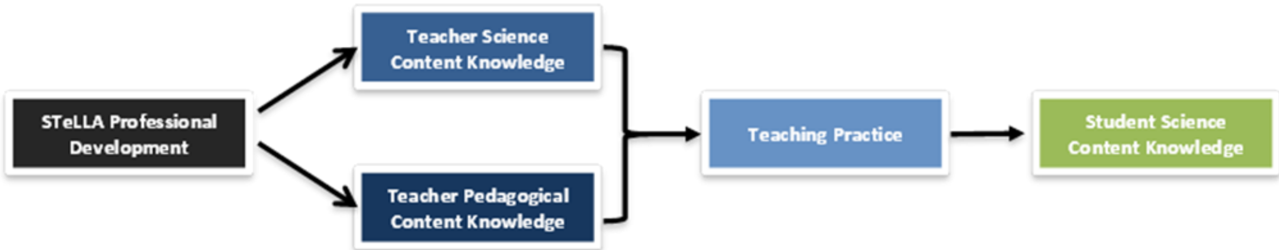
1. Ask questions to elicit student ideas and predictions
2. Ask questions to probe student ideas and predictions
3. Ask questions to challenge student thinking
4. Engage students in interpreting and reasoning about data and observations
5. Engage students in using and applying new science ideas in a variety of ways and contexts
6. Engage students in making connections by synthesizing and summarizing key science ideas
7. Engage students in communicating in scientific ways

STRATEGIES TO CREATE A COHERENT SCIENCE CONTENT STORYLINE

A. Identify one main learning goal
B. Set the purpose with a focus question and/or goal statement
C. Select activities that are matched to the learning goal
D. Select content representations matched to the learning goal and engage students in their use
E. Sequence key science ideas and activities appropriately
F. Make explicit links between science ideas and activities
G. Link science ideas to other science ideas
H. Highlight key science ideas and focus question throughout
I. Summarize key science ideas

Documented Results

In an initial quasi-experimental study conducted with 48 teachers in Los Angeles, the STeLLA program significantly improved students' science learning by deepening teachers' science content knowledge and pedagogical content knowledge and by improving their practice through use of the STeLLA teaching strategies. The program's pathway of influence is captured in the diagram below:



Funded by the National Science Foundation, Biological Sciences Curriculum Study (BSCS) is now testing the scalability of this innovative professional development program in an even more rigorous study. The five-year research study is testing the effectiveness of the STeLLA PD program when it is scaled to (a) reach larger numbers of teachers (150) and students in a wider array of settings, (b) include random assignment to two treatment groups, and (c) be delivered by professional development leaders who were not program developers. *The preliminary results from Cohort 1 show results similar to those in the initial study in terms of both teacher and student science content learning.*

Current Applications

You can go to http://vista.bscs.org to read about and explore an online version of the STeLLA PD program, called BSCS Videocases for Science Teaching Analysis (BSCS ViSTA). The five BSCS ViSTA modules (electricity, force and motion, inquiry, plants, and water cycle) provide rich videocases of K–8 science teaching and learning. The modules are structured around a sequence of analysis tasks and short associated readings that introduce teachers to the Student Thinking and Science Content Storyline Lenses and associated teaching strategies, and that engage teachers in using these conceptual tools to analyze the videocases. In addition to videos from classroom lessons and interviews with students and teachers, the videocases include lesson plans, written student work, student pre-posts, and any other materials used during the videotaped lessons. BSCS provides support services for PD providers who are interested in using these materials in either face-to-face or online contexts.

Acknowledgments

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For More Information

For additional information about the online BSCS ViSTA program and facilitation services available, contact Paul Numedahl (pnumedahl@bscs.org). For information about the STeLLA PD program, contact Kathleen Roth (kroth@bscs.org). For information about the STeLLA research study, contact Joe Taylor (jtaylor@bscs.org).