Final Evaluation

APS STEM Focus Schools for the Future

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I. Introduction

Program rationale

Few students have opportunities to learn multidisciplinary science, technology, engineering and mathematics content and skills, particularly in the formative K-8 years when attitudes towards these fields are forming (Maltese & Tai, 2010). This is particularly a concern in Arizona, where continuing to increase the number of STEM students is critical to expanding Arizona’s STEM-qualified workforce (Hill, Castelazo & Hoffman, 2011). When STEM is integrated within the school, students will have new opportunities to learn and develop these important skills and abilities for the modern workforce. Few, if any, K-8 teachers have the background in these areas, or experience promoting systemic change needed for promoting multidisciplinary curricula in their schools. Professional learning for teachers is a critical component for improving student learning, by providing these teachers new knowledge, skills and abilities and support for implementation of new teaching methods. The goal of the APS STEM focus schools program is to develop teacher leaders at 12 schools in the APS service area through professional learning, in order to promote high quality STEM learning opportunities in these schools. A conceptual model of this program is in Figure 1:

![Figure 1: Overarching model for the APS STEM-Focused Schools Program](image)

Program Overview

The APS STEM Focused Schools for the Future program was funded in 2012 by the APS Foundation. This evaluation reports on the activities and success at achieving the program goal from July 3, 2012 to May 31, 2014.

The overarching goal of the program is to assist 12 Arizona schools to develop more STEM-literate students, by building capacity to design and implement effective STEM education for today’s learners. The program model is based on a philosophy that in order for schools to fundamentally change STEM learning and practices, they must:
- Form effective school leadership teams consisting of teacher leaders and one or more administrators
- Learn STEM content and processes
- Practice effective STEM teaching strategies
- Develop leadership skills
- Address STEM within the school system (not just the classroom)

Program Context

The program was developed and coordinated by the Center for Science Teaching and Learning (CSTL) at NAU in collaboration with the APS Foundation. The CSTL is a teaching, research, evaluation, professional development and materials resource center for students and faculty, K-20 teachers, and informal educators. CSTL recruits, advises, and supervises undergraduate and graduate secondary science and mathematics teachers through the NAUTeach
and Masters in Science Teaching programs. CSTL has worked with over 550 teachers since 2008, over three-quarters of whom teach at the highest need schools in Arizona. By May 2017, NAUTeach will graduate approximately 63 math or science teachers annually, impacting more than 37,000 K-12 students per year.

Twelve schools participated in the program (a thirteenth school participated in some of the professional learning at their own expense). Students in these schools represented the diversity of Arizona: Six counties were represented (Coconino, Gila, Maricopa, Navajo, Pinal, and Yavapai), 47% of the students were at schools with School-wide Title 1 designations (more than half of the students are from low-income families), 40% of the students are from groups underrepresented in STEM fields (American Indian, African American and Hispanic), and 49% of the students were female.

**Evaluation overview**

The goal of the evaluation is to examine the project activities, processes and overall effectiveness of the Program at meeting the program goal. The following evaluation questions developed during the program proposal and aligned with the program objectives are answered through the program evaluation:

1. To what extent are teacher leaders satisfied with the design and delivery of the program?
2. Has the capacity of the leadership team to develop an effective STEM education program improved over the course of the project? If so, in what ways?
3. Has the confidence of teacher leaders to lead and support STEM-related instructional efforts in their schools improved over the course of the project? If so, in what ways?
4. Are the schools creating and beginning to implement high quality action plans?
5. In what ways have APS employees been involved with schools’ STEM-related efforts?
6. How many NAUTeach classrooms and students have been involved in program activities?

**II. Methods**


**III. Program Activities**

Schools applied to the program and were selected through a competitive process. Two educators from each school were identified as future leaders and participated in professional learning provided through the program. One school administrator from each school was required to attend the first session, and was subsequently invited to participate as available after that.

At school sites, teachers organized and conducted “Kick-off” events early in the program, inviting APS personnel, and local businesses and science organizations and teachers and students to showcase STEM activities. Many of these events were well attended by students, their families and business and community representatives. Regional APS representatives were also invited to each event.

Five professional development sessions were developed and implemented over the 18-month period, including four two-day sessions (January 2013, May 2013, November 2013, and January 2014) and one five-day session (June 2013). A five-hour session was also held in May.
2014 for schools and the professional learning team to celebrate their accomplishments and to showcase the program video, developed with grant funds. Levels of participation were very high: 18 educators participated in 102 hours and an additional eight educators participated in 70 hours of professional learning. The twelve principals also participated in an average of 16 hours of professional learning each.

The Professional Learning Framework for this program emphasized leadership, teaching and learning, STEM content and reflection. Professional learning provided active opportunities for teacher leaders to both learn and to apply their learning through plans for school-specific implementation. Learning opportunities centered on improving STEM content through active investigations focusing on energy and water, developing leadership skills, and learning new teaching strategies. To learn about STEM careers, participants also spoke with STEM experts, including astrogeologists, engineers and APS employees. To apply learning, participants developed specific “Action Plans” for integrating STEM into their schools, with an emphasis on change that could be both systemic and sustainable in the long term. Processes for systemic school change were built into the program throughout.

In November 2013, school teams participated in a statewide conference entitled Building Capacity in Science Instruction through the Framework for K-12 Science Education: A Workshop for Science Educators and Leaders, Presented by Arizona Department of Education, Arizona Science Teachers Association and Partnership for Effective Teaching and Learning. Roger Bybee, a world-renowned educator was an event speaker and also participated in a special session for the teachers in this program. He had an opportunity to learn about the work of the APS STEM-focused schools; according to the program co-PI, he was very impressed with the work of the schools.

Professional Development Coordinators Joëlle Clark (co-PI), Jane Kirkley and Trenda Vannette made site visits regularly to the schools to provide guidance and advice, check on progress and to co-teach with teacher leaders as requested.

IV. Evaluation findings:

1. To what extent are teacher leaders satisfied with the design and delivery of the program?

The professional learning experiences have been very positive for participating educators, with 100% of the participants satisfied or very satisfied with both program design and delivery. As one educator stated, “I loved the program. It has greatly enhanced my own teaching and the confidence I need to share it with my fellow staff.”
Table 1: Participant rating of the quality of the professional Development sessions

<table>
<thead>
<tr>
<th>Session</th>
<th>Participant number</th>
<th>Rating of “High Quality”</th>
</tr>
</thead>
<tbody>
<tr>
<td>January 2013</td>
<td>33</td>
<td>100%</td>
</tr>
<tr>
<td>May 2013</td>
<td>28</td>
<td>89%</td>
</tr>
<tr>
<td>June 2013</td>
<td>25</td>
<td>100%</td>
</tr>
<tr>
<td>November 2013*</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>January 2014</td>
<td>24</td>
<td>100%</td>
</tr>
</tbody>
</table>

*Formal evaluation was not conducted during the November session

Teachers also assessed strands of the professional learning framework for effectiveness:

Table 2: Participant rating of the effectiveness of the professional development content (N=25)

<table>
<thead>
<tr>
<th>Framework strand</th>
<th>Very ineffective</th>
<th>Ineffective</th>
<th>No opinion</th>
<th>Effective</th>
<th>Very effective</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEM Content Learning</td>
<td>0</td>
<td>0</td>
<td>1 (4%)</td>
<td>11 (44%)</td>
<td>13 (52%)</td>
</tr>
<tr>
<td>Teaching and Learning</td>
<td>0</td>
<td>0</td>
<td>2 (8%)</td>
<td>10 (40%)</td>
<td>13 (52%)</td>
</tr>
<tr>
<td>Systems Thinking</td>
<td>0</td>
<td>0</td>
<td>2 (8%)</td>
<td>11 (44%)</td>
<td>12 (48%)</td>
</tr>
<tr>
<td>Leadership</td>
<td>0</td>
<td>0</td>
<td>1 (4%)</td>
<td>8 (32%)</td>
<td>16 (64%)</td>
</tr>
<tr>
<td>Sharing Resources</td>
<td>0</td>
<td>1 (4%)</td>
<td>2 (8%)</td>
<td>5 (20%)</td>
<td>17 (68%)</td>
</tr>
<tr>
<td>Framework for STEM Education Model*</td>
<td>0</td>
<td>0</td>
<td>1 (4%)</td>
<td>11 (48%)</td>
<td>11 (48%)</td>
</tr>
</tbody>
</table>

*Only 23 participants responded to this question

It is clear that the professional learning was well thought out and implemented, and was relevant to teachers needs. Teachers were very satisfied with all aspects of the program. Particularly effective were the professional development strands and the many tools that were introduced to teachers through this program that teachers were able to use to build their programs, including the STEM framework, model based inquiry, engineering design and leadership tools such as norms of collaboration. As one teacher commented, “The program has provided the tools (scaffolds) I needed to help me become a peer leader”.

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2. Have the capacity of school leadership teams to develop an effective STEM education program at their school site improved over the course of the project? If so, in what ways?

Most of the school leadership teams have developed requisite skills and abilities and have been able to develop a STEM program at their school sites. Two of the school teams struggled to develop programs other than classroom-based STEM learning, primarily due to constraints placed on them by the school leadership or a need for further support at the school site. These teams appeared to be able to work through these challenges and began to create a program by the end of the school year. Two other teams have implemented programs but have struggled to grow as desired, due to a variety of factors including administration turnover and lack of support.

Evidence that school teams’ capacity has improved are the activities that these teams have developed, including professional learning for other teachers at their school sites and opportunities for student learning.

**School-specific professional learning:** Through the program emphasis on leadership and STEM teaching and learning, participants have developed their capacities to be leaders at their school sites in STEM education. Since participation, these educators have collectively organized and/or led an average of 10.3 hours of professional development for another 268 educators and 14 administrators at their school sites.

**Student learning opportunities:** Through this program, all twelve schools created new or refined learning opportunities for the approximately 7939 K-8 students who attend these schools (see Table 3). Several schools introduced more than one of these learning opportunities. Three schools created a new STEM course or a “school-within-a-school” program, involving 234 of the students (3%), with another school planning a STEM course for fall 2014. Six schools integrated STEM significantly (weekly or more often) into their curricula, involving 1700 (21%) of the students. Six schools integrated STEM periodically into their curricula, involving 3535 (45%) of students. Five schools created or modified after school or summer camps with STEM content. Six schools are holding regular STEM nights with their students and families.

<table>
<thead>
<tr>
<th>Learning opportunity</th>
<th>Number of schools</th>
</tr>
</thead>
<tbody>
<tr>
<td>New STEM course or “school-within-a-school” program</td>
<td>3</td>
</tr>
<tr>
<td>Significant STEM integration</td>
<td>6</td>
</tr>
<tr>
<td>Periodic STEM integration</td>
<td>6</td>
</tr>
<tr>
<td>After-school or summer camp</td>
<td>5</td>
</tr>
<tr>
<td>Regular STEM nights</td>
<td>6</td>
</tr>
</tbody>
</table>

One teacher commented about the positive impact of the new STEM class at her school, “The kids love it—they refuse to transfer out, refuse to leave at lunch and ALL other kids want in the classes”. A student in the STEM program said, “STEM is harder, but it’s worth it”.

Table 3: New learning opportunities for students 2013-2014
3. Has the STEM knowledge of lead teachers improved over the course of the program? If so, in what ways?

As part of the professional development, teachers learned about STEM through an emphasis on teaching and learning, grounded in guiding principles for learning and STEM learning design.

Baseline data were collected to identify growth over time in participants’ understanding of STEM, and STEM teaching and learning through several writing prompts that participants responded to during the first weekend of the program. A comprehensive understanding of STEM was determined to include four components: 1. Disciplinary knowledge, attitudes, and skills, 2. Integration, 3. Purpose driven application – real world issues/problem, and 4. Preparation for future – 21st century skills/literate citizens.

At the beginning of the program, few participants had a comprehensive understanding of the concept of STEM or the importance of STEM in modern life. At this time the majority of participants thought of STEM as solely the integration of subject matter (56%). About one-third of the participants identified STEM as: purpose driven (problem-solving) (35%) and less than one third thought of STEM as disciplinary knowledge/skills (26%) or preparation for the future (30%).

One year later, there is evidence that teachers improved their understanding of STEM. More than two-thirds of the teachers described STEM as: integration of subject matter (70%), disciplinary knowledge/skills (65%), as purpose-driven (70%), and/or as preparation for the future (65%).

Findings indicate that through the program activities participants improved their own understanding of STEM and improved their understanding of how to teach STEM. Through opportunities to experience lessons as learners, teachers increased their understanding of STEM as an interdisciplinary construct and the purpose driven application of STEM. As one teacher said, “Having to problem solve and work through problems ourselves defines the importance/need for this in the classroom. Also, [we] see how the activities reach across disciplines”. The opportunity for teacher leaders to experience model lessons helped them improve their content understanding and facilitated the building of school STEM programs. As one teacher commented, “Now... I have lessons to demonstrate to my staff this year in order to introduce STEM”. Another said, “The content learning increased my learning so that I may present a coherent and content-rich introduction for our plan”

4. Has the confidence of teacher leaders to lead and support STEM-related instructional efforts in their schools improved over the course of the project? If so, in what ways?

Teachers responded in focus group interviews and questionnaires about the influence of the program on their confidence. Overall, 23 of the 25 teachers (92%) identified that their confidence has improved over the course of the project; the other two teachers indicated that they were unsure about confidence improvement. Towards the end of the program about half (50%) of the teachers identified that confidence was one of the most important leadership
Characteristics in which they had improved over the course of the program, critical for presenting STEM teaching and learning to their school teaching staff and administration. Their success at implementing new programs at their schools is also a sign that teachers have developed confidence in their abilities to lead. As reported previously, these teacher leaders have collectively organized and/or led professional development for another 268 educators and 14 administrators at their school sites. They have also been instrumental in creating STEM learning opportunities for students (Table 3).

Teachers clearly gained in their feelings of confidence. It is especially critical to be confident about their ability to lead STEM at their schools as many of these teachers are taking a new leadership role, and need to gain the trust of their peer teachers. As one teacher commented,

“I have gained a better knowledge of the focus and purpose of STEM and therefore feel more confident in gaining peers trust and desire to become STEM teachers. I am applying processes that I have been evolving through this process and been able to “tweak” to form a plan I am confident in sharing”.

Another teacher shared, “I am a good leader, BUT only when I feel confident I know what I am talking about. These meetings help me feel confident in what I am doing. I can go back and share the new pieces with my peers”.

5. Are the schools creating and beginning to implement high quality action plans?

All schools created action plans through the program. The purpose for the action plan was for schools to have a blueprint for developing their STEM school specific to their site, based on school interest, mission, vision, resources etc. Although action plans are varied, the action plan of one school provides an example of the types of activities that schools integrated into their curricula:

• Developing 6th grade integrated curriculum
• Communicate with stakeholders
• Professional development for interested teachers
• Repository for lessons
• Real world connections- through speakers and field practica for students

A matrix was created to identify the components that schools included explicitly in their first-year action plans and/or components that were observed during site visits by the program staff. The program team considered the following components, identified by research as important for effective student STEM learning (National Research Council, 2011), to be important for an effective action plan: Diversity/equity, Instructional materials, Pedagogies, Content, Leadership, Community, Capacity building/professional development and sustainability.

Schools included some of these components in their plans more than others:
Diversity/Equity- Five of the twelve schools demonstrated evidence that diversity/equity was being addressed through their plan (42%) and five planned to include equity in their future plans (42%).

Instructional materials- Ten of the school teams identified instructional materials as part of their plan (83%) and two did not (17%). One of these schools was aware of the importance of instructional materials for their plans.

Pedagogies- Five of the school teams demonstrated evidence that pedagogy were being addressed through their plan (42%). Three of these schools were aware of the importance of pedagogy for their action plans (25%)

Content- Ten of the schools specifically mentioned content in their plan; especially that STEM instruction should be integrated across subject areas and have a context, issue or problem to solve (83%).

Leadership- All twelve schools included the role of leadership in their school action plans.

Community- Nine of the schools addressed community capacity building (community outreach) specifically in their plan. There was evidence during the site visit that community support was important for the other three schools as well. Many schools planned to hold additional STEM nights for families and the community or to invite community members to participate in STEM career sessions.

Capacity building/Professional development: All schools demonstrated the role of capacity building/professional development within their plans.

Sustainability – Four of the twelve schools (25%) had sustainability planning in place. Some teachers expressed concerns about sustaining these efforts financially as well as evaluating the results of these programs.

Teachers were asked how successful they felt developing and implementing these action plans. Sixty-eight percent felt successful or very successful developing their plans and 56% felt success at implementing plans, with others acknowledging challenges (Table 4):

<p>| Table 4: Teachers perceptions about development and implementation of action plans, N=25: |
|---------------------------------|----------|---------|-----------|----------|----------|</p>
<table>
<thead>
<tr>
<th>Success at developing action plans</th>
<th>Very Unsuccessful</th>
<th>Unsuccessful</th>
<th>Ups and Downs</th>
<th>Successful</th>
<th>Very Successful</th>
</tr>
</thead>
<tbody>
<tr>
<td>Success at implementing action plans</td>
<td>0</td>
<td>2 (8%)</td>
<td>9 (36%)</td>
<td>8 (32%)</td>
<td>6 (24%)</td>
</tr>
</tbody>
</table>
Teachers who felt a range of success commented that change can be a slow process or that they had to make midstream adaptations in their plans. Other teachers expressed some challenges with their plan, due to time, administrative support or other competing initiatives. One teacher commented, “The change in administration presents unexpected conditions that have limited our ability to achieve some of our goals”. Nevertheless, 17 (68%) of the teachers also felt supported through the process of developing and enacting their plans.

Teachers expressed that implementation successes they experienced included new integrated curricula, more collaborations between teachers from different content areas and more teaching of STEM by other teachers in the school. One teacher commented that success was observed at “the campus wide STEM days where all teachers are doing STEM [which] shows the success of our professional development”

6. How many NAUTeach classrooms and students have been involved in program activities and in what ways?

Mount Elden Middle School (MEMS) was the only NAUTeach partner school that is also an APS STEM-focused school. MEMS includes grades 6-8, is designated as a Title 1 school by the state of Arizona and has a total current enrollment of 819 students. There were four NAUTeach mentor teachers at the school, two of which are APS STEM Focus School for the Future lead teachers. According to the NAUTeach director, the teachers at MEMS who mentor pre-service teachers in the NAUTeach program are receiving professional learning that benefit pre-service teachers and their future students. The NAUTeach program is “grateful for the training these mentor teachers are receiving”. About 75 pre-service teachers taught lessons and observed classes at MEMS over the course of the program.

There were no NAUTeach pre-service teachers placed at other NAUTeach partner schools that are also APS STEM Schools. According to the NAUTeach Director, although West Sedona and Beaver Creek Schools are NAUTeach partners, they are both 45-minute drives from NAU and the NAUTeach program was able to place all students locally.

Two STEM-themed workshops have been implemented that were supported by this project and will benefit NAUTeach classrooms and students in the future. Joelle Clark and Jane Kirkley led a workshop with NAUTeach Master Teachers about the new national science standards proposed for implementation nationwide, called the Next Generation Science Standards (NGSS), and the proposed practices that tie-in with STEM education and engineering curricula. According to the the NAUTeach Director, this session was valuable. However, according to the director, most NAUTeach mentor teachers are not yet ready to implement engineering curricula in their classrooms, because they are waiting for NGSS to pass legislation to become the official science standards for the state of Arizona.

Joëlle Clark led a four-hour workshop for student teachers and mentor teachers called Unwrapping Standards in August 2013. Four middle school teachers participated, all from northern Arizona. At the beginning of the workshop teachers identified understanding NGSS and how it will change their classroom science curricula as a main learning expectation.
At the end of the workshop teachers described understandings that they learned. They described that engineering practices must be purposefully incorporated into the curriculum. Teachers also described that they learned that all science is integrated and also learned about how new emphases in science based on the Frameworks and NGSS will change their teaching, such as the focus on science practices and argumentation in science. They also learned the importance of integrating disciplines. One teacher commented on learning specific concrete examples for integrating engineering, such as filtering water to solve pollution and constructing a tower for an artist. Teachers felt the workshop was of high quality, commenting, “Great workshop- time well spent” and “The workshop was a great combination of hands on/and theoretical application”.

One NAUTeach math education graduate has been recently hired by an APS STEM-focused school as a math teacher. The administrator at this school was very impressed with the interest of this graduate in his continued professional learning and hopes to bring this new teacher into the team in the future.

Fewer connections developed between NAUTeach and APS STEM-focused schools than was originally anticipated, with only one local school providing opportunities for NAUTeach students. Nevertheless, the relationship between NAUTeach and this STEM-focused school is an important one because so many NAUTeach students interact with the teacher leaders at this school. A number of teacher leaders commented during focus groups about the importance of educating preservice and beginning teachers about STEM. Therefore, continuing to build these connections and opportunities for NAUTeach students should be an important priority.

7. In what ways have APS employees been involved with schools’ STEM-related efforts?

A regional APS employee representative was invited to every school kick-off event in the spring of 2013. Ten employees participated in these events by representing APS during the presentation of plaques to school leaders at eight of the twelve schools: Seligman School, Holbrook Junior High School, Beaver Creek School, Copper Ridge Elementary School, Freedom Elementary School, Canyon Springs Elementary School, Mount Elden Middle School and Casa Grande Middle School. Several representatives stayed and interacted with teachers, staff and students during the events. Two APS service professionals participated in a STEM career panel during a professional development session with the twenty-four teacher leaders in May 2013 along with a number of other STEM professionals. The teacher leaders really appreciated the insights from this panel about what skills todays’ students need to succeed in the workforce. A number of the teacher leaders considered the panel the highlight of this professional learning session. As one commented,

“The panelist Q and A was most important to me because it reinforced the specific needs in STEM career fields...and gave feedback about what was important in panelist’s education that set them up for their future careers”.

APS employees visited schools at kick-off events and participated in a STEM career panel. The addition of business and industry is an important contribution to the teachers’ professional learning. As the schools continue to evolve their STEM programs, with
brainstorming, creativity and commitment there may be additional ways to build connections between APS and the schools so that teachers and students have a deeper understanding of the role of STEM in many career opportunities.

V. Strengths
The evolution of the APS STEM-focused Schools for the Future program has been a pleasure to observe. Time will tell, but it appears that the program has the potential to develop strong systemic school programs by emphasizing the importance of systemic change from within, based on the individual school vision, as well as the abilities to implement change through developing school leadership and a vision for STEM. Despite some challenges, the majority of schools have been able to implement at least some portion of their action plan, providing professional learning for teaching staff as well as opportunities for students. Further evidence of the quality of this program is the commitment of the schools and teacher-leaders, as attendance has been almost 100% at every professional development session and all schools have signed on to continue with the program into the future. The program staff has been committed to these schools throughout, demonstrated by the provision of on-site feedback and resources, as well as acting as troubleshooters as necessary. This program fills an important gap by providing needed STEM education for K-8 teacher leaders in Arizona.

VI. Recommendations for improvement
• Continue to brainstorm ways for community members and industry to participate in a meaningful way in school STEM programs.
• Continue to build opportunities for educators to learn about contemporary STEM education, including integration of Next Generation Science Standards and Arizona Career and College Readiness Standards.
• Provide tools for participants to evaluate their own school programs and collect data about student learning.
• Focus on areas in the action plans in which schools still need to develop, including sustainability, pedagogy and diversity/equity.
• Continue to emphasize the importance of administrator buy-in and participation, as this is essential for schools to continue to develop their programs.

Teacher leaders suggest:
• Provide “workdays” to share ideas and collaborate on lessons, including more time for lesson/unit development.
• Develop an easily accessible on-line space for sharing resources and lessons.
• Provide specific sessions about how to conduct professional development and evaluate school programs.
VII. Citations

