Developing STEM Site-Based Teacher and Administrator Leadership

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“There are no “leader-proof” reforms — and no effective reforms without good leadership.” A Bridge to School Reform, The Wallace Foundation (2007).

Setting

Helios Education Foundation is dedicated to creating opportunities for individuals in Arizona and Florida to succeed in postsecondary education. To achieve that goal, the Foundation invests resources across the education continuum to advance student preparedness and to foster college-going cultures in Arizona and Florida. The Foundation focuses its investments in three key priority areas: Early Grade Success, College and Career Readiness and Postsecondary Completion. Ultimately, the Foundation’s goal is to build sustainable education systems to ensure every student graduates college and career ready and completes a high-quality postsecondary certificate or degree.

Recognizing that strong, knowledgeable teacher leaders and administrators can become the agents for change within their school and district, the Helios Education Foundation is an engaged thought partner and funder of a number of initiatives focused on school leadership as part of its investment strategy across the Transition Years. These initiatives improve academic rigor and relevance with an emphasis on STEM Education by creating and sustaining highly skilled teachers and effective leaders as well as embed college-going culture supported by actively engaged families and communities.
Overview of the Programs

Rodger Bybee, Executive Director (Retired), Biological Science Curriculum Study, has reported that “Writing... about the reform of education and reforming education are two very different activities. The former requires that a small group agree on a set of ideas and express those ideas clearly and with adequate justification. The latter requires that millions of school personnel in thousands of autonomous school districts change.” (Bybee, n.d.) As hard as it is, defining STEM is the easy part, implementing STEM education on a large scale is the challenge. The following two projects are focused on this challenge!

The Helios Education Foundation and its funded partners define STEM education as an interdisciplinary approach to learning that removes the traditional barriers separating the four disciplines of science, technology, engineering, and mathematics and integrates them into real-world, rigorous, and relevant learning experiences for students.

Program #1

STEM in the Middle is a three-year project which began in the spring of 2011 to develop the mathematics and science content, assessment, and pedagogical knowledge of grades 5 – 8 middle school teachers of mathematics and science. The goal was to give these teachers the skills necessary to become STEM education experts in their schools and districts by providing them with deeper understanding of key concepts, skills, and reasoning methods of middle school mathematics and the sciences, strategies for designing integrated projects, implementing project-driven learning programs, differentiating instruction, and working with adult learners to enhance the STEM education of students. Teachers learned to develop proposals to fund needed materials and other resources to enhance the implementation of integrated projects.

STEM in the Middle (SIM), under the leadership of Dr. Carole Greenes, Associate Vice Provost for STEM Education, Director of the PRIME Center, and Professor of
Mathematics Education, at Arizona State University, has other targeted goals beyond developing STEM Teacher leaders. These include:

1) **Club STEM** engages sixty grades 5-8 students in STEM explorations for three hours each Saturday for seven Saturdays per semester. They employ a Scientific Village approach in which students engage in long-term integrated projects which are designed and led by scientists and mentored by high school students and college undergraduates. ClubSTEM students are actively engaged in high interest activities like this one where they are dissecting a kidney to explore the filtration system.

![Club STEM students dissecting a kidney](image)

The seventh session is the Showcase Open House where students present their projects to families and the community. Topics of past STEM villages include: Anatomy and Physiology, Forensic Science, Creative Photography, Computer-Designed 3-D Structures, SumoBots, Computer Game Design-Programming and Illustration, Flight/Aviation, and Rube Goldberg Constructions.

2) Key to the success of the ClubSTEM is the **mentoring program** which engages high school students interested in entering STEM university programs as well as undergraduate college STEM majors to assist scientist leaders of Club STEM with integrated project implementation and to serve as role models for students. In this
picture the ClubSTEM students are engaged in a Forensic Science Scientific Village where they prepare a cast of a footprint as they investigate impression evidence left at a simulated crime scene.

Students who apply to serve as mentors are interviewed by project staff and the senior mentor and are trained by the scientists and project staff. Depending on the projects, ten to seventeen mentors are appointed each semester.

3) The MATHgazine Junior is a four-page on-line magazine available to teachers, students and families of students. It is designed to develop readers mathematical and scientific reasoning talents. Readers solve problems and send them in to the PR"I"ME Center staff for solution verification. At the end of the academic year, the solver with the highest score receives a STEMatician certificate and is highlighted in the first issue of the subsequent academic year.

**Methodology**

This initiative has many parts to their “Village” approach. The purpose in this Chapter will focus only on the STEM Teacher Leader development which is core to the SIM strategy. Following is an overview of the Saturday ConCourses for Teachers:
• Teachers meet semi-monthly for eight Saturdays during the academic year and for one week (5 days) in the summer including four hours per session. These Saturdays and summer days are spent in a combination CONference (STEM experts presenting key concepts/strategies) and COURSE (in-depth study of those key concepts/strategies, their implementation and their assessment). Teachers organize in Concept Study Groups (i.e., communities of practice) led by ASU faculty. In each group, teachers explore a concept in grades 5-8 mathematics or science curricula, how the ideas grow in complexity across the domains, and then decide how to introduce, maintain, enrich, and assess an integrated STEM project.

• In the weeks between Saturday ConCourses, teachers use their instructional materials and strategies with their own students in their own schools. They bring evidence (e.g., videos, documentation of interviews, and observations, student papers, models, and computer programs) to include their implementation for feedback from the other SIM teachers and staff.

• In the final summer and academic year the teachers learn to conduct need assessments for professional development in their schools, analyzing and interpreting the results, and designing and conducting a professional development program for their staff with mentorship from SIM project leaders. With mentorship, teachers gain confidence in their abilities to provide professional development to teachers for the different grade levels. This is all set up as a learning cycle effect which can be repeated over and over, first the teachers are the students and finally they are the teachers of other teachers.

The Evaluation of the three-year SIM Project includes both quantitative (descriptive and inferential statistics) and qualitative (descriptive results of surveys, interviews, and focus groups) method. This report covers results after two years.

The methodology was designed specifically to address the over-arching goals of SIM to: 1) Promote grades 5-8 students' curiosity and success with the study of mathematics and the sciences by developing their algebraic reasoning and problem solving abilities, engaging them in activities and projects like those carried out by STEM
professionals, and communicating regularly with scientists; and 2) Develop middle-
school teachers' knowledge of key concepts of mathematics and the sciences, how
student understanding of those concepts becomes more robust, instructional strategies
that promote perseverance behaviors, techniques for designing and conducting
integrated projects, and methods for assessing and assisting students with varying
talent.

Data Collection Methods and Types of Data Collected:

1. Demographic Data. Basic information about student and teacher characteristics
was gathered during the application process. Demographics include grade level,
gender, self-identified ethnicity and race, school and district information for both
students and teachers. Additional information on subject areas taught was
collected for each teacher.

2. Baseline assessment of Algebraic and Scientific Reasoning. During Year One a
validated 7-item Algebra Test of Linearity (Greenes, et al, 2007) and a 15-item
Test of Scientific Reasoning were administered to all SIM teacher participants
and the students in their classes, as well as all grades 5 – 8 students in Club
STEM scientific villages. In Year Three, SIM teachers and SIM students are to be
assessed again.

3. Participant Satisfaction Surveys. Participant satisfaction surveys were
administered by the external evaluator at the end of the spring session for Club
STEM students and SIM teachers.

4. Village Leader and Mentor Survey. Project staff support surveys regarding the
perceptions of student growth and development as a result of student
participation in Club STEM were administered yearly.

5. Focus Group Interviews. Random samples of students and teachers were
interviewed at the start of the fall programs.

6. Pre- and Post-Village-Specific Knowledge Assessments. Assessments, focusing
on math and science constructs and village content, were administered to all
students in Club STEM as pre- and post-assessments in their scientific villages.
Data Analysis

Results are included as Goals and Outcomes. Extensive amounts of data has been collected on students, including both mathematics and science pre-village and post-village assessments.

Goal One: Promote grades 5-8 students curiosity and successes with the study of mathematics and the sciences by developing their algebraic reasoning and problem solving abilities, engaging them in activities and projects, and communicating regularly with scientists.

Five students were randomly selected to be part of a focus group before the end of the fall 2011 and 2012 Showcase for Open Houses for families and friends. When asked about mathematics and science in their home schools, several comments provided insight into how different Club STEM is when compared to regular classroom teaching.

“Here we get to build and create stuff. And the college kids (mentors) think we are smart.”

“I like how the mentors help us, but don’t tell us. We get to find out answers by trying our ideas and then they help us put it together.”

“I’m doing better in school and I like coming here on the weekends. Meeting other kids who don’t go to my school and who like science helps.”

“I wish my teachers at my school did classes like this. I really liked my photography village. Our teacher is really smart and we create art and science at the same time.”

Goal Two: Develop middle-school teacher knowledge of key concepts of STEM, how student understanding of those concepts becomes more robust, instructional strategies that promote perseverance behaviors, techniques for designing and conducting integrated projects, and methods for assessing and assisting students with varying talents. Here the teachers are working together in teams to check the temperature of a chemical reaction that releases energy in the form of heat.
Essential to teacher success in their own classroom is the understanding of the content by actually doing the activities and being in the role of the learner they are able to gain insight in to how their own students develop conceptual understanding.

**Teacher Outcome 1:** Increased knowledge of concepts/skills and related fields
Two content assessments were undertaken for teachers during each of the Summer ConCourse programs. Changes in performance from pre- to post-test were statistically (\( p < .001 \)) significant, indicating a dramatic increase in comprehension based on the module explorations.

Feedback from interviews and surveys conducted during the school year and summer program revealed powerful quantitative and qualitative results regarding teacher insights into their own skills, abilities, and behaviors. When asked how they have grown as teachers as a result of participation in SIM, all teachers interviewed commented that they had (1) grown in their understanding of STEM, and (2) were more aware of student challenges about those same “Concept” mastering. Sixty-seven percent of those interviewed felt that they were more comfortable with offering challenging problems and a variety of problems which will "make them (teachers and students) work harder."

“SIM has improved MY problem solving skills and that benefits my students.”
“\( I've \) gained confidence in my abilities of problem solving \( \) which will make me more likely to do these projects with kids.”
“I don’t freeze or call the math teacher for help in physics. I work through math problems in science with greater ease.”

“I think I’m more open-minded when it comes to my teaching/learning. I’m also more excited about teaching science!”

“I now spend more time on problems and challenge students to find different methods to solve the same problem.”

**Teacher Outcome 2:** Increased knowledge of ways to address student concerns and talents.

Giving teachers experiences of actually struggling with their own understanding is a powerful way to help them put themselves in the place of their students. In this picture the teachers are exploring the balance of forces by trying to figure out where to stand on a beam whose ends rest on scales.

![Teachers exploring forces on a beam](image)

The task is laid out for them but discovering the solution is up to the group. It also points out to teachers that for activities to be meaningful for all students they must build in enough time for students to go through the processes of learning.

Feedback on year-end surveys indicated that 96% of teachers felt that the educational materials provided during SIM were “excellent.” Interviews revealed that teachers were more aware of student abilities and capabilities as a result of the project.
“SIM has reinforced the importance of hands-on teaching and problems need to be relevant to all students (e.g., food, shopping, and design).”

“I consider how each student may be processing the math/science problems now. I am more patient.”

“I learned that students benefit from struggle, and I have incorporated this philosophy with my students. I learned that when math is presented in real life contexts, it is more palatable and effective for students.”

“I believe that all students are capable of understanding and participating.”

“I feel that my students can express themselves more, which has shown me that they are more capable.”

“I have come to understand that it is not completely the fault of students for not understanding math 100%-- much of the challenge lies in the material and how it's presented.”

“There are many resources available outside of textbooks to supplement instruction (like the Macy’s coupons) and the importance of proportions and rates in math.”

“We are starting a STEM Summer Camp this year!”

Interviews conducted with parents during the Showcase event each semester

Speaking directly, one-on-one, with parents provided great opportunities to address their perceptions of the program, progress their children had made, and what additional supports they felt were needed to help their children proceed into STEM subjects in high school.

“Our son is more focused and is doing better in math at his school. He was a good student and has improved. We are pleased that he is more focused to prepare for high school.”

“We were surprised at his willingness to share what he learned at STEM (in the Middle) with teachers and students at his school. Socially, he has become much more outgoing.”

“This project helps us to reinforce the idea that college is very realistic for our child. He has always liked hands-on science and he sees that he can go far. The teachers are very supportive of him here.”
“My child’s appreciation of technology and not taking it for granted has been helpful. And seeing how he can use different technology tools and the ‘why’ of it.”

“I absolutely appreciate having him learn different aspects of science. This project-based learning has helped him greatly. He loves science and I think this is motivating him to continue science studies.”

Program #2

The Pinal County Education Service Agency, Next Generation STEM Leaders (NGSL), project is a rural county wide initiative covering a section of southeastern Arizona which is approximately the size of the State of Connecticut. It involves nine school districts, ranging in size from 250 to over 8,000 students. Beginning in 2010 the ESA has now worked with thirty-six 5-8th grade math and science teachers to enhance their content knowledge, develop effective pedagogy, and to help the teachers to develop strategies to align effective STEM teaching and learning based data driven decision making.

The over-arching goal of the project is that by 2014 the NGSL program will develop STEM teachers in all Pinal County districts and charter schools who will have a solid understanding of STEM teaching and learning, become knowledgeable in technology application in the classroom, demonstrate knowledge of content, pedagogy and problem solving skills in STEM curricula, and become skilled at unwrapping academic standards for teacher instructional use. These STEM teacher Leaders will become the school-based systemic change agents that will expand the STEM learning and maintain program sustainability in the coming years. In addition, The STEM teacher leaders will be able to increase student and parent exposure to STEM higher education programs and provide avenues for support for those students to who aspire at a post-secondary education.

Methodology
The NGSL program focuses on a several activities:
1. Professional Development of Teacher Leaders.

Professional development branched into three areas of concentration: 1) science and math content knowledge, 2) STEM pedagogy, and 3) leadership development. Content knowledge was developed/deepened through college-level courses each spring semester at Central Arizona College. Pedagogy and leadership were addressed through 24 hours of professional development offered throughout the school year and an intensive four-day Summer Institute each year. Through these workshops participants worked collaboratively to learn and develop STEM lessons using the Project-Based Lesson (PBL) planning model developed by the Buck Institute.

2. Development of Digital Literacy and a Virtual Learning Community.

At the beginning of the project, the majority of NGSL teachers could be characterized as being at the ‘entry level’ of integrating technology into lessons and activities. They also had no developed means of communicating between their far-flung schools, using the Internet. The project provided iPads for each teacher along with training on using technology and developing teacher websites.

3. Student and Parent Outreach.

Outreach to students and their families to educate them on the opportunity and possibility of post-secondary STEM education was provided by “college information” nights throughout the county, family nights at Central Arizona College and, an annual Student Field Day at the college for the NGSL teachers and their students.

Upon the conclusion of the first year, the team leaders of the NGSL program reflected upon the NGSL Teacher Leaders progress and growth. It became evident there was an opportunity to increase the expansion of the STEM knowledge and learning beyond the initial core teachers by including administrators in the project. In order to facilitate and bridge the STEM teaching and learning at the district level, administrators needed to become STEM Leaders and have the opportunity to fully support the efforts of the
STEM Teacher leaders through a deeper understanding of STEM Teaching and Learning. They would also become more supportive of release time for their teachers to participate and more open to the resource requests to support STEM education on their campuses.

Data Collection Next Generation STEM Administers’ Program

The Pinal County STEM Administrators participated in a Leadership Roundtable as well as completed interviews. The analysis of the results from this first meeting and the survey indicated needs in the areas of Data-Driven Decision Making, School Collaboration Networks, and Technology Integration. From this information, A21CE Administrators for 21st Century Education) quarterly networking and professional development meetings were scheduled to address these needs with support activities. The pyramid in Figure 1 points out the over-arching goals set for the Administrators: Develop School Collaboration Networks, Technology Integration, and Data-Driven Decision Making.

Figure 1- Administrator STEM Pyramid

Overall, when asked how the Pinal County Education Service Agency could best help the administrators meet their district goals and objective, the superintendents focused on the need to develop leadership capacity in their districts. Within that overall need, several areas of concern were identified with more specific issues (e.g., dealing
with budget cuts) to broader initiatives (e.g., improve parent/community relationships). In the two telephone surveys leading change through STEM implementation was mentioned fairly regularly, but cannot be considered a high priority. Nevertheless, the needs most often identified by the respondents corresponded well to the goals of the NGSA project and the 21st Century Teaching and Learning initiative in Pinal County. They can be summarized in three primary areas of need as follows:

1) Consistently high in priority across all three samples was the need for data literacy among school administrators. There is concern that administrators cannot lead teachers in data-driven decision-making unless and until the administrators themselves understand how to simplify data, analyze data in a timely manner, and use data to drive adaptive change in classroom practice. Specific interest in data literacy for the administrators ranged from analyzing dips in AYP to understanding Galileo and Dibels results. In terms of leadership development, the administrators expressed a need for skill in coaching teachers on how to better utilize data in their teaching. One administrator recommended learning to lead “test talks” with teachers in a collaborative setting of administrators and teachers. Several respondents asked for support in helping teachers implement response to intervention (RTI), which is dependent upon frequent progress measurement and research-based interventions.

2) The second aspect of leadership capacity building noted by the administrators was the need to organize, manage and sustain collaborative networks among the administrators and teachers at school sites, and across school sites within district.
Providing these opportunities for administrators to work together fosters their understanding for the need to have ongoing collaborative work throughout their schools. They may know this at one level but do not necessarily understand how effective this can be unless they themselves have experienced it. These collaborative activities also provide administrators with opportunities to experience the need in which their own teachers can feel empowered to embrace and lead change.

These collaborative networks are seen as important for successful use of data in decision-making, ongoing learning among the staff, successful implementation of many new initiatives, including common core, RTI, and Beyond Textbooks, and non-threatening, productive teacher evaluations. They also see the need for collaboration and information exchange among administrators through the district and county, however, they also do not understand how to develop and maintain a network with this capacity.

3) Throughout the surveys, the administrators noted a need to develop a better understanding of how to integrate technology in the classrooms. At present, it appears that their identified need for technology integration involves the practical aspects of utilizing specific technologies in the classrooms (e.g., smartboards or iPads). There were numerous requests for more staff development on the use of
specific technologies. However, from the standpoint of leadership in the schools, it was determined that the administrators need a better understanding on how to lead their teachers from seeing technology integration as a technology-driven enterprise to a focus on technology-enabled learning. That is, a cognitive shift from functionality of isolated technologies, to seeing that 21st Century learning uses technology to expand the classroom into the global collaborative educational network.

**Conclusions**

Based on the needs assessment, it is recommended that professional development for the NGSA project addresses the following:

1) Adoption of STEM education and 21st Century teaching and learning will only succeed if there is a demonstrable need and the project-based learning model being used by the NGSL project can present demonstrable evidence of improvements in student performance. To understand the evidence, administrators will need a high degree of data literacy. Therefore, it is recommended that professional development focus on data literacy with specific exemplars from PBL assessments, AIMS, Galileo and Dibels. Data literacy should include how to simplify data, lead teachers in data interpretation and planning, and implementing and evaluating interventions in a timely manner.

2) Successful adoption of STEM education and 21st Century teaching is highly dependent upon developing a strong communication and collaboration network. Administrators will need the skills to develop and maintain networks among themselves and among their teachers. Therefore, it is recommended that professional development focus on how to organize, manage and sustain collaborative networks that empower teachers and administrators alike, provide opportunities to discuss problems, and share best practices.

3) Of the three areas, this will probably be the least intuitive for the administrators. Their responses indicate that they perceive technology integration as learning how
to use specific technologies (e.g., iPads) in an individual classroom. On the other hand, technology in the 21st Century classroom connects students and teachers to a global learning community and promotes self-directed learning beyond the school walls. Therefore, it is recommended that professional development on leading technology integration be explored by engaging administrators in a study of problem-based learning using technology in a global setting, including direct involvement of the local community.

Next Generation STEM Leaders Project (NGSL)

Data collection has been an ongoing activity throughout the lifetime of the NGSL and NGSA Projects. Both quantitative and qualitative data are utilized to serve a variety of purposes. While there are a variety of measures for the administrators participating in the project, the focus here is on the teacher leaders. A variety of surveys are used to inform program developers of the teacher leaders perceived progress in understanding and implementing change and to assess ongoing professional development needs. Additional measures are used to assess short-term outcomes and the evaluation of intermediate outcomes, and long-term program impact along with its potential utility for replication in other environments.

Data Collection Methods

1. Demographic Data. The thirty-two participants in the NGSL Teacher Leader cohort represent a sample of Pinal County math and science teachers in the 5-8th grades. Demographic data are used to track their impact on their schools and districts. These include their educational background, teaching experiences, recent professional development in math/science content, pedagogy, or curriculum, and the schools and number of students with whom they have direct contact.

2. Participant Satisfaction Surveys. ESA-developed participant satisfaction surveys were administered at the end of every professional development session to
ensure quality control and assess their immediate responses to content and its applicability to the classroom.

3. Pre/Post Attitudes, Actions and Beliefs Survey. The 31-item survey was constructed by adapting items from the TIMMS 2007 Teacher Questionnaires for eighth grade mathematics and science and the SWEPTS Pre-Program Questionnaire. It was designed to assess participants’ perceptions of themselves as teachers, their emphasis on specific teaching goals and objectives, and the teaching and learning activities used in their classrooms. Participants completed pre/post surveys yearly to inform project organizers of potential programming needs.

4. Pre/Post Leadership Confidence Survey. In Year Two, NGSL organizers targeted leadership development to start preparing participants for their roles as teacher leaders in their schools and to track their self-reported growth in competency as an effective teacher. This is a 29-item survey, modeled after the seven domains of the 2010 Teacher Leader Model Standards. Perceived changes in year two were assessed by comparing pre and post survey responses. Participants will complete a final survey at the end of year three.

5. NGSL Technology Use Survey. To better understand the role and purpose of technology use in the NGSL teacher leader classrooms, they completed a pre/post retrospective questionnaire each year to examine use of technology in the classrooms, their comfort level in using technology, and the level of support provided by their schools.

6. Teacher content knowledge measure: Diagnostic Teacher Assessments in Math and Science (DTAMS). To provide pre/post measures of content knowledge development in conjunction with their college coursework in mathematics and science, content-specific assessments are administered each year during the program. Results are analyzed statistically overall, and by knowledge type and content subcategories.

7. Teacher teaching skill measure: Reformed Teacher Observation Protocol (RTOP). The RTOP observational instrument is a widely accepted criterion-referenced assessment of reformed classroom activities. For the NGSL project,
each teacher was video-taped while conducting a lesson in their home classroom (approximately one-hour sample each session). A trained external evaluator scored each lesson and conducted statistical tests to assess pre/post change. Pre/post RTOPs were conducted in years one and two. In year three, each teacher will select a sample of classroom teaching for group analysis.

8. **NGSL Teacher Leader Interviews.** Telephone interviews were conducted in year three to assess participants perceptions of the overall program, their classroom applications, student responses, and administrator support.

9. **Parent Survey.** To examine parent attitudes and beliefs about the importance of STEM education for their children and their involvement in and support of their children’s preparation for post-secondary STEM education and STEM careers. A twenty-five-item online survey was developed in year three. These results can be used for ongoing program activities and by the regional institutions of higher education.

10. **Student Survey.** In year three, all NGSL teacher leaders’ students were invited to complete a 30-item online survey to assess their attitudes about STEM disciplines as future education and career options and their perception of the others families attitudes. As with the parent survey, these data are being used to inform future project activities as well as inform high schools and colleges in the county.

**Data Analysis**

A fundamental goal of the NGSL project was to develop participants STEM content knowledge and pedagogy skills. In each year of the project, both science and math cohorts have shown statistically significant gains on the DTAMs content knowledge assessments. They also have improved their ability to implement reformed teaching methods and activities in their classrooms, as evidenced by statistically significant gains in their RTOP scores. In addition, survey responses have shown increased willingness to incorporate in a wider variety of teaching methods and technologies in their teaching, as well as increased confidence as teacher leaders. They are making presentations on
STEM education in their schools, districts, and communities. Some additional specific achievements include:

1) 21st Century Standards-based Teaching and Learning Model

When the project proposal was developed, the 21st Century Standards-Based Teaching and Learning Model (2008) for Pinal County focused solely on STEM education as shown in the Figure 1. Throughout the first two years of the project, it became increasingly evident to both organizers and participants that their vision of STEM education required a better framework and language to communicate that STEM was more than a program to emphasize science and mathematics as academic content areas. In their view, STEM Education was the motivation and catalyst for a paradigm shift in teaching and learning in Pinal County schools. Figure 2 reflects the evolution of this model, which is now the current vision for 21st Century Teaching.

Figure 1: Beginning Vision Focus

Figure 2: Evolution of NGSL Vision
2) To support this evolving model, there was a focus on developing an identity for the group as STEM teacher leaders who were confident in their understanding of STEM education. They were individually able to create Project Based Learning lessons and units that were research-based, referenced cross-disciplinary standards, and integrated technology. They had developed a rubric for quality STEM PBLs. Throughout year two they continued to clarify and define their lessons and collaboratively developed STEM PBLs as a model for cross-discipline collaboration at their home schools.

3) Every teacher participant also developed aspects of each of the following characteristics or attributes of 21st Century teaching and learning. Much of the evidence is available on the NGSL website. Currently, NGSL teacher leaders are moving toward 21st century teaching and learning and grantees plan to assess where potential participant schools currently are on the STEM Immersion Matrix (available on the Arizona Science Foundation website, http://www.sfaz.org/stem).

- Collaborative Teaching and Learning Skills
  - Project-based Learning
  - Web Quests
  - Integrated Curriculum
  - Student-Centered
  - Systems Thinking

- Multiple Platforms
  - Virtual Teaching
  - Virtual Schools
  - Virtual Learning
  - Teacher Websites
  - Distance Learning
  - On-line Courses,
  - Virtual Collaboration in Classrooms

- Global Awareness and Cultural Literacy
- Real Time Learning
• Balanced Assessment System
  o Formative
  o Student Involved
  o Performance-based
  o Summative

The purpose of Data-driven Decision Making (D3M) in the current HELIOS grant is to establish a systematic approach to collecting, organizing, and analyzing student learning data that allows educators to monitor academic growth that occurs as a result of initiatives taken during the project. To model this process, project directors used the ongoing data collection for the evaluation of the project to monitor participant progress and to adjust their professional development. Each professional development session involved some examination of their data.

To help participants transfer this learning to the task of monitoring their students progress, the project coordinators decided to establish benchmark assessments that assessed student learning on project-based learning. Math teachers had previously used tests such as Saxon Math. Science teachers had previously used assessments from texts or common grade level assessments created by teaching staff. This project provided professional development to math and science teachers on a Balanced Assessment System that included, student involved, performance based, formative, and summative assessments.

In the second year, the Summer Academy focused on creating a Balanced Assessment System. The result was better PBL’s, and the assessments posted on the website reflected a deeper understanding of Balanced Assessment. Examples of PBL’s are listed on the NGSL website under Project-based Learning tab with the following URL: https://sites.google.com/site/ngslarea/project-based-learning
The project developed a digital communication system where the information is delivered in a true 21st century model. As an example, the NGSL developed a group website where each participant was required to design and maintain a professional website which contained their communication system with students, parents, and administrators. As a resource for administrators, specific to all Pinal County teachers, information delivery is provided through access to the website, including professional development materials, college course materials, teacher developed materials, and student projects. Digital literacy has been facilitated by electronic communication with parents in the form of electronic flyers, emails, and surveys. In addition, iPads are used within the classroom, to facilitate both communication and collaboration among students and teachers, as well as between classrooms and schools.

Conclusions
1) Professional development must be agile and embrace participant diversity.
   Like most programs, teacher participants never started with the same levels of
knowledge, skills, and abilities, or willingness to embrace change, or progressed at the same rate. In addition, over time, teachers replacing participants lost to attrition had to be absorbed into ongoing collaborations. Teachers changed schools and districts, disrupting on-site collaborations and leaving participating administrators short a STEM teacher leader. The project organizers discovered that all multi-year programming must be conceived as an open system, subject to a wide variety of perturbations. The nature and intent of programming should be resilient under change. They developed an ongoing data collection system to assess needs and agile programming that could address learners needs wherever they were in their personal development. This agility allowed the project to embrace a newer, more comprehensive model of 21st century teaching and learning that better reflected their evolving identity, and to incorporate new technologies in weeks/months, rather than years.

2) Use the product to teach the process.

Similarly, project organizers discovered that their participants often got mired in the process of developing and implementing cross-discipline project-based STEM lessons. Developmentally, this occurred at different stages of the process for different teachers. As programming evolved, they found a more effective professional development model would be to start with the product and use it to discover the underlying process. That is, starting with the STEM Immersion Matrix or a PBL, participants should use the product, collect data, assess, and reflect on current strengths and needs, then modify and cycle through the process again. This professional development model will be developed more fully in year three as the teacher leaders train more of their colleagues at their schools. This model will be supported by the development of a STEM lesson rubric.

3) Align STEM education with district initiatives.

Initially, there was little thought given to the how the standards-focused STEM lessons aligned to their district’s curriculum maps and pacing guides. Administrators also did not have the adequate background education on STEM education, so they were reluctant to integrate STEM into their regular education. They were considering implementation after AIMS testing, so as not to interfere with standards-based
instruction. After learning this, project leaders realized that the student achievement measurement was inadequate. Project leaders made a decision to involve administrators in the project guidance, including development of an administrator cohort. A decision was made for teacher leaders to use the “backwards design model” so that PBL’s were aligned to the Common Core standards for math and state science standards as well as district planning guides. The administrator cohort assisted the project leaders to set an altered direction for the grant in the sense that the original goals for the project were maintained, but so the grant also met the administrator goals for standards-based instruction and increased student achievement in math and science.

4) Re-tool the infrastructure of the virtual learning community.
   The NGSL project has developed a successful virtual learning community by providing training and support to build professional websites for all teacher participants, the project, and administrators. To date, this infrastructure has been used as a repository for sharing information, posting PBLs, and other materials. In year three, they envision using this infrastructure for more direct instruction for the participants. Virtual professional development will assume a greater role for sharing, analysis of participants’ teaching activities, reflection, etc.

5) Remove roadblocks to student technology use.
   Initially, many of the participating rural school teachers needed basic technology tools such as document cameras. In year two, each participant was provided with an iPad for use in their classrooms. Additional sets of iPads also were made available for loaning to whole classrooms using a simple online reservation tool at the NGSL website. As the teacher participants technology infusion skills increased, district and school policies on privacy, internet use, etc., obstructed inter-school student collaborations as part of the learning process. These policies still hamper this virtual platform. To keep up with future projects gatekeeper’s policies will need to be reviewed and revised to better serve student learning in this virtual world we now all live in.

6) Increase student and parent exposure to higher education programs.
   Initially the project directors thought that students attending isolated events were
sufficient to increase student and parent exposure to higher education programs. This had limited success for a couple of reasons. First, it was difficult to work around district privacy policies that prevented regular correspondence with students and families. When NGSL organizers started a web form for parents to sign up to receive information, over 350 parents signed up. Second, the attrition of contributing staff at the partnering college reduced participation by new staff that had different priorities. Finally, they realized that in order to get students to consider STEM post-secondary education and careers, the county needed to develop a pathway for these students beginning in elementary school.

7) Develop a resilient evaluation plan.

The evaluation plan and data collection for the NGSL project were derived from a logic model developed at the outset of the project. Each year the logic model and evaluation plan were revised to better represent the evolving program. This also meant revision of some of the measures, with some being modified throughout the course of the project (e.g., surveys), others were discarded as they became less relevant to meaningful evaluation (e.g., RTOP in year 3). It is an ongoing challenge with program design to know in advance how to track measurements that are meaningful, consistent, and allow change in the program.

Evidence of Success from the Two Initiatives

“Teachers are leaders when they function in professional communities to affect student learning, contribute to school improvements, inspire excellence in practice, and empower stakeholders to participate in educational improvements” (Childs-Bowen, Moller, & Scrivner, 2000, p. 28).

In most professions, as the practitioner gains experience, he or she has the opportunity to exercise greater responsibility and assume more significant challenges. This is not true of teaching as it can be a flat profession. The 20-year veteran’s responsibilities are essentially the same as those of the newly licensed novice. Therefore, in many settings, the only way for a teacher to extend his or her influence is to become an administrator. This desire for greater responsibility, if left unfulfilled, can
lead to frustration and even in some cases dropping out of the profession all together. As shown by these two initiatives, developing strong site-based math and science leadership can provide for effective changes not only in the classrooms but within the system in which they are working. The research shows these teachers will have greater buy-in in school policy and curricular decisions, increased student achievements, and will become better communicators to parents and the whole community.

Both **STEM in the Middle** and the **Next Generation of STEM Leaders** incorporated the same approach to developing the skills and knowledge of math and science middle school teams. Their design approach, although differing in some aspects, both have shown success because they encompass the same basic key elements. They include:

- Develop STEM content and pedagogical knowledge,
- Provide a variety of strategies for implementing STEM in their own classrooms,
- Create standard-based STEM instruction materials aligned with assessment.
- Nurture and develop presentation skills in order to work with other teachers and administrators,
- Provide and maintain connectivity between all the participants both on-line, web-based and Professional Learning Communities.

As the quote from Rodger Bybee at the beginning of this chapter says, “reform of education and reforming education are two very different activities.” In order for us to move beyond the STEM slogan and into classroom practice the first step in making this a reality is to work on effectively changing teacher practices. Both of these initiatives have shown that working with a concentrated set of math and science teachers over a sustained period of time will produce change in their practices. The difficulty in this is trying to take this to scale. Both of these projects are now moving into their third year of implementation. The evaluation goal for Year 3 is to start to measure their influence upon their system and begin to track student achievements. This will be especially true within the Next Generation grant as most of these teachers are in the 6th – 8th grade span at a school site. This will be the biggest push from Helios within the evaluation for both of these projects. Until the final results are in, seeing the change in teacher
practices, and their confidence, and attitudes toward teaching is considered all pay back for our investments.

References


